From: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Date: November 8, 2000 10:30:43 AM PST
To: <barry@corazon.com>
Subject: **air india**
Reply-To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>

Mr. Corazon,

I am an associate with Peck and Company, which has been retained to represent Mr. Bagri in the Air India prosecution. I understand that you have authored a study in which you concluded that the cause of the crash of Flight 182 may not have been a bomb.

We would be very interested in taking a look at your study. Could you please advise how we might obtain a copy?

Thank you for your assistance.

Yours truly,

PECK and COMPANY

Jeff Campbell

From: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Date: November 14, 2000 3:42:25 PM PST
To: "John Barry Smith" <barry@corazon.com>
Subject: **Re: Evidence exists to confirm cargo door cause for AI 182**
Reply-To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>

Mr. Smith:

Thank you for your messages. We are presently undertaking to apply for the
release of our client on bail, and we have yet to receive/review the huge
volume of evidence which is involved in this case. As we have just recently
been retained, it is unknown yet how the tasks will be divided; undoubtedly
there will be a number of counsel working full time on it for many months.
I have provided your e-mails to lead counsel and we will be in touch down
the road, when we have given the materials their due consideration.

Jeff Campbell

----- Original Message -----
From: John Barry Smith <barry@corazon.com>
To: <jeffreytcampbell@home.com>
Sent: Saturday, November 11, 2000 7:38 AM
Subject: Evidence exists to confirm cargo door cause for AI 182

Dear Mr. Campbell, 11 Nov 00

I have not heard back from you so I assume you are evaluating the
data and analysis at www.corazon.com and would question me if

there
are any doubts.

There is enough wreckage and videotapes of the wreckage on the ocean
bottom to accurately determine the cause of AI 182. Seen from the
perspective of an open cargo door in flight, and not a bomb, the
wreckage and video can be reexamined to match subsequent events and
wreckage evidence such as PA 103 and UAL 811 and TWA 800. RCMP and
TSB have access to those videotapes and must be evaluated as evidence
at trial. I believe you have the authority to release those tapes for
independent expert evaluation. John Garstaing of TSB has viewed those
tapes personally and talked to me about it.

It's not only the door area that is important but the right wing
fillet, the starboard engines, and right horizontal stabilizer. The
investigators did not thoroughly check those areas because they were
looking for proof of bomb, not open cargo door in flight. I would be
willing to view and evaluate those video tapes for you, should you
get access, to match with wreckage of other 747s.

The forest is four 747s and the trees are AI 182, PA 103, UAL 811,
and TWA 800. Each tree has its own group explaining why it fell, but

only through the analysis of all four does the pattern become clear;
inadvertent opening of the cargo door in flight, probably caused by
known faulty Poly X wiring.

I leave all this conspiracy talk to others, it's counterproductive to an airplane crash investigation. Machines don't conspire. I understand the political implications about India and independent homelands and temples and assassinations all wrapped up into accusations of mass murder but, really, this is an airplane crash that matches other airplane crashes that were mechanical events and
not bombs.

I am non religious, non political, and not associated with any airline or manufacturer or government. I believe that that is the reason why I can be so objective and look at the evidence unemotionally to reach the cargo door conclusion which is rejected by
authorities. It is an unpleasant truth and most reject that.

As a air crash survivor I have a strong interest in preventing the next crash of a 747 caused by explosive decompression when that cargo
door opens in flight again. The same fault that caused AI 182 and others is still there.

Here's the patterns of the trees that make up the forest derived from
close analysis of the official accident reports.

103 to 811 were both
aged
high flight time
poly x wired
early model Boeing 747
which took off in no sun
running late
and after takeoff
experienced a sudden initial event in the forward cargo hold
which left a
short
sudden
loud
sound on the cockpit voice recorder, an
abrupt data loss to the flight data recorder,
foreign object damage to starboard engines number 3
fire on engine number 3
enginge three fodded number four
more severe inflight damage on starboard side,
at least nine never recovered bodies,
torn off skin in forward cargo door area on starboard side,
fracture at forward cargo door at aft midspan latch,
outward peeled skin on upper forward fuselage,
downward bent floor beams in cargo door area,
vertical fuselage tear lines forward of the wing and aft of forward cargo
door,
shattered fuselage shape on right side forward of the wing is
vertical large rectangle around forward cargo door.
door in two big halves split at longitudinal midline.
radar reflection from aircraft at event time

103 and 182 were both:
early model
poly x wired
Boeing 747
suffers hull rupture in forward cargo hold
engine three falls apart from other engines
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
sound does not match bomb sound
outward peeled skin in cargo door area
midspan latch status not determined
took off in no sun
running late
more severe inflight damage on starboard side
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
inadvertent opening of the forward cargo door in flight offered as explanation during official inquiry
bomb in forward cargo hold initially suspected

Pan Am 103 and TWA 800 were both:
aged
high time
early model
poly x wired
Boeing 747
shortly after take off
suffers hull rupture forward of the wing
fodded number three engine

sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
outward peeled skin in cargo door area
midspan latch status not determined
took off in no sun
running late
more severe inflight damage on starboard side
downward bent floor beams in cargo door area
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
bomb in forward cargo hold initially suspected
bomb in forward cargo hold placed two flights previous to final fatal
flight exploding in flight and nose coming off explanation is still believed to be the correct probable cause at least for the last nine years.
Non bomb structural failure offered as explanation for sudden loud
short sound on the CVR.
Non bomb structural failure rejected.
Bomb planters are terrorists of foreign countries.
Bomb planters not tried in court.
Bomb planters deny they planted bomb.

800 to 182
Forward Cargo door frayed
Door Skin shattered outward.
Bottom eight latches latched.
Midspan latch status undetermined.

early model
poly x wired
Boeing 747
suffers hull rupture forward of the wing on the right side in cargo door
area
damaged number three engine
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
took off in no sun
running late
more severe inflight damage on starboard side
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
bomb in forward cargo hold initially suspected
bomb in forward cargo hold placed at least one flight previous to final fatal flight exploding in flight and nose coming off
explanation was thought to be explantion for at least seventeen months.
Forward cargo door opening in flight considered as explanation for
sudden loud short sound on the CVR.
Forward cargo door opening in flight rejected.
Bomb planters would have been terrorists of foreign countries.
Bomb planters not charged.
Bomb planters deny they planted bomb.
Conspiracy explanations considered seriously.

TWA 800 leads to UAL 811 which were both:
aged
high flight time
poly x wired
early model Boeing 747
which took off in no sun
running late
and shortly after takeoff
while climbing
experienced a sudden initial event in the forward cargo hold
which left a
short
sudden
loud
sound on the cockpit voice recorder, an
abrupt data loss to the flight data recorder,
foreign object damage to starboard engine #3
more severe inflight damage on starboard side,
smooth port side forward of the wing
at least nine never recovered bodies,
torn off skin in forward cargo door area on starboard side,
rupture at forward cargo door at aft midspan latch,
outward peeled skin on upper forward fuselage,
downward bent floor beams in cargo door area,
vertical fuselage tear lines forward of the wing and aft of forward cargo
door,
inadvertent opening of forward cargo door considered as probable cause.
bare wires found in cargo door area.
destruction initially thought to be have been caused by a bom

From: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Date: November 16, 2000 12:53:37 PM PST
To: "John Barry Smith" <barry@corazon.com>
Subject: **Re: Bail**
Reply-To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>

Mr. Smith:

expert evidence that the deaths due to the Air India disaster were not the
result of a bomb may be placed before the judge on the bail application, and
it may very well improve the prospects of our client being released on bail.

I am currently working on another case, but I am passing hard copies of your
emails along to lead counsel. Thank you for your ongoing interest.

-jeff campbell.

----- Original Message -----
From: John Barry Smith <barry@corazon.com>
To: <jeffreytcampbell@home.com>
Sent: Friday, November 16, 1956 2:55 AM
Subject: Bail

Dear Mr. Campbell, 15 Nov 00

Is it too early to present to the Court at the bail hearing that there is not conclusive evidence that a crime has been committed at
all? The official report of the Canadian and Indian aviation authorities states that a mechanical event such as open cargo door in
flight would cause the damage shown by the evidence.

"3.4.1 Aircraft Break-up
The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally
about one-quarter of the distance above the lower frame. The damage
to the door and the fuselage skin near the door appeared to have been
caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen
on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing
as an initial event would cause an explosive decompression leading to
a downward force on the cabin floor as a result of the difference in
pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated
from the support structure in an upward direction."

(Note that floor panels separating in an upward direction gives same evidence as floor beams going in down direction, which is what happens to explosive decompression when floor beams, not panels, get sucked down, whereas, a bomb makes floor beams go up, which did not happen.)

The only group stating a crime was committed are law enforcement authorities, aviation authorities have left the probable cause in doubt. This is an airplane crash, not a bank robbery. The first assumption must be pilot error, weather related, or mechanical fault.

Bringing the official suggestion that it may have been a mechanical event and not sabotage may help get bail, in my humble opinion. That possibility of mechanical event will lead aviation authorities to start consideration and they will have 15 years of similar mechanical events with similar evidence to ponder. Let the aviation media do some of your legwork for you. The open cargo door suggestion is not weird, not wild, not last straw, not misdirection, but an suggested possible mechanical explanation which mean nobody, especially your client, put a bomb on board AI 182.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom

The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device

having been
detonated on AI 182.

3.4.6.14 That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a
high explosive device, then the spectra should have shown large low
frequency content, but this was absent.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-
"It is considered that from the CVR and ATC recordings supplied for
analysis, there is no evidence of a high explosive device having
detonated on AI 182.
"There is strong evidence to suggest that a sudden explosive
decompression occurred but the cause has not been identified.

I urge you sir, just because the authorities have for fifteen years
been crying bomb, the actual evidence is nowhere near conclusive, and
in fact, much evidence supports a mechanical sudden decompression
from some other source, such as open cargo door in flight.

To assume it was a bomb but your client did not plant it is to assume
something not confirmed and very detrimental to a defense. If I were
the judge and it were presented to me that a plane was bombed but
your client, although tied to others who have bombed or been
connected to bombings, did not do it, I would not grant bail

fearing
fleeing. But, if the entire event were in doubt as to being a crime or not, and no bomb on board, and supported by Canadian authorities
in an official written report, a Canadian judge might grant bail.

Well, Mr. Campbell, just sticking my nose in where it may not belong,
good luck in Court.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: December 4, 2000 5:26:17 AM PST
To: jeffreytcampbell@home.com
Subject: **Reporter called me**

Mr. Campbell, 4 Nov 00

A reporter from the Globe and Mail just called me and asked me for your name as the attorney for the accused for AI 182.

I told him I would check with you first. It is OK for me to give him your name?

Robert Matas
West Coast reporter for Globe and Mail

Cheers,
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Date: December 4, 2000 6:08:16 PM PST
To: "John Barry Smith" <barry@corazon.com>
Subject: **Re: Reporter called me**
Reply-To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>

Mr. Smith:

Lead counsel for Mr. Bagri is Richard Peck, Q.C.

-Jeff Campbell

----- Original Message -----
From: John Barry Smith <barry@corazon.com>
To: <jeffreytcampbell@home.com>
Sent: Monday, December 04, 2000 5:26 AM
Subject: Reporter called me

Mr. Campbell, 4 Nov 00

A reporter from the Globe and Mail just called me and asked me
for
your name as the attorney for the accused for AI 182.

I told him I would check with you first. It is OK for me to give him your
name?

Robert Matas
West Coast reporter for Globe and Mail

Cheers,
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: January 12, 2001 12:11:55 PM PST
To: Jeffrey_T._Campbell
Subject: **Speak before group**

Dear Mr. Campbell,

A thought, I could speak before a group of sympathetic listeners about the wiring/cargo door cause of AI 182. It could be in Vancouver and might be another fundraiser for the accused. It would be a one to three hour presentation discussing the facts, data, evidence and skipping any political talk.

I don't know anybody up there, but you might know of someone to organize it. They can contact me at phone mail or email.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: "M. Singh" <babbar187@yahoo.com>
Date: January 23, 2001 3:47:01 PM PST
To: barry@corazon.com
Subject: **Air India Trial**

Dear Mr. Barry, we are currently working to free Mr. Ajaib Singh Bagri and Mr. Ripudaman Singh Malik from the Air India Bombing trial for which they have already been denied bail. We have seen some of your information online and it seems to be very intriguing and amazing. We would like to get into contact with you and possibly even meet you in person and discuss some facts with you. If you could email us at this address and leave a number for us to contact you at that would be very appreciated. I'll also leave a cell phone number of a friend of mine, Perry, and you can get into touch with him if you like. The number is 1-604-833-4550. Thank you very much and we look forward to seeing you in the future.

From: John Barry Smith <barry@corazon.com>
Date: January 31, 2001 2:19:20 PM PST
To: Jeffrey_T._Campbell
Subject: **Life Imprisonment**

Dear Jeffrey,

Perry Dulai, did not call back. I assume you also believe AI 182 was a bomb but your clients did not plant it and therefore anyone who says it was not a bomb is nuts, unlike the conspiracy groups.

Well, the PA 103 defence team also tried that and lost the freedom of one client for life.

Now will you go to www.corazon.com and investigate the wiring/cargo door explanation for PA 103? It is a mechanical explanation with precedent supported by documents photographs and charts that indicate the explosion was not a bomb but an explosive decompression which occurred when the forward cargo door opened in flight.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone

551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: "aniljit singh uppal" <aniljitsingh@hotmail.com>
Date: February 20, 2001 9:32:19 AM PST
To: barry@corazon.com
Subject: **Update of telecon**

Thank you for your assistance. My number is 604-834-8888. I have noted the following three items to request from the crown.

1. All video tapes
2. Complete wreckage database.
3. All photographs.

I have also noted the name of the person to contact on the Transport Safety Board - John Garstaign.

I will share this information with you as soon as I receive it.

Thank you and I look forward to seeing you in March

Aniljit Singh

Get Your Private, Free E-mail from MSN Hotmail at http://www.hotmail.com.

From: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Date: February 20, 2001 1:44:41 PM PST
To: "John Barry Smith" <barry@corazon.com>
Subject: **Re: Are these names of real people?**
Reply-To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>

Mr. Smith:

I believe that the people named in the email are people working on this
matter.

-Jeff Campbell

This e-mail message (and any attachments thereto) is directed in confidence solely to the person or entity to whom it is addressed. The
contents of this e-mail (and any attachments thereto) may be subject to
solicitor-client privilege. All rights to that privilege are expressly claimed and not waived. Any review, retransmission,

----- Original Message -----
From: John Barry Smith <barry@corazon.com>
To: Jeffrey T. Campbell <jeffreytcampbell@home.com>
Sent: Sunday, February 18, 2001 8:01 PM
Subject: Are these names of real people?

Dear Mr. Campbell,

Can you confirm for me if the names below are genuine and if the
email is legitimate?

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Date: Sat, 17 Feb 2001 11:59:06 -0800 (PST)
From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: Shyrone Kaur
To: kaursingh@webtv.net
MIME-Version: 1.0
Content-Type: text/plain; charset=us-ascii

WJKK, WJKF!!!

Shyrone Kaur,

Hi, my name is Sundeep Kaur. I am working on the Air India file for Mr. Malik. Aniljit Singh (Mr. Malik's legal assistant) is inviting Mr. Barry Smith to Vancouver so that we can discuss his findings with Mr. Smart. I was wondering if you could hrete back and let me know you availability.

Thank you

From: John Barry Smith <barry@corazon.com>
Date: February 20, 2001 3:58:36 PM PST
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **Kuldip Chaggar**

Dear Mr. Campbell, there is an attorney representing Mr. Reyat, a Mr. Chaggar. Below is just sent email with my offer to discuss the wiring/cargo door explanation with him.

Cheers,
Barry

Dear Mr. Bharij,

Ms. Shyrone Kaur and I have been in email contact these past few months and I appreciate her efforts in bringing my explanation for AI 182 to the notice of interested parties. AI 182 was caused by a mechanical event of shorted wiring causing a forward cargo door unlatch motor to turn on allowing the rupture of the door and the subsequent explosive decompression leading the destruction of the aircraft. This conclusion is based on twelve years of research and the precedent of a similar Boeing 747 event, UAL 811 in Feb 1989.

I understand you are in contact with Mr. Kuldip Chaggar who is representing Mr. Reyat at the extradition process. I will be glad to answer questions about my wiring/cargo door explanation from Mr. Chaggar regarding his client's non-involvement in AI 182. Mr. Reyat did not put a bomb on AI 182, nobody did.

Cheers,

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: February 20, 2001 4:00:11 PM PST
To: aniljit singh uppal <aniljitsingh@hotmail.com>
Subject: **Kuldip Chaggar**

Dear Aniljit,

Below is email I just sent to offer to discuss the wiring/cargo door explanation for AI 182 with the attorney representing Mr. Reyat in Britain.

Cheers,
Barry

Dear Mr. Bharij,

Ms. Shyrone Kaur and I have been in email contact these past few months and I appreciate her efforts in bringing my explanation for AI 182 to the notice of interested parties. AI 182 was caused by a mechanical event of shorted wiring causing a forward cargo door unlatch motor to turn on allowing the rupture of the door and the subsequent explosive decompression leading the destruction of the aircraft. This conclusion is based on twelve years of research and the precedent of a similar Boeing 747 event, UAL 811 in Feb 1989.

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Cheers,

John Barry Smith
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US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: "aniljit singh uppal" <aniljitsingh@hotmail.com>
Date: February 21, 2001 8:54:54 AM PST
To: barry@corazon.com
Subject: **Re: Obtaining evidence**

From: John Barry Smith <barry@corazon.com>
To: "aniljit singh uppal" <aniljitsingh@hotmail.com>
Subject: Obtaining evidence
Date: Tue, 20 Feb 2001 10:29:49 -0800

Thank you for your call. This email confirms we have two way communication. I will send the electronic version of AAR 92.02 for
UAL 811 in separate email.

May I conclude by saying that I know that your clients did not bomb
AI 182 because nobody bombed AI 182. I can prove that conclusion
beyound most doubt with facts, data, evidence, and official documents.

In addition you have access to the video tapes of the actual wreckage
to match that damage to the confirmed wiring/cargo door event of UAL
811; you can get the wreckage database to match against the databases
of PA 103, TWA 800; we can plot the actual debris pattern on the surface to deduce the destruction sequence and area of first damage;
you can get the photographs of the actual wreckage that they retrieved. They may have photographs of the forward cargo door area
before it slipped back into the ocean.

All of the above contain actual irrefutable facts and will avoid the
conspiracy nonsense which plagues the four Boeing 747 fatal accidents, AI 182, PA 103, TWA 800 and UAL 811. I shall inform you of
other evidence that may be relevant that you may obtain through discovery.

I am a little concerned that an attorney, Keith Hamilton, paid for by
the Crown is 'helping' the defense. Regardless I shall explain everything to him if you say so.

The extradition of Mr. Reyat is wrong also and a hearing in Britain
is the appropriate time to broach the concept of no bomb but mechanical cause.

Feel free to call me anytime for voice contact and email is always
available. Here are some backup email addresses,
corazonsmith@msn.com, CEO@internetpagepublishing.com and of course,
barry@corazon.com

May I address you as Aniljit? I am Barry.

The defense must know the complete details of AI 182, PA 103, UAL
811, and TWA 800, they are all caused by the same probable cause,
wiring shorting on the forward cargo door unlatch motor allowing the
midspan latches to rupture causing explosive decompression and the
structural failure of the fuselage. AI 182 is an airplane crash and
not a bank robbery. The similar crashes and causes to AI 182 must be
completely evaluated. The three match UAL 811, the only confirmed
mechanical electrical caused open cargo door event.

To know the accidents is to read the Aircraft Accident Reports for each.

I shall send you the ones for AI 182, PA 103, and UAl 811, the one
for TWA 800 is available at their website for download.

Looking forward to talking with you again, Aniljit.

Cheers,
Barry
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

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noted the following three items to request from the crown.

1. All video tapes
2. Complete wreckage database.
3. All photographs.

I have also noted the name of the person to contact on the Transport
Safety Board - John Garstaign.

I will share this information with you as soon as I receive it.

Thank you and I look forward to seeing you in March

Aniljit Singh

Thank you for your e-mails.

It is quite common for the crown to fund a defence lawyer. In this case Keith Hamilton will be working solely for the defence. In order to insulate him from the crown, his legal invoices will be reviewed by an independent lawyer.

There is no doubt about his integrity and I believe Mr. Smart and Mr. Peck have known Mr. Hamilton for over 15 years.

I look forward to contacting you.

Aniljit Singh

From: Aniljit Singh <aniljitsingh@hotmail.com>
Date: February 22, 2001 11:30:36 AM PST
To: John Barry Smith <barry@corazon.com>
Subject: **Re: 747 retired Sikh pilot**

on 21/2/01 11:36 PM, John Barry Smith at barry@corazon.com wrote:

Dear Aniljit,

Mr. Santokh Singh is a retired Boeing 747 pilot who has been following the wiring/cargo door explanation for AI 182 for the past
few months, as well as Ms. Shyrone Kaur, an active airline ticket agent.

They have expressed interest in contacting you and have technical
knowledge about AI 182 related items.

Cheers,
Barry

At 11:28 PM +0100 2/21/01, Santokh Singh wrote:
X-From_: maan100@worldonline.nl Wed Feb 21 22:40:24 2001
X-Sender: maan100/pop3.worldonline.nl@pop3.norton.antivirus
Date: Wed, 21 Feb 2001 23:28:59 +0100
To: John Barry Smith <barry@corazon.com>
From: Santokh Singh <maan100@worldonline.nl>
Subject: lawyer

Can you confirm that "aniljit singh uppal"
<aniljitsingh@hotmail.com>

is defending the 2 accused in Canada?
This could be our voice.

Thank you. I will definitely be contacting them as well.

Also I learned yesterday that the crown may refuse the funding for Keith
Hamilton, the joint defence lawyer and that we may have to go at it by
ourselves.

Aniljit Singh

From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Date: February 22, 2001 4:53:34 PM PST
To: barry@corazon.com
Subject: **AI 182**

Hi Barry!

My name is Sundeep Kaur, I am helping Aniljit Singh
and Mr. Malik with legal research, etc.

YOu sent three reports to Aniljit Singh and he has
asked me to print them up, I was wondering if you
could send those reports to me as attachments so that
i can do that. It is easier for us to review hard
copies of reports than on the computer. This would be
much appreciated.

Thanks in advance.

Sundeep Kaur

From: John Barry Smith <barry@corazon.com>
Date: February 22, 2001 5:15:20 PM PST
To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **AI 182 report**

To: aniljit singh uppal <aniljitsingh@hotmail.com>
From: John Barry Smith <barry@corazon.com>
Subject: AI 182 report
Cc:
Bcc:
X-Attachments:

Canadian Aviation Bureau canadien Safety Board de la sécurité aérienne AVIATION OCCURRENCE AIR INDIA BOEING 747-237B VT-EFO CORK, IRELAND 110 MILES WEST 23 JUNE 1985 1.0 INTRODUCTION
Air India Flight 182, a Boeing 747-237B, registration VT-EFO, was on a flight from Mirabel to London when it disappeared from the radar scope at a position of latitude 51°O'N and longitude 12°50'W at 0714 Greenwich Mean Time (GMT), 23 June 1985, and crashed into the ocean about 110 miles west of Cork, Ireland. There were no survivors among the 329 passengers and crew members. The depth of the water at the

crash site is about 6,700 feet.

At 0541 GMT, 23 June 1985, CP Air Flight 003 arrived at Narita Airport, Tokyo, Japan, from Vancouver. At 0619 GMT a bag from this flight exploded on a baggage cart in the transit area of the airport within an hour of the Air India occurence. Two persons were killed and four were injured. From the day of the occurrences, there have been questions about a possible linkage between the events.

This Submission examines the information available to the Canadian Aviation Safety Board (CASB) with respect to the circumstances surrounding the AI 182 accident. The sources of information include: information made public to the Indian Inquiry as a result of the RCMP investigation; the flight data recorder (FDR), cockpit voice recorder (CVR) and Shannon ATC tape recording analyses by Canadian, United Kingdom, and Indian authorities; the medical evidence obtained from Dr. Hill of the Accident Investigations Branch of the United Kingdom; and the evidence obtained by examination of the wreckage recovered, the wreckage distribution pattern, photographs, and videotapes of the wreckage on the ocean bottom.

2.0 EXAMINATION

2.1 Vancouver

On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight East Indian accent.* He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vancouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

On the same date at approximately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

On 20 June 1985 at about 1210 PDT (1910 GMT), a male appearing to be of East Indian origin purchased the tickets with cash from a CP Air ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to M. Singh. The telephone contact number was also changed. The final itinerary was as follows:

a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22 June 1985

*See Appendix A for chronology of events.

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22 June 1985

b) L. Singh - CP 003 Vancouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 (local time in Tokyo), 23 June 1985

On 22 June 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy East Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that he was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

On Saturday morning, 22 June 1985, a CP Air passenger agent worked check-in position number 26 at the CP Air ticket counter, Vancouver International Airport, and recalls dealing with a passenger booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto he could not interline his baggage. The passenger insisted and, as the line-ups were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that M. Singh checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage. The flight manifest for CP 003 shows that on the same day the person using the name of L. Singh with a ticket to Bangkok also checked in through the same counter, was assigned seat 38H, and checked one piece of baggage.

A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as M. and L. Singh did not board these respective flights.

2.2 Toronto

Air India Flight 181 from Frankfurt arrived at Toronto on 22 June 1985 at 1430 EDT (1830 GMT) and was parked at gate 107 of Terminal 2. All passengers and baggage were removed from the aircraft and processed through Canada Customs. Passengers continuing on the flight to Montreal were given transit cards, and on this flight 68 cards were handed out. These transit passengers are required to claim their luggage and proceed through Canada Customs. Prior to entering the public area, there is a belt which is designated for interline or transit baggage. Transit passengers deposit their luggage on this belt which carries it to be reloaded on the aircraft. This baggage was not subjected to X-ray inspection as it was presumed to have been screened at the passengers' overseas departure point. When the transit passengers checked in to proceed to Montreal, their carry-on baggage was subjected to the normal security checks in place on this date. Passenger and baggage security checks were conducted by Burns International Security Services Ltd. and all passenger and baggage processing for both off-loading and on-loading was handled by Air Canada staff.

Air India Flight 181 was composed of the following:

- passengers continuing to Montreal (68)
- passengers from connecting flights

AC 102 (Saskatoon) 2
AC 106 (Edmonton) 4
AC 192 (Winnipeg) 1
AC 170 (Winnipeg) 4
AC 136 (Vancouver) 10
CP 060 (Vancouver) 1 Standby (M. Singh)

- passengers originating at Toronto
- diplomatic bags from the Vancouver India Consul General via AC 508
- produce cargo from India
- cargo in the form of 5th pod engine components loaded in the aft cargo compartment.

It should be noted that some passengers from India book flights to Montreal with their intended destination being Toronto. The reason is that the fare to Montreal is cheaper and therefore some passengers get off the flight in Toronto, claim their luggage and leave without reporting a cancellation of the trip to Montreal. It has been established that 65 of the 68 transit passengers reboarded the flight to Montreal.

Air India personnel were in charge for the overall operation at Toronto regarding the unloading and loading of both passengers and cargo. Although the actual work was performed by various companies under contract, Air India personnel oversaw the operation. The Air India station manager was away on vacation on 22 June 1985. The evidence does not clearly establish who had been assigned to replace the station manager and assume his duties.

Air Canada had stored in a hangar an engine that had failed on a previous Air India flight from Toronto on 8 June 1985. Air Canada received a message from Air India stating that the failed engine was to be mounted as a 5th pod on Flight 181/182 on 22 June 1985. The engine was prepared for loading and component parts were crated for loading into the aft cargo compartment. On 22 June, the component parts were taken from the hangar and placed outside to be delivered to the aircraft by MEGA International Air Cargo. The component parts were placed just inside the airport fence separating the restricted and unrestricted areas. The installation began immediately upon the arrival of Flight 181 and was completed at 1530 EDT (1930 GMT). The front engine cowling was crated but would not fit through the aft cargo door. The crating was rearranged, and the door stops on the cargo door were removed to permit the loading of the crate and the remaining engine parts were loaded on pallets. Due to problems with loading the 5th pod and component parts, the departure was delayed from 1835 EDT (2235 GMT) to 2015 EDT (0015 GMT, 23 June).

CP Air Flight 060 arrived in Toronto at 1610 EDT (2010 GMT) and docked at gate 44, Terminal 1. A number of passengers on this flight were interlined to other flights including passenger M. Singh wait-listed on Air India Flight 181/182. It has been established that this passenger did not board Flight CP 060 but did check baggage onto the flight. This baggage was to be interlined to the Air India flight departing from Terminal 2. In this case, CP Air employees would have off-loaded all baggage from CP 060 and deposited the baggage at Racetrack 6 on the ring road of Terminal 1 to be transported to the Air Canada sorting room at Terminal 2.

Consolidated Aviation Fuelling and Services (CAFAS) is a company which is contracted to pick up and deliver baggage from one terminal to the other. The CAFAS driver on duty at the time recalls picking up a bag from a CP Air flight originating in Vancouver and destined for Air India at Terminal 2. As this piece of luggage did not turn up as found luggage, it is deduced that normal practice was followed, and the luggage was interlined and loaded on AI 181/182.

MEGA International Air Cargo is a firm that handled air cargo and containers for Air India. Since the flight was carrying a 5th engine and component parts, no commercial cargo could be loaded at Toronto. MEGA delivered the engine component parts to be loaded in the cargo compartment by Air Canada employees. Later, MEGA received two diplomatic bags and delivered these to the aircraft. The bags were loaded into the valuable goods container (see Appendix B). These bags were not subjected to X-ray or any other security checks.

All checked-in baggage for AI 181/182 was to be screened by an X-ray machine which was located in Terminal 2 at the end of international belt number 4. This location would permit all baggage from the check-in counters and interline carts to be fed through the X-ray machine before being loaded. It has been established that this machine worked intermittently for a period of time and stopped working during the loading process at about 1700 EDT (2100 GMT). Rather than opening the bags and physically inspecting them, the Burns security personnel performing the X-ray screening were told by the Air India security officer to start using the hand-held PD-4 sniffer.

One Burns security officer checked the bags with the sniffer while another put stickers on the bags and forwarded them. The security officer forwarding the baggage recalls the sniffer making short beeping noises not long whistling ones. The security officer who used the sniffer claims it never went off, and the only time any sound was made was when it was turned on and off. At those times, it would emanate a short beep (refer to section 2.8 for further information regarding the PD-4 sniffer).

Burns International Security had a contract with Air India for the security of the aircraft while it was docked. The security arrangements contracted from Burns were as follows:

- security at the bridge door leading to the aircraft;
- security inside the aircraft from the time the passengers disembarked upon flight arrival until flight departure;
- security guards assigned the physical inspection of all carry-on baggage in the departure room; and
- security guards in the international baggage make-up room conducting screening of baggage using an X-ray machine and a hand-held PD-4 sniffer.

The statements taken from Burns security personnel in Toronto indicated that a significant number of personnel, including those handling passenger screening, had never had the Transport Canada passenger inspection training program or, if they had, had not undergone refresher training within 12 months of the previous training.

As a result of official requests made by Air India in early June 1985 for increased security for Air India flights, the RCMP provided additional security as follows:

- one member in a marked police motor vehicle patrolling the apron area;
- one member in a marked police motor vehicle parked under the right wing from time of arrival until push-back;
- one member on foot patrol at Air India check-in counter; and
- one member at the loading bridge during boarding.

In addition, all RCMP members working in that particular area of

Terminal 2 were aware of the Air India flight and would check in with the assigned personnel during their patrols in the area of the aircraft and check-in/boarding lounges. Uniformed members are to patrol and monitor security within the airport premises as detailed in section 2.5 below.

Passenger check-in was handled for Air India by Air Canada under contract with Air India. The check-in included passengers originating in Toronto and interline passengers but did not include the transit passengers to Montreal. The check-in passengers were numbered using a security control sheet in accordance with instructions from Air India; however, the check-in and interline baggage was not numbered, and no attempt was made to correlate baggage with passengers. Hence, any unaccompanied interline baggage would not have been detected.

The flight and cabin crew had been in Toronto for the week prior to this flight and were to take the aircraft to London where they would be replaced by another crew. The crew members themselves and their carry-on baggage were not subjected to any security checks; however, their checked-in baggage was screened in the same manner as other baggage.

2.3 Montreal

Air India Flight 181 from Toronto arrived at Mirabel International Airport at about 2100 EDT (0100 GMT, 23 June) and parked in supply area number 14 at 2106 EDT (0106 GMT). The 65 passengers destined for Montreal along with three Air India personnel deplaned and were transported by bus to the terminal building. The remaining passengers remained on board as transit passengers and were not permitted to disembark at Montreal. Air Canada baggage handlers off-loaded four containers of cargo, three containers of baggage and a valuables container. Two diplomatic pouches from the Indian High Commission in Ottawa were delivered to the aircraft by MEGA International Cargo. One pouch weighing one kilogram was hand-delivered to the flight purser for storage in a valuables locker within the cabin and the other pouch was loaded into the valuables container.

During the check of the aircraft at Montreal, the second officer pointed out to an Air Canada mechanic that a rear latch on the fan cowl for the 5th engine did not appear to be properly secured. The mechanic examined the latch and found it well secured, but the handle was not flush and was hanging about five degrees. The mechanic applied high-speed tape to the latch handle for aerodynamic smoothness. This repair was examined by the second officer who was satisfied with the work. No records were completed by Air Canada in connection with this temporary repair.

At about 1730 EDT (2130 GMT), Air Canada, which is Air India's contracted agent, opened its check-in counter to passengers who would be flying on Air India Flight 182. Burns security personnel were also assigned at this time to screen the checked baggage. Passenger tickets were checked, issued a number, and copies of the tickets were removed and retained by Air Canada. Boarding passes were then issued and affixed to the numbered tickets. Also attached to the ticket booklets were numbered tickets which corresponded to each piece of checked baggage. The numbered checked baggage was sent to the baggage area by Air Canada personnel to be security-checked by Burns security personnel.

The passengers for AI 182 after checking in were free to enter the departure area. At the entrance to the departure area, Burns security staff used X-ray units and metal detectors to screen passengers and carry-on baggage. At about 2100 EDT (0100 GMT), the passengers proceeded to gate 80 where they gave their boarding passes and numbered tickets to an Air Canada agent. The agent kept the numbered flight tickets and checked the numbers against the passenger list. Also, at gate 80, a secondary

security check was done on passengers by a Burns security officer using a metal detector. Hand-carried baggage was subjected to further physical and visual checks. A total of 105 passengers boarded the flight at Mirabel Airport; there were no interline passengers.
Between 1900 (2300 GMT) and 1930 EDT (2330 GMT), Burns security personnel identified a suspect suitcase using the X-ray machine. The suitcase was placed on the floor next to the machine. The Burns security supervisor told Air India personnel that a suspect suitcase had been located and was advised within 15 to 20 minutes to wait for the Air India security officer who would be arriving on the flight from Toronto. Subsequently, a second suspect suitcase was identified and a little later a third. The three suitcases were placed next to the X-ray machine.
Between 1930 (2330 GMT) and 1945 (2345 GMT), all the Burns security personnel at the X-ray machine were assigned to other duties and the three suspect suitcases remained in the baggage area without supervision. At about 2140 (0140 GMT), the Air India security officer went to the baggage room and inspected the three suitcases with the X-ray machine and a sniffer that was in the possession of the security officer. The Air India security officer decided to keep the three suitcases and, if further examination proved negative, send them on a later flight. At approximately 2155 (0155 GMT), the Air Canada Operations Centre supervisor contacted the airport RCMP detachment regarding the suspect suitcases. At about 2205 (0205 GMT), an RCMP member located the suitcases in the baggage room and requested that an Air India representative be sent to the baggage room. About five minutes later, the Air India security officer contacted the baggage room by telephone and advised that he could not come to the room immediately. The Air India security officer arrived in the baggage room at about 2235 (0235 GMT) and, when asked to determine the owners of the suitcases,

informed the RCMP member that the flight had already departed [2218 (0218 GMT)]. The three suspect suitcases were later examined with negative results.

The remainder of the checked baggage which cleared the security check was identified by a green sticker. The baggage was then forwarded to Air Canada personnel who loaded the baggage in containers to be placed on board the aircraft. A later check with Canada Customs and Air Canada at Mirabel revealed no unclaimed baggage associated with AI 181/182. A similar check at Dorval Airport was conducted with negative results.

No record was kept as to the location and number of individual pieces of checked-in luggage. Records were kept as to the location of the containers according to destination, where loaded and the number of pieces of luggage in each container (see Appendix B).

The Mirabel Detachment of the RCMP provided the following security at the airport on 22 June 1985:

- one member in a police vehicle for airside security;
- one member on patrol in the arrival and departure areas;
- one member on general foot patrol throughout the terminal; and
- one member as a telecommunications operator in the detachment office.

In addition, due to the increased threat to Air India flights, the RCMP provided the following supplementary coverage to Air India Flight 181/182 on 22 June 1985:

- one member in a police vehicle escorted the aircraft to and from the runway and the terminal building and remained with the aircraft while it was stationary;
- one member in a police vehicle remained at the entrance to the ramp;
- two members patrolled the area of the ticket counter and access corridors, and one of these members also served in a

liaison capacity with the airline representatives.

2.4 International Standards and Recommended Practices

International security standards and recommendations to safeguard international civil aviation against acts of unlawful interference are listed in ICAO Annex 17 to the Convention on International Civil Aviation. Suggested security measures and procedures are amplified in the ICAO Security Manual for Safeguarding Civil Aviation Against Acts of Unlawful Interference.

Annex 17 requires contracting States of which Canada is one to "take the necessary measures to prevent weapons or any other dangerous devices, the carriage or bearing of which is not authorized, from being introduced by any means whatsoever, on board an aircraft engaged in the carriage of passengers."

In addition to other recommendations, Annex 17 recommends that contracting States should establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage, cargo, mail and stores to be carried on board aircraft.

The Security Manual specifies that,

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Recently, ICAO has proposed amendments to Annex 17. These proposals arise from a decision taken by the Council in its 115th Session on 10 July 1985. The Council instructed its Committee on Unlawful Interference, as a matter of urgency, to review the entirety of Annex 17 and to report on those provisions which might be immediately introduced, upgraded to Standards, strengthened or improved. Among the proposed amendments is the following upgrading in the Standards:

- Each contracting State ensure the implementation of measures at airports to protect cargo, baggage, mail stores and operator's supplies being moved within an airport to safeguard such aircraft against an act of unlawful interference.

2.5 Canadian Law

In terms of Canadian statutory requirements, the Civil Aviation Security Measures Regulations and the Foreign Aircraft Security Measures Regulations made pursuant to the Aeronautics Act require specified owners or operators of aircraft registered in Canada or specified owners or operators who land foreign aircraft in Canada to establish, maintain, and carry out security measures at airports consisting of:

- systems of surveillance of persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- systems of searching persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas that are inaccessible to any person other than a person who has been searched and the personnel of the owner or operator;
- a system that provides, at airports where facilities are available, for check-points at which persons intending to board the aircraft of an owner or operator can be searched;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas in which cargo, goods and baggage that have been checked for loading on aircraft are inaccessible to persons other than those persons authorized by the owner or operator to have access to those areas;
- a system of identification that prevents baggage, goods and cargo from being placed on board the aircraft if it is not authorized to be placed on board by the owner or operator; and
- a system of identification of surveillance and search personnel and the personnel of the owner or operator.

Specified carriers including Air Canada, CP Air, and Air India were required to provide a description of their security measures to the Canadian Minister of Transport.

An Order-in-Council on 29 September 1960 established that the RCMP was responsible for the direction and administration of police functions at major airports operated by Transport Canada. The duties of the Police and Security Detail at these designated airports include the following:

- carry out policing and security duties to guard against unauthorized entry, sabotage, theft, fire or damage;
- enforce federal legislation;
- respond to violations of the Criminal Code of Canada, Federal, Provincial, and Territorial statutes, and perform a holding action pending arrival of the police department having primary criminal jurisdiction;
- man guard posts; and
- provide a police response in those areas of airports where pre-board screening takes place.

Section 5.1(9) of the Aeronautics Act states that "The Minister may designate as security officers for the purposes of this section any persons or classes of persons who, in his opinion, are qualified to be so designated." Pursuant to this section Transport Canada has established criteria for persons or classes of persons that are designated as security officers in a Schedule registered on 11 April 1984. The criteria also specify that a security guard company and its employees will meet Transport Canada requirements provided that the company:

- is under contract with a carrier to conduct passenger screening under the Aeronautics Act and Regulations;
- is licensed in the province or territory;
- complies with the security guard criteria as follows in that the guard must:
- be 18 years or older,

- be in good general health without physical defects or abnormalities which would interfere with the performance of duties,
- be licensed as a security guard and in possession of the licence while on duty, and
- meet the training standards of Transport Canada consisting of successfully completing the Transport Canada passenger inspection training program, attaining an average mark of 70 per cent, and undergoing refresher training within 12 months from previous training;
- uses a comprehensive training program which has been approved by Transport Canada and is capable of being monitored and evaluated;
- keeps records showing the date each employee received initial training and/or refresher training and the mark attained; and
- provides supervision to ensure that their employees maintain competency and act responsibly in the conduct of searching passengers and carry-on baggage being carried aboard aircraft.

2.6 Canadian Security Procedures

In accordance with the Canadian Aeronautics Act and pursuant regulations, air carriers are assigned the responsibility for security. Transport Canada provides the following security services for the air carriers using major Canadian airports, including the international airports in Vancouver, Toronto and Montreal:

- security and policing staff including RCMP airport detachments;
- specific airport security plans and procedures;
- secure facilities (e.g., secure areas, pass identification systems, etc.); and
- security equipment and facilities (e.g., X-ray detection units, walk-through metal detectors, hand-held metal detectors,

explosive detection dogs).
As of 22 June 1985, the following general security measures were in place at Canadian airports:
- metal detection screening of passengers; and
- X-raying of carry-on baggage.

Checked baggage was not normally subject to any security screening. A few air carriers such as Air India had extra security measures in place because of an assessed higher threat level (see section 2.7 below).
On 23 June 1985, Transport Canada required additional security measures to be implemented by all Canadian and foreign air carriers for all international flights from Canada except those to the continental United States. These measures required:
- the physical inspection or X-ray inspection of all checked baggage;
- the full screening of all passengers and carry-on baggage; and
- a 24-hour hold on cargo except perishables received from a known shipper unless a physical search or X-ray inspection is completed.

Further, on 29 June 1985, Transport Canada directed that all baggage or cargo being interlined within Canada to an Air India flight was to be physically inspected or X-rayed at the point of first departure and that matching of passengers to tickets was to be verified prior to departure.

2.7 Air India Security Program in Canada

In accordance with the Foreign Aircraft Security Measures Regulations, Air India had provided the Minister of Transport with a copy of its security program. It included measures to:
- establish sterile areas;
- physically inspect all carry-on baggage by means of hand-held devices or X-ray equipment;
- control boarding passes;

- maintain aircraft security;
- ensure baggage and cargo security; and
- off-load baggage of passengers who fail to board flights.

Under these procedures established by Air India, passengers, carry-on baggage, and checked baggage destined for AI 181/182 on 22 June 1985 were subjected to extra security checks. A security officer from the Air India New York office arrived in Toronto on 22 June 1985 to oversee the security operation at Toronto and Montreal.

On 17 May 1985, the High Commission of India presented a diplomatic note to the Department of External Affairs regarding the threat to Indian diplomatic missions or Air India aircraft by extremist elements. Subsequently, in early June, Air India forwarded a request for "full and strict security coverage and any other appropriate security measures" to Transport Canada offices in Ottawa, Montreal and Toronto, and RCMP offices in Montreal and Toronto.

2.8 PD-4 Sniffer

On 18 January 1985, prior to the inaugural Air India flight out of Toronto on 19 January, a meeting on security for Air India flights (Toronto) was held with representatives from Transport Canada, RCMP and Air India. At this meeting, a PD-4 sniffer belonging to Air India was produced. It was explained that it would be used to screen checked baggage as the X-ray machine had not yet arrived. At that time, an RCMP member tested its effectiveness. The test revealed that it could not detect a small container of gunpowder until the head of the sniffer was moved to less than an inch from the gunpowder. Also, the next day the sniffer was tried on a piece of C4 plastic explosives and it did not function even when it came directly in contact with the explosive substance. It is not known if this was the same sniffer used on 22 June 1985.

2.9 Medical Evidence

Medical examination was conducted on the 131 bodies recovered after the accident. This comprises about 40 per cent of the 329 persons on board. It should be noted that assigned seating is based on preliminary information. Also, the exact position of passengers is not certain because it is not known if passengers changed their seats after lift-off. On the information available, the passengers were seated as follows:

Passengers:*

	Seats Available	Occupied	Bodies Identified
Zone A	16	1	0
Zone B	22	0	0
Upper Deck	18	7	0
Zone C	112	104 + 2	29
Zone D	86	84 + 1	38
Zone E	123	105 + 3	50
SUB-TOTAL	377	301 (+6 infants)	117
Crew:			
Flight Deck	3	3	0
Cabin	19	19	5
TOTAL	399	329	122

There were 30 children recovered and they showed less overall injury. The average severity of injury increases from Zone C to E and is significantly less in C than in Zones D and E.

Flail pattern injuries were exhibited by eight bodies. Five of these were in Zone E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evenly

*See Appendix C for interior seating arrangement.

distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 in Zone D, 11 in Zone E, 2 crew and 1 unknown), and 16 had little or no clothing.

Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

There is a general absence of signs indicating the wearing of lap belts.

Pathological examination failed to reveal any injuries indicative of a fire or explosion.

2.10 Flight Recorders and Shannon Air Traffic Control (ATC) Tape Analyses

VT-EFO was equipped with a Fairchild A100 Cockpit Voice Recorder (CVR) and a Lockheed 209E Digital Flight Data Recorder (DFDR). These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the aft pressure bulkhead. The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor.

The Shannon Air Traffic Control Centre was in contact with VT-EFO and recorded radio communications with the aircraft. At the time of the accident, 5.4 seconds of noise was recorded, and the transponder signal seen on the radar scope was lost from the aircraft. This signal which displays aircraft altitude showed no deviation before disappearing from the radar scope.

2.10.1 Analysis by National Research Council, Canada

From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder. The initial waveform of the cockpit area microphone signal is not consistent with the sharp pressure rise expected with detonation of an explosive device close to the flight deck, but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, the possibility that it originated from such a device elsewhere in the aircraft cannot be excluded.

By correlating the oscillograph records of the CVR and the Shannon ATC VHF recording, it was estimated that the unusual sounds recorded on the ATC tape started 1.4 ± 0.5 seconds after the start of the sudden sound detected by the cockpit area microphone and lasted intermittently for 5.4 seconds. It was felt the closeness in time of the two noises indicated the 5.4 seconds recorded on the ATC tapes originated from AI 182. The ATC recording that followed the cockpit area microphone sounds appeared at first to contain a series of short intermittent sounds. Listening to the sounds, it also appeared that a human cry occurred near the end of the recording. Spectral analysis of these sounds and comparison with voice imitations revealed that the recorded sounds do not contain all the pitch harmonic frequencies normally associated with voice sounds. The origin of these sounds has not been determined.

An examination of the DFDR showed no abnormal variations before the accident. With the spare engine, this aircraft was restricted to altitudes below 35,200 feet and indicated airspeeds less than 290 knots. During the last 27 minutes of the flight, the computed airspeed did gradually increase to nine knots above this limit in the first part of this period and the power was readjusted several times. The speed fell below the 290 knot limit at about 07h:09m GMT as recorded by the DFDR; power was increased again at about 07h:10m causing the aircraft to accelerate to six knots above the limit by the time the accident occurred at 07h:13m:59s. The observed excursions outside the specified limits are not considered significant.

The aircraft was flown with 1.5-degree left-wing-down with 4.2 degrees clockwise control wheel as compared to the aircraft without the 5th engine installation. Also, 9.4 per cent of right rudder pedal was applied giving a 1.1-degree right deflection of the upper and lower rudders. Considering the carriage of the 5th engine on the left side, these figures are not considered abnormal.

When synchronized with the other recordings, it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR.

Irregular signals were observed over the last 0.27 inches of the DFDR tape. Laboratory tests indicated that the irregular signals most likely occurred as a result of the recorder being subjected to sharp angular accelerations about the lateral axis of the recorder, causing rapid changes in tape speed over the record head. This equates to an angular acceleration on the recorder about the aircraft's longitudinal axis in a left-wing-down sense. Therefore, these tests indicate that the digital recorder was subjected to a sharp jolt separate from any violent motion of the aircraft.

The other possibility for the irregular signals is that the Flight Data Acquisition Unit which generated the serial digital data signal and which is located in the electronics bay under the cabin floor forward of the cargo compartment could have suffered some damage or had an intermittent power supply that caused it to generate the irregular signals.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom

The AIB analysis was restricted to the CVR and the Shannon ATC tape. The correlation of the CVR and ATC tapes showed that the ATC recording started after the CVR had stopped recording and 1.1 ± 0.4 seconds from the start of the sudden sound. The total duration of the signal on the ATC tape was 5.4 seconds.

An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Evidence of the presence of audio warning signals buried amongst the noise was investigated with negative results. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.

The analysis of the ATC tape audio determined three or four words could be heard at the beginning of the transmission, but extensive filtering did not allow the sounds to be transcribed. Two bursts of tone occurred during the first second. The spectrum of the tone does not coincide with any B747 audio warning. The transmission is chopped until at about 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound is similar to that heard in other accidents where there has been a rapid increase in airspeed. Toward the end of the transmission a crying sound was heard; however, a study of the noise indicates a human cry would contain more harmonics. The origin of this sound was not determined. Knocking sounds were also heard during the transmission. These were initially thought to be due to hand-held microphone vibration, but this was discounted because of the frequency of the sounds. Almost identical sounds were heard on the DC-10 CVR after the explosive decompression had occurred. Their source was not identified. On the DC-10, the pressurization audio warning sounded 2.2 seconds after the decompression. No such warning was identified on the ATC tape.

*Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization. A loud noise is associated with this event but not necessarily an explosion.

Every aircraft provides a different signature when the press-to-transmit button is released. These signatures were compared with transients which occurred during the open microphone transmission. There is a close match with the previous AI 182 signatures. Therefore, it is almost certain that the ATC tape recording originated from AI 182.

The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182. It further states there is strong evidence to suggest a sudden explosive decompression of undetermined origin occurred. Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. However, the AIB report is of the opinion that the device would have to be small not to be detected as it is considered that a large high-explosive device could not fail to be detected on the CVR.

2.10.3 Analysis by Bhabha Atomic Research Centre (BARC), India

The BARC analysis was restricted to the CVR and the Shannon ATC tape.

Channel 3 of the recording which corresponded to the cockpit area microphone showed the first indication of a rising audio signal. The signal level rises from the ambient level in the cockpit by about 18.5 decibels in approximately 45 milliseconds. The signal starts falling and stabilizes at a level about 10 decibels higher than ambient for about 375 milliseconds. The total duration of the signal is about 460 milliseconds.

The timings of the CVR and the Shannon ATC tape were correlated, and it was determined that the explosive sound on the CVR coincided with the beginning of the series of audio bursts on the ATC tape. The report concluded that the sounds recorded on the ATC tape emanated from AI 182 at the time of the occurrence.

The noise on the CVR was compared with an explosion which caused the crash of an Indian Airlines B737. In this occurrence, the explosive sound recorded on the cockpit area microphone showed a rise time of about 8 milliseconds. It was also determined that the explosion occurred 8 feet from the microphone. The report concluded that the rise time is a measure of the distance from the cockpit area microphone to the source of an explosion. Hence, the exact location in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the cockpit judging from the rise time of 45 milliseconds.

The report concluded that the series of audio bursts on the ATC tape were most probably generated by the break-up of AI 182 in mid-air.

2.11 Aircraft Structures Examination

The examination of aircraft structures consisted of the following areas: floating wreckage, wreckage mapping and surveying, wreckage distribution, photographic and video interpretation of wreckage, wreckage recovery and initial examination, and examination of recovered wreckage.

2.11.1 Floating Wreckage

During the search, aircraft wreckage was sited and recovered by several search vessels. The wreckage was transported to Cork, Ireland, where preliminary examination was conducted. This examination took place in June and July, 1985.

The wreckage consisted mainly of various leading edge skin panels of the left and right wings, left wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canoe fairing pieces, landing gear wheel well doors, pieces of elevator and aileron, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggage, suitcases, personal effects and a number of internal fittings. The floating wreckage constitutes about three to five percent of the aircraft structure.

The wreckage was then transported from Ireland to Bombay, India where it underwent further examination by the Floating Wreckage Structures Group which then produced a report which was submitted to the Indian Inquiry. The report concluded:

- There was no evidence of fire damage.
- There was no evidence of lightning strike damage.
- The cabin floor panels from the forward and rear sections of the aircraft separated from the support structure in an upward direction (floor to ceiling) pulling free from the attaching screws and, in some cases, breaking the vertical web of the seat track/ floor beams.
- The position of the leading edge flap rotary actuator and the damage to the flap structure indicated that the leading edge flaps were in the retracted position.
- The six spoiler actuators found were in the retracted position. The lower surface of all the spoiler panels showed signs of spanwise skin splits with the edges curled into the core of the honeycomb. The report concluded that this was possibly due to the loading of the spoilers by being deployed in flight at high speed, resulting in compression on the lower surfaces. This, in turn, caused splitting of the lower skin into the honeycomb.

- The right wing root leading edge, number 3 engine inboard fan cowling, the right inboard midflap inboard leading edge, and the right stabilizer root leading edge all exhibited damage possibly due to objects striking the right wing and stabilizer before water impact.

In addition to the above conclusions, the following significant information regarding the floating wreckage is noted in the report:

- The aircraft was carrying a -7Q engine at the 5th pod and a -7J 5th pod kit in the aft cargo compartment. In all there were 14 engine fan cowls (four in the aft cargo compartment). Out of these 14 fan cowls, nine, including six from the working engines and three from the aft cargo compartment, and two additional pieces of fan cowls were found. Five of the fan cowls from the working engines showed folding damage lines at about the three and nine o'clock positions. The number 3 engine inboard fan cowl had severe impact damage on its leading edge and had small outward puncture holes but no penetration through the outer skin in the lower centre region. The two fan cowls of the -7J 5th pod kit stowed in the aft cargo compartment showed severe damage. One piece was cut at one corner in an arc of about 20 inches diameter and its external skin was peeled back.
- The cockpit entry door and the side bulkhead panel were found relatively intact but had come out of their attachments.
- Twelve toilet doors out of 16 were found and were relatively intact but had come out of their attachments.
- Cabin interior panels and overhead bins of the main and upper decks which were recovered exhibited only minor damage.
- The wooden boxes which contained the fan blades of the 5th pod engine were loaded in container 24L in the forward cargo compartment and were found broken apart exhibiting no burn marks.
- One passenger oxygen bottle and one portable oxygen bottle

were recovered and showed no sign of damage.
Mr. V.J. Clancy, an aviation explosives expert representing Boeing Aircraft Corporation, prepared a preliminary report based on his examinations of certain items of recovered and floating wreckage. Mr. Clancy's report notes the following with respect to floating wreckage:

- A foam-backed floor panel which showed a small number of perforations was recovered. Mr. Clancy recommended that it should be X-rayed and a detailed examination completed.
- One of the lavatory doors had, into its inner surface, a number of fragments of glass mirror - presumably from breakage of a mirror normally fitted into the lavatory. Most of the fragments, buried edgeways, were oriented parallel to each other. The remainder were approximately at right angles to the others. Mr. Clancy concluded that it would be improbable that any reliance could be placed on the penetration by mirror fragments as being indicative of an explosion.
- Three steel oxygen cylinders which were stowed in the forward cargo compartment were recovered. One had been dented apparently by the impact of an object measuring about one to two centimetres. The depression had a maximum depth of about four millimetres.
- A few suitcases recovered among the floating wreckage were examined. Mr. Clancy felt that one might provide useful information. It was of red plastic material with a blue lining. Mr. Clancy reported that plastic material has been found to retain identifiable traces of explosive after long immersion in the sea. Also, the lining which was severely tattered resembled that of one found after an explosion in an aircraft in Angola.
- A wooden spares box was found on the foreshore of Wales. It was of the kind used on the aircraft. It was charred on one side and partially on the bottom. The depth of charring suggested that the burn time was three to four minutes. This box was normally

stowed in the aft cargo compartment; however, on this flight it may have been stowed in the forward compartment.

- Two pieces of the cover of an overhead locker originating above either door 2R or 4R were also found on the foreshore. They were partially damaged and blackened by fire. Mr. Clancy concluded that this indicated the presence of fire.
- Two pieces of U-section alloy channel partially filled with plastic foam were found on the foreshore. The alloy was of a kind not used in aircraft structure; however, it could have been from some fitting supplied by a sub-contractor. Also, since the pieces were found near an area where practice firings at targets are carried out off the west coast of the United Kingdom, it could have come from some other source. One piece of the alloy bore marks ("mooncraters") typical of an attack by very high velocity fragments such as produced by an explosion. X-rays showed the presence of a few small particles buried in the foam which Mr. Clancy recommended should be extracted and examined. He also felt that this provided the strongest single indication of an explosion and that it was essential to determine if these pieces came from the aircraft or any of the equipment or cargo aboard the aircraft.

The CASB in its examination of the floating wreckage noted the following:

- The fan cowls of the number 4 engine had a series of five marks in a vertical line across the centre of the Air India logo on the inboard facing side of the fan cowl. These marks had the characteristic airfoil shape of a turbine blade tip. It is possible that a portion of the turbine parted from the number 3 engine and struck the cowl of the number 4 engine.
- The upper deck storage cabinet which was located on the left side had unusual damage to its bottom. A large rounded dent in the bottom inboard edge of this stiff cabinet structure revealed smooth stretching without breakthrough. The damage did not

seem to be achievable by inertia or impact forces as the cabinet except for the bottom was undamaged. The damage was considered by a CASB investigator to be compatible with the spherical front of an explosive shock wave generated below the cabin floor and inboard from the cabinet; however, it is not known if this damage could be caused by some other means.

- The right wing root fillet which faired the leading edge of the wing to the fuselage ahead of the front spar had a vertical dent similar to that which would have resulted had the fillet run into a soft cylindrical object with significant relative velocity. The paint on the inboard chord appeared to be scorched brown in the centre areas of three honeycomb panels. It has been determined that sudden heat can turn these panels brown, but it is not known if other reasons for the discolouration exist. The fillet abutted the fuselage side at the aft end of the forward cargo compartment.
- There was blackened erosion damage to the bottoms of some seat cushions. The damage had an appearance similar to that which would have been caused by an explosive device. It is not known if marine life feeding on the cushions or some other cause could have produced the same effect.
- The charred wooden spares box contained some sand and small shellfish. The flesh from the shellfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

An electronic device was found among some floating wreckage and was forwarded to the Bhabha Atomic Research Centre for analysis. There was some concern that it could have been used to detonate an explosive device. The device was forwarded to the RCMP who in conjunction with the CASB determined it to be an item manufactured for use in radiosondes (weather balloons) and was not modified as a detonating device.

2.11.2 Wreckage Mapping and Surveying

The Canadian Coast Guard Ship (CCGS) John Cabot was given the task of mapping the wreckage on the ocean floor. On 19 July 1985, the Cabot with a SCARAB deep submersible on board departed Cork. On arrival at the site, and based on surface wreckage distribution and bottom side scan sonar plots, four transmitters were placed on the sea bed. These transmitters provided signals for the ALLNAV navigation system used to accurately plot the sea bed wreckage.

Based on all the data available, the SCARAB was launched on 24 July 1985 to begin the bottom search in position 51°01.9'N 12°41.0'W. During the mapping, stage areas were designated for search and each progressive area was determined based on the information gained during the search. The search was conducted using sonar and video. Wreckage found was recorded on video tape and on 35mm positive film.

The first object plotted on the sea bed was a torn suitcase located at lat 51°02.63'N, long 12°53.15'W and was the most westerly object located. This suitcase has not been recovered, nor has it been positively identified as having come from the accident aircraft.

As the search progressed eastward, the first positive identification of aircraft wreckage was made at lat 51°02.9'N, long 12°49.93'W. Slowly, over a period of about 90 days, a detailed bottom wreckage plot was developed.

While mapping was in progress, some of the wreckage was revisited to obtain additional data. During the transit through areas already searched, wreckage not previously plotted was found, and, in some areas, the density of wreckage physically precluded 100 per cent coverage. Components and major structural items were identified from all sections of the aircraft and when the mapping of the sea bed ended, most of the aircraft had been found and photographed. Although positive identification of each piece of wreckage could not be made, it was decided in late October 1985 that the search phase was essentially completed and wreckage recovery could begin. A bottom wreckage distribution plot is contained separately in an envelope as Appendix F.

2.11.3 Wreckage Distribution

The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling on the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled.

Although badly damaged, sections 41, 42 and 44*, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been plotted or photographed.

Sections 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the westernmost identified aircraft component located at lat 51°02.90'N and long 12°50.1'W. The wreckage extended in a line about 110 degrees True to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern.

A?? third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southeast orientation. One of the operating engines was displaced 0.5 nautical miles to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

*See Appendix D for location of aircraft sections and aircraft body stations (BS).

2.11.4 Photographic and Video Interpretation of Wreckage

2.11.4.1 Photographic Interpretation

All wreckage sighted was recorded on video tape and all major items were recorded on 35mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage patterns. For example, the sine wave bending of target 7* appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into account.

2.11.4.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

2.11.4.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gear were in the 'up' position at the time of impact.

2.11.4.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

*See Appendix E for location of targets on aircraft.

2.11.4.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

2.11.4.6 Section 42

Portions of section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers.

All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

2.11.4.7 Section 44

Section 44, containing the aircraft structure between body station (BS) 1000 and BS 1480 including that area where the fuselage and wings were mated was located in the same general area as the forward sections of the aircraft. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one-third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gear were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

2.11.4.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northernmost area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

2.11.4.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of BS 1480 and, for purposes of this Submission, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were identified (targets 35, 37, 73 and 296), and one portion of the bulkhead was never located. Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognizable as having come from a specific area of the aircraft.

Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from BS 1600 to BS 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

The tail cone and the auxiliary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure of air or water.

The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabilizer was missing and the auxiliary spar was exposed. There was localized damage to the right-hand root of the leading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

2.11.4.10 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from sections 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42, and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat-belts were not fastened.

2.11.5 Wreckage Recovery and Initial Examination

During the wreckage mapping, some small items were recovered, and an unsuccessful attempt was made to recover a portion of the forward cargo door. On completion of the sea bed survey, an offshore supply ship, Kreuztrum, chartered by the National Transportation Safety Board (NTSB), joined John Cabot for a wreckage recovery operation. Prior to the commencement of the wreckage recovery, the structures group met at the Boeing facility in Seattle, USA and reviewed the video tapes and photographs of the wreckage. Based on their findings, a list of items was identified as being most desirable for recovery. The priority list was prepared by a group in Cork, Ireland, headed by Dr. V. Ramachandran. On 8 October 1985, the John Cabot sailed, and on 9 October 1985, the Kreuztrum sailed for the accident site. The following target numbers and items were recovered during the mapping and wreckage recovery stages of the investigation: 7, 8, 35, 47, 117, 193, 223, 245, 287, 296, 299, 362/396, and 399 (as the location on the aircraft of some of the targets was not known when Appendix E was created, some are not shown in the appendix). The first officer's seat, some suitcases and small debris were also recovered using a metal frame basket. Initial examination of the wreckage was carried out in Cork and then it was transported to Bombay for detailed examination.

2.11.6 Examination of Recovered Wreckage

Although all the recovered wreckage was examined, only those items exhibiting characteristics which provided some evidence as to what may have happened to the aircraft during its final moments of flight are discussed. CASB engineering personnel and other participants examined the recovered wreckage at Cork and Bombay. The observations made during their examinations are discussed below.

2.11.6.1 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from BS 1480 to 1860 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear, and the torn edge was buckled in waves, like the trace of a sine wave. On the right side, between the one-quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at BS 1480. The skin tear located at about BS 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distorted and elongated.

The left and right trunnion vertical support fittings located at BS 1480 were examined optically using the stereomicroscope. Both trunnions were fractured through the three bolt holes. The right fracture characteristics were consistent with an overload mode of failure. Although most of the left fracture surface was also characterized by overload features, there were heavily corroded areas where the fracture mode could not be confirmed through optical examination. One lug fracture was sectioned from the left trunnion and prepared for scanning electron microscope (SEM) examination. After the corroded area was cleaned, the examination revealed some ductile characteristics on the fracture surface. There was no evidence of intergranular fracture observed to suggest a stress corrosion cracking mode of failure, nor was there any evidence of progressive failure observed. The corrosion appeared to have developed after the accident.

2.11.6.2 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from BS 1860 to 1960 and from stringer 46L to 46R. A small section from the aft end along the belly skin splice at stringer 46L was removed for examination. SEM examination revealed that the fracture was characterized by slightly elongated ductile dimples along its length, including areas adjacent to the edges of the rivet holes. On the aft edge of each rivet hole examined, a distinctive shear lip was observed. These features are consistent with an overload mode of failure along the skin splice with an apparent direction of failure from aft to forward.

2.11.6.3 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 o'clock position. The piece from 12 to 1 o'clock had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 o'clock position, the outer edge showed sinusoidal buckling, and the edge sector at 9 o'clock was partially collapsed and its edge was turned under. Samples taken for optical stereomicroscope and SEM examination revealed that the fracture characteristics were consistent with an overload mode of failure. The examination suggested a general direction of failure from the aft to the forward edge of the rear pressure bulkhead panel.

2.11.6.4 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occupied the 7 to 9 o'clock position. Optical and SEM examination were undertaken on this item.

The fracture along the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

Representative fracture samples were cut from the left-hand and right-hand edges of the fracture surfaces. Optical and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

2.11.6.5 Target 47 - Aft Cargo Compartment

This portion of the aft cargo compartment roller floor was located between BS 1600 and BS 1760. Based on the direction of cleat rotation on the skin panel (target 7) and the crossbeam displacement on this structure, target 47 moved aft in relation to the lower skin panel when it was detached from the lower skin. No other significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

2.11.6.6 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between BS 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

2.11.6.7 Target 399 - Left-Hand Side Triple Seat with Tray Arms

It would appear that this section was from row 18, seats A, B and C, the first set of triple seats aft of door 2L. The notable damage to this unit was as follows: front leg aisle side buckled and crushed in place; front leg window side buckled and crushed in place; forward edge tube to seat broken and bent downwards at joint with fore and aft tube between window and centre seats; and fore and aft tube between centre and aisle seat broken at start of T-connection to rear edge of seat tube. The damage suggests that the failures resulted from vertical loading. All the life-jackets were in place.

2.11.6.8 Target 399 - Fuselage Side and 2R Entry Door

The fuselage segment was located between BS 780 and 940. This piece was badly damaged and buckled inwards along a line through the lower door hinge. There were 12 holes or damaged areas on the skin generally with petals bending outwards. The curl on a flap around a hole had one full turn. This curl was in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.

When this target was recovered from the sea, along with it came a few hundred tiny fragments and medium-sized pieces. One of the medium-sized pieces recovered with this target was a floor stantion about 35 inches long. It was confirmed that this stantion belonged to the right side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the stantion.

Scientists from the Bhabha Atomic Research Centre, the National Aeronautical Laboratory and the Explosives Research and Development Laboratory in India conducted a metallurgical examination of certain items of wreckage. Their report on target 399 concluded that:

- the curling of the metal on the floor channel was indicative of a shock wave effect;
- the large number of tiny fragments from the disintegration of nonbrittle aluminum was a characteristic indication of explosive forces; and
- the indications of punctures, outward petalling around holes, curling of metal lips, reverse slant fracture, formation of spikes at fracture edges and certain microstructural changes all were indicative of an explosion.

2.11.6.9 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segment was located between BS 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

2.11.6.10 Target 362/396 - Lower Skin Panel - Forward Cargo Area

This section of skin panel was located between BS 720 and 860 and is just below target 399. The skin was badly crumpled and torn and had several punctures. It was pulled free from a large mass of debris which included some mangled cargo floor beams and roller trays. Some of the punctures had a feathered or spiked profile, with spikes angled at approximately 45 degrees to the edge. Other puncture holes gave clear indication of being formed by underlying stiffeners at impact. Two of these holes contained pieces of web stiffener. Most of the punctures were the result of penetrations from inside.

In the preliminary report of Mr. V.J. Clancy, representing Boeing, the following observations regarding target 362/396 were made:

- There were about 20 holes in the lower skin panel clearly resulting from penetration from inside.
- In addition to the fact that perforation was from inside, there were certain features which suggested that they were made by high velocity fragments such as those produced by an explosion.

Mr. Clancy's report describes these features as follows:

- the presence of toothed or spiked edges at some parts of the metal which has petalled out from the perforations;

(Tardif and Sterling, Canadian Aeronautics and Space Journal, 1969, 15, 1, 19-27, obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.)

- the presence of marked curling (in some cases of more than 360 degrees) of some of the petals;

(Tardif and Sterling stated that such curling was a feature of explosively produced fragments.)

- the virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal;
- the virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object, thereby suggesting that the production of at least many of the perforations were separate independent events; and
- the presence of one perforation (identified as number 14) resembling a "bullet hole" that was clearly punched out - a type of hole usually associated with a high velocity missile.
- There was evidence that the forward part of the skin panel had been folded back inward along the line of station 760 and then bent back again along a line slightly forward of this station.
- Such folding, perhaps violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces, thus producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.
- One hole (identified as number 13) was almost certainly caused by a slipping wire rope used as a sling.
- Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken of this area for further examination for evidence of fire or explosives.
- A large number (several hundred) of small fragments were recovered. These varied in size from an inch or less to a few inches. They included fragments broken out of sheet metal, and these were reported to be from the same area as T362.
- The production of a large number of small fragments is generally regarded as an indication of an explosion.
- One piece, which was isolated, was about an inch square of sheet alloy with characteristic spikes on one edge similar to those

described by Tardif and Sterling.

The following is an excerpt from the report by Mr. V.J. Clancy wherein he gives his opinion and conclusions regarding target 362.

"Opinion

The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

A more detailed study, metallurgical and fractographic, is required.

The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

The single "bullet hole," No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

If the forward part of this item was forcefully and rapidly folded back to impact on the other part, it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility.

The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation. The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

Mr. Clancy concluded that:

"there is strong circumstantial evidence that an explosion occurred but neither individually nor collectively do the several pointers give the degree of confidence necessary for a firm and final conclusion, at this time."

With respect to target 362/396, in his report Mr. Clancy recommended:

"that firing trials be carried out projecting various size missiles at targets similar to the material of T362 to obtain reference samples for laboratory comparison with the perforations in T362."

The Indian report, in addition to the observations made by Mr. Clancy, noted the following with respect to the metallurgical examination:

- The microstructure in the various areas examined on target 362/396 confirmed explosive loading in this part of the aircraft.
- The holes and other features observed in targets 362/396 and 399 must have been due to shock waves and penetration by fragments resulting from an explosion inside the forward cargo hold.
- The chemical nature of the explosive material was not identified. No part of an explosive device, its detonator or timing mechanism was recovered.

2.11.6.11 Examination of Wreckage in India with CASB Participation

The examination of the targets recovered did not reveal any pre-existing defect, premature cracking or pre-impact corrosion damage associated with any of the failures.

3.0 DISCUSSION

3.1 Initial Event

From the correlation of the recordings of the DFDR, CVR and Shannon ATC tape, the unusual sounds heard on the ATC tape started shortly after the flight recorders stopped recording. The conversations in the cockpit were normal, and there was no indication of an emergency situation prior to the loud noise heard on the CVR a fraction of a second before it stopped recording. The DFDR showed no abnormal variations in parameters recorded before it stopped functioning. The only unusual observation was the irregular signals recorded over the last 0.27 inches of the DFDR tape. Laboratory tests indicated the possibility that these signals resulted from the recorder being subjected to a sharp disturbance at the time it stopped recording. The other possibility for the irregular signals on the DFDR is that they were caused by a disturbance to the Flight Data Acquisition Unit in the main electronics bay. Since there was an almost simultaneous loss of the transponder signal, this indicates the possibility of an abrupt aircraft electrical failure. The medical evidence showed a general absence of signs indicating that seat-belts were fastened. From the video and photographic examination of the wreckage on the bottom, it was ascertained that the majority of seats located did not have the seat-belts fastened. The above evidence indicates that the initial occurrence was sudden and without warning. The abrupt cessation of the data recorder could be caused by airframe structural failure or the detonation of an explosive device as the initial event. The millisecond noise on a CVR as observed in this case is usually, as described in the available literature, the result of the shock wave from detonation of an explosive device. However, in this case, certain characteristics of the noise indicate the possibility that the noise was the result of an explosive decompression. There is some disagreement regarding the cause and location of the source of the noise heard on the CVR, that is, whether the noise resulted from an explosive device or an explosive decompression and whether the noise originated from the rear or closer to the front of the aircraft.

3.2 Passenger/Flight Deck Area

From the examination of the wreckage recovered and wreckage on the bottom, there is no indication that a fire or explosion emanated from the cabin or flight deck areas. The medical examination of the bodies also showed no fire or explosion type injuries. However, pieces of an overhead locker coming from above door 2R or 4R had been blackened by fire. There was blackened erosion damage to the bottoms of some seat cushions, showing damage possibly from an explosive device, and the upper deck storage cabinet had a large rounded dent in the bottom inboard edge which might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet. It should be noted that the pieces of the overhead locker were found on the Welsh shore some time after the accident, and it is not known if the pieces were subjected to a fire after the accident. Also, it is not known if the damage to the seat cushions and the upper deck storage cabinet could have been caused by other means. Nevertheless, the above evidence suggests that some areas of the passenger cabin may have been subjected to minor fire and explosive damage possibly emanating from below the cabin floor.

3.3 Aircraft Break-up Sequence

The medical evidence showed a proportion of the passengers with indications of hypoxia, decompression, flail injuries and loss of clothing. The incidence of hypoxia and decompression indicates that the aircraft experienced a decompression at a high altitude. The flail injuries and loss of clothing indicate a proportion of the passengers were ejected from the aircraft before water impact. The severity of injuries increased from Zones C to E and was significantly less in Zone C than in Zones D and E. The wreckage of the forward portion of the aircraft up to and including the aircraft body wheel well area and the wings was lying about 0.8 miles north of the vertical and horizontal stabilizers. Hence, it is likely that the aft portion of the aircraft separated from the forward portion before striking the water. In addition, the wreckage found west of longitude 12°48' consisted of suitcases and aft cargo compartment lower skin panels. There was also a wide scatter of sections 46 and 48 in an east-west direction, whereas the wreckage of the forward portion was mainly localized within a relatively small area.

The higher severity of injuries in the aft end of the passenger cabin appears to coincide with the break-up of the aft end, sections 46 and 48 of the aircraft. The fact that items from the aft cargo compartment were found further west than the tail section indicates that the aft cargo compartment ruptured first during the break-up sequence of the aft end. The forward portion of the aircraft was highly localized, which indicates that it struck the water in one large mass.

3.4 Aircraft Structural Integrity

As described earlier, the sudden nature of the occurrence indicates the possibility of a massive airframe structural failure or the detonation of an explosive device.

3.4.1 Aircraft Break-up

The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer before water impact. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.

The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile

to the west indicating that there was some break-up of the number 3 engine before water impact.
The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction. Also, passenger seats viewed and recovered exhibited that they had been subjected to an upward force from below. They showed that the seats to the rear in sections 46 and 48 had their back legs buckled, and the seats toward the front had both front and back legs buckled. This indicates the vertical force was greater at the front than the rear of the aircraft. It is possible that this vertical force on the floor was caused by the force of the water during impact, but the rear of the aircraft broke up before impact and therefore any vertical loading on the floor in this area is unlikely to have occurred at impact. Twenty-three passengers also showed evidence of vertical impact injuries. These could have been caused from a force from below during flight or at water impact. Sixteen of these passengers had little or no clothing indicating that some may have been ejected before water impact. Therefore, there is some indication that the upward force on the floor may have occurred in flight and was more severe toward the front.
3.4.2 Aft Pressure Bulkhead

The localized impact mark found on the leading edge of the right horizontal root leading edge is indicative of an object striking the stabilizer in flight before water impact. This suggests that the loss of the tail plane was not the first event. The horizontal and vertical stabilizers were found separated and each was intact and in good condition. Items from the aft cargo compartment were found further to the west of the tail plane. The absence of the type of damage to the tail plane as was found in the Japan Airlines (JAL) Boeing 747 accident where the aft pressure bulkhead failed and which took place shortly after this occurrence, and the rupture of the aft cargo compartment before the loss of the tail indicate that there was not an in-flight failure of the aft pressure bulkhead. In addition, examination of the recovered portions of the bulkhead shows evidence of overload failures from the rear to front only and no evidence of any pre-existing defect, premature cracking or pre-impact corrosion damage.

3.4.3 Target 7 - Lower Fuselage Skin Panel

Target 7 which extends from BS 1480 to 1860 shows a break at the joint at BS 1480. The forward keel joint splice plate is bent and the keel joint holes are distorted and elongated. Some of the fracture surface was heavily corroded. An in-flight failure in this area would cause a massive failure of the aircraft's structural integrity. Further examination showed the fractures to be overload, and there was no evidence of an intergranular type fracture to suggest a stress corrosion cracking mode of failure. The corrosion was concluded to be post-impact and, therefore, there is no evidence to suggest an in-flight failure in this area as the initial event.

3.4.4 Structural Failure

The examination of the floating and recovered wreckage and the analysis of the photos and videos of the wreckage on the bottom failed to indicate any evidence of a failure of the primary or secondary structure as a result of a pre-existing defect. The initial event has been established as sudden and without warning. The abrupt cessation of the flight recorders indicates the possibility of a massive and sudden failure of primary structure; however, there is evidence to suggest that there were ruptures in the forward and aft cargo compartments prior to any failure of the primary structure in flight. Therefore, available evidence tends to rule out a massive structural failure as the initial event.

3.4.5 Explosive Device

A violent explosion occurring within an aircraft in flight usually leads to a complicated break-up mode and sequence of failure. Fractures of metal caused by an explosion are normally different in character to those caused by overstressing or crash impact forces. Shattering of metal into very small and numerous fragments and minute deep penetration of a metal surface are not usually found in aircraft accident wreckage. The size and characteristics of these particles often accompanied by rolled edges, surface spalling, pitting or evidence of heat are indicative of an explosion.

Of the floating wreckage, there is little to indicate the possibility of an explosion:

- the lining in one suitcase was severely tattered;
- although the wooden spares box was burned, this could have happened after the occurrence;
- although pieces of an overhead locker were damaged by fire, it is not known if the burning happened at the time of the occurrence;
- although the pieces of U-section alloy clearly indicated evidence of an explosion, it is quite possible that these pieces were not associated with the aircraft;
- the bottoms of some seat cushions show indications of a possible explosion;
- the inside of the right wing root fillet appears to have been

scorched; and

- the deformation of the floor of the upper deck storage cabinet might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet.

It is not known if the suitcase came from the aft or forward cargo compartment, and the location of the seats from which the cushions came is also unknown.

The scorching of the right wing root fillet and the damage to the upper deck cabinet suggest, if there was an explosion, it emanated from the forward cargo compartment.

From the examination of the recovered wreckage, the following deductions can be made:

- Target 47, which is a portion of the aft cargo compartment roller floor, shows no indications characteristic of an explosion emanating from the aft cargo compartment.
- Target 362/396, which is a lower skin panel from the forward cargo compartment is badly crumpled and torn and has about 20 punctures resulting from penetration from inside. It appears that some folding occurred on water impact which brought stringers or stiffeners from the aircraft structure into forceful contact with the internal surface of the panel producing most of the penetrations. However, there are certain punctures which indicate no evidence of impact marks on the inside surface and show evidence of being produced by high velocity fragments. Part of the inner surface of the skin panel appeared to have been blackened by soot from a fire.
- Target 399, consisting of a piece of the skin and stringers on the right side in the area of the forward cargo compartment contained holes and several hundred metal fragments. The damage to the floor stantion and the presence of the fragments are consistent with an explosion.

The examination of the recovered wreckage contains no evidence of an explosion except for targets 362/396 and 399 which contain some evidence that an explosion emanated from the forward cargo compartment.

An explosion in the forward cargo compartment would explain the loss of the DFDR, CVR and transponder signal as the electronics bay is immediately ahead of the cargo compartment.

3.5 Security Aspects

There is a considerable amount of circumstantial and other evidence that an explosive device caused the occurrence. Therefore, it is reasonable to examine the security measures in place on 22 June 1985. The evidence indicates that if there was an explosion, it most likely occurred in the forward cargo hold, not the passenger and flight deck areas or exterior to the fuselage. Although an explosive device could have been placed in a cargo hold in a number of ways, the available evidence points to the events involving the checked baggage of M. and L. Singh in Vancouver. The investigation determined that a suitcase was interlined unaccompanied from Vancouver via CP Air Flight 060 to Toronto. In Toronto, there is nothing to suggest that the suitcase was not transferred to Terminal 2 and placed on board Air India Flight 181/182 in accordance with normal practice. The aircraft departed Toronto for Mirabel and London with the suitcase unaccompanied. Similarly, a suitcase was interlined unaccompanied on CP Air Flight 003 from Vancouver to Tokyo to be placed on Air India Flight 301 to Bangkok. The explosion of a bag from CP 003 at Narita Airport, Tokyo, took place 55 minutes before the AI 182 accident. Therefore, the nature of the link between the two occurrences raises the possibility that the suitcase which was unaccompanied on AI 182 contained an explosive device.

3.5.1 Canadian Security Situation

Canadian security arrangements in place prior to 23 June 1985 met or exceeded the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand luggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

In Canada, the Department of Transport (Transport Canada) is responsible for establishing overall security standards for airports and airlines, and for the provision of certain security equipment and facilities at airports. By regulation, air carriers are responsible for applying security standards for passengers, for baggage and cargo and for ensuring security within individual aircraft. The RCMP provides airport physical security and responds to criminal incidents.

Air carriers contract for or otherwise provide the personnel who operate the security check-points through which passengers and their carry-on baggage enter the secure area of the airport terminal. These personnel also operate security equipment for the screening of cargo, passengers and checked baggage. Usually, air carriers use the service of private security firms. Transport Canada has established certain standards required for licensed security guards, such as the successful completion of the Transport Canada passenger inspection training program and annual refresher training. As stated earlier, a significant number of the security guards did not meet the criteria with respect to the completion of the training program and refresher training. In addition, the criteria do not require training for the screening of cargo and checked baggage.

ICAO Annex 17 recommends that contracting States establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage or cargo intended to be carried on board aircraft. For all Canadian airlines, Canadian regulations before 23 June 1985 required a system of identification that prevented baggage, goods and cargo from being placed on board an aircraft if it was not authorized to be placed on board by the airline operator. However, if someone were to purchase a ticket, check in baggage and not board the aircraft, the baggage would in all likelihood have been authorized by the airline to be placed on board the aircraft. Therefore, it was possible to interline baggage unaccompanied and this explains how a suitcase was interlined to AI 181/182 from CP 060. It is not the normal practice of airlines to interline baggage if there is not a confirmed reservation to the destination. In this case, the ticket agent allowed the suitcase to proceed; however, if there had been a confirmed reservation, the suitcase would have been interlined unaccompanied without question.

3.5.2 Air India Security

Air India, as required by Canadian regulation, had a security program. Because of the threat level assessed against the airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and received extra security from Transport Canada and the RCMP for the month of June 1985. For Air India Flight 181/182, Air India provided a security officer from its New York office to oversee the security arrangements at Toronto and Mirabel. The security program at each airport was under the overall supervision of the respective Air India station managers. In Toronto, it was not clear who, if anyone, was undertaking this function.

It is not known if the suitcase interlined from CP 060 was screened before or after the X-ray machine broke down in Toronto. Although baggage not examined by X-ray was screened by a PD-4 sniffer, there are indications that the sniffer could have been ineffective in detecting explosives, especially plastics. Rather than using the sniffer, it would have been more effective to open all bags and physically inspect them. Even though a number of security personnel were not adequately trained in the screening of passengers and baggage, it is not known whether more training would have prevented an explosive device from being placed on board.

Although airline procedures required baggage to be accompanied, the agents checking in passengers in Toronto used a passenger security numbering system but did not number checked-in baggage, and baggage was not correlated with passengers. Therefore, the interlined unaccompanied suitcase from CP 060 was not detected. At Mirabel, checked-in passengers and baggage were numbered so that the number of passengers checking in baggage could be correlated with the number of passengers boarding the aircraft. Had a passenger-baggage correlation been carried out in Toronto, the suitcase from CP 060 would have been detected. The airline procedures would have prevented the placement of the suitcase on the aircraft.

Once loaded on the aircraft, the suitcase would have been placed in container 11L and 12L (see Appendix B) if in the forward cargo compartment, in container 44L or 44R if in the aft cargo compartment, or in position 52 if in the bulk cargo compartment. It could not be determined in which cargo compartment the suitcase was loaded.

Therefore, although the procedures were in place to prevent an explosive device from being placed on board the aircraft in checked-in baggage, there was a breakdown in the X-ray machine used to screen baggage, and there are indications that the PD-4 sniffer was inadequate. Also, the security numbering system used in Toronto was ineffective in preventing unaccompanied interlined baggage from being placed on board the aircraft.

4.0 CONCLUSIONS

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion.

4.2 Other Findings

Even though they may not be causal or related to the accident, the following additional conclusions can be drawn from the investigation with respect to certain security arrangements and their application pertaining to this flight:

1. In compliance with the International Civil Aviation Organization Annex 17 to the Convention on International Civil Aviation, the Department of Transport of Canada has made regulations requiring foreign aircraft operators who land in Canada to establish, maintain, and carry out certain security measures at airports.
2. In accordance with these regulations, Air India submitted a security program to the Minister of Transport which included security measures with respect to aircraft, cargo, baggage, and passengers.
3. On 22 June 1985, an unaccompanied suitcase was interlined from Vancouver to Toronto on CAP Flight 060 for transfer in

Toronto to Air India Flight 181/182.

4. The baggage loaded in Toronto was screened through an X-ray machine process but, during the course of this procedure, the X-ray machine broke down.

5. After the X-ray machine breakdown, an explosives detector was used to screen the baggage; the baggage was not opened and physically examined.

6. The effectiveness of the explosives detector is in doubt.

7. It is not known whether the unaccompanied suitcase interlined from Vancouver was screened before or after the X-ray machine broke down.

8. The security numbering system used in Toronto did not prevent unaccompanied interlined baggage from being placed on board the aircraft.

9. The normal procedures for interlining baggage in Toronto indicate that the unaccompanied suitcase was loaded on Air India Flight 181/182.

Appendix A

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CAPT. B. K. BHASIN
SECRETARY
MR. S. N. SHARMA
FEBRUARY 26, 1986

CONTENTS

INTRODUCTION

1.1.1 On the morning of 23rd June, 1985 Air India's Boeing 747 aircraft VT-EFO (Kanishka) was on a scheduled passager flight (AI-182) from Montreal and was proceeding to London enroute to Delhi and Bombay. It was being monitored at Shannon on the Radar Scope. At about 0714 GMT it suddenly disappeared from the Radar Scope and the aircraft, which has been flying at an altitude of approximately 31,000 feet, plunged into the Atlantic Ocean off the south-west coast of Ireland at position latitude 51° 3.6'N and Longitude 12° 49'W. This was one of the worst air disasters wherein all the 307 passengers plus 22 crew members perished.

1.1.2 The fact that emergency had arisen was first noticed by Shannon Upper Area Control (UAC) after the aircraft had disappeared from the Radar Scope. The control gave a number of calls to the aircraft but there was obviously no response. Thereafter various messages were transmitted and that is how the rest of the world came to know of the accident.

1.1.3 Shannon Control at 0730 hours advised the Marine Rescue Coordination Centre (MRCC) about the situation which appeared to have arisen. MRCC, in turn, explained the situation to Valencia Coast Station and requested for a Pan Broadcast. Thereafter ships started converging on the scene of the accident and they commenced search and rescue operations.

1.1.4 The aircraft in question - Kanishka, was named after the most powerful and famous king of the Kushanas who perhaps ruled in India from AD 78 to AD 103. Besides being a great conqueror, he was an ardent supporter and follower of Budhism - a religion which preaches non-violence. Emperor Kanishka, however, met a violent end. After 25 years of reign he was killed by some of his own subjects. His life was thus brought to an abrupt end.

1.1.5 It is indeed ironical that the Jumbo Jet which bore the name 'Kanishka' also met with a violent and a sudden end on that fateful morning of 23rd June, 1985.

INITIAL ACTION TAKEN BY THE GOVERNMENT OF INDIA

1.2.1 Initial intimation of the accident was received by Air India who, in turn, communicated the same to Mr. H.S. Khola, Director of Air Safety, Civil Aviation Department, New Delhi. The Accident Investigation Branch of United Kingdom also sent information to the Director General of Civil Aviation, New Delhi to the effect that the accident had taken place on international waters and as such it was India which was the authority to investigate the accident in accordance with the provisions of ICAO Annex 13.

1.2.2 Thereupon Order No. AV.15013/8/85-AS dated 23rd June, 1985 was issued by the Director General of Civil Aviation whereby Mr. H.S.Khola was appointed Inspector of Accidents for the purpose of carrying out the investigation into the aforesaid air accident. This appointment was made under Rule 71 of the Aircraft Rules, 1937.

1.2.3 While search and rescue operations were underway at the site of the accident, a team of officials headed by Dr.S.S. Sidhu, Secretary, Ministry of Tourism & Civil Aviation rushed from India to Cork. The said team was joined by Mr. Kiran

Doshi, the Indian Ambassador to Ireland, and also by two officers of the Indian Navy who were attached to the Indian High Commission at London. Subsequently two Medical Experts from India also joined the said Team.

1.2.4 The Indian Team arrived at Cork, Ireland on 24th June, 1985. Representatives of the Governments of United States of America, Canada and United Kingdom also reached there that day. They were met by the representatives of the Government of Ireland.

1.2.5 The members of the Team saw the rescue and salvage operations being conducted. They also visited the Cork Regional Hospital and had discussions with Irish and other Authorities with a view to release the bodies of the victims which were being brought to Cork.

1.2.6 For facilitating the process of investigation the Inspector of Accidents after consulting the representatives of the aforesaid Governments formed the following groups:

a. Structures, Power Plant and Systems Group.
b. Operations Weather & ATS Group.
c. Medical and Human Factor Group.
d. Search & Rescue Group.

The aforesaid groups were required to collect evidence and to submit their respective reports to the Inspector of Accidents.

1.2.7 The bodies which were being recovered were brought to the Cork Regional Hospital for identification and post-mortem. At that time it was considered proper that apart from the two medical experts from India, Wing Commandor Dr.I.R. Hill, who is an expert in aviation pathology should also be called from United Kingdom.

1.2.8 It was also being speculated that the accident may have occurred due to an explosion on board the aircraft. In order to see whether there was any evidence of an explosion which could be gathered from the floating wreckage which was being salvaged, the Government of India requisitioned the services of Mr. Eric Newton, a Specialist in the detection of explosives sabotage in aircraft wreckage.

1.2.9 In order to coordinate and guide the operations of the various ships working at the crash site, a control centre was set up at Cork Airport on 30th June, 1985.

1.2.10 The control centre was manned by representatives of the Governments of Ireland, Canada and United States. The Indian Naval Officers from the High Commission at London were overall in-charge of this centre. After the flight recorders had been recovered the centre continued to function, but the representatives of the United States departed.

1.2.11 For retrieving the Cockpit Voice Recorder (CVR) and Digital Flight Data Recorder (DFDR), a cable ship named Leon Thevenin was engaged which had on board Submersible Robot (Scarab) which was fitted with a Sonar receiver and TV Cameras. The aforesaid ship was engaged and after an intensive search CVR and the DFDR (more popularly known as 'the black boxes') were located and retrieved on 10th July and 11th July, 1985 respectively.

1.2.12 The Government of India, in exercise of the powers conferred by Rule 75 of the Aircraft Rules, 1937 vide Notification No. AV.15013/10/85-A, dated 13th July, 1985, directed that a formal investigation of the accident be carried out. Mr Justice B.N. Kirpal, Judge of the Delhi High Court, was appointed as the Court to hold the said investiation. The Central Government also appointed Dr. V. Ramachandran of National Aeronautical Laboratory, Bangalore; Mr. J.S. Gharia of Explosive Research and Development Laboratory, Pune; Captian J.S. Dhillon, retired Director of Operations, Air India, Bombay; Mr. J.K. Mehra, retired Manager (Technical Training), Indian Airlines, Hyderabad and Captain B.K. Bhasin, Deputy Managing Director of Indian Airlines, New Delhi to act as Assessors of the said Investigation. The Court was required to make its report to the Central Government by 31st December, 1985, which date was later extended to 28th February, 1986.

1.2.13 Mr. S.N. Sharma, Director of Airworthiness, Civil Aviation Department, was appointed as Secretary to the Court vide Ministry of Tourism & Civil Aviation letter No. AV/ 15013/10/85-A, dated 22nd August, 1985. The appointment was to take effect from 13th July, 1985.

ACTION TAKEN BY IRELAND, INCLUDING THE CORK REGIONAL HOSPITAL

1.3.1 The accident had occurred on the Atlantic Ocean approximately 100 miles south-west of the coast of Ireland. It is the Air Traffic Control at Shannon, Ireland who first became aware of the tragic event.

1.3.2 On coming to know of the accident, various authorities in Ireland took immediate action. The Shannon ATC asked the Marine and Rescue Coordinating Centre there to take emergency action. Thereupon MRCC, Shannon asked Valantia Coast Radio Station (CRS) for a PAN broadcast requiring all the vessels in areas 51N/1250W to keep a look out for the wreckage of an aircraft. The PAN broadcast was repeated and all ships were directed to proceed to the site of accident which was determined as 5101.9N/1242.5 W.

1.3.3 Irish authorities also took great pains in rendering every possible assistance to the Indian and other authorities. Some of the wreckage which had floated in to the west coast of ireland was transported to Cork where a boat house had been hired by the Government of India. The wreckage which was placed in the said boat house was protected from any outside interference by the local Gardai (police).

1.3.4 Irish ships proceeded to the scene of accident and helped in search and rescue operations. The ATC at Shannon gave details about the accident, in so far as they were aware of it, and copies of the ATC tapes were supplied. Aer Lingus, national airline of Ireland, provided assistance by making available its local engineering facilities to the coordinating centre at Cork and also to the other authorities.

1.3.5 Cork is a city having a population of approximately 1,34,000. One of the hospitals which was opened in 1978 is the Cork Regional Hospital which had been set up to meet the needs of the people. This 600-bed hospital was designated for the purposes of the Major Accident Plan of the Southern Health Board and thus became the appropriate centre for the reception of the casualities of the Air India disaster. Since the hospital first opened, it had dealt with a number of major accidents involving road, rail and marine incidents. The Major Accident Plan of the Southern Health Board sets out formally, the strategy and procedure which the hopital is required to follow while deailing with major accidents.

1.3.6 On the morning of 23rd June, 1985 at approximately 11.20 A.M. the hospital was put on alert following the disappearance of the Air India Flight 182 off the south-west coast of Ireland. The first message which was communicated to the hospital indicated that it was unlikely that there would be any survivors. The key hospital personnel were alerted and a meeting was arranged in the hospital for the purposes of discussing and making arrangements for the receipt of the bodies on the basis of the information which was available at that time.

1.3.7 On being informed that there were no survivors in the accident and that the hospital should be prepared to receive a large number of bodies, then, in accordance with the Major Accident Plan, mortuary facilities were improvised by appropriating the gymnasium attached to the Deparatment of Rheumatology. Subsequently it became evident that additional mortuary and postmortem facilities would be needed. In order to decide where the second mortuary was to be located, the hospital

had to take into cosideration the following factors:-
(a) The number and the condition of the bodies;
(b) The period during which the bodies would be retained;
(c) The hospital would be required to provide an on-going service for in-patients, out-patients and serious accident and emergency cases;
(d) To avoid unnecessary internal transport problems, the bodies should be near the Post-Mortem and Pathology Departments; and
(e) To facilitate traffic flow in the hospital curtilage and to to aviod unduc public access.
The hospital authorities accordingly located the second mortuary in a recreational room adjoining the gymnasium.
1.3.8 Two rooms were put at the disposal of the Garda (Police) authorities for use as Garda Control Rooms in the hospital. Telecommunications lines were set up immediately for their assistance as the Gardai was responsible for the forensic and identification procedures in regard to the bodies brought to the hospital.
1.3.9 A small Co-ordinating Group was set up consisting of the Chief Executive Officer of the Southern Health Board, Medical Co-ordinating Officer, Press Liaison Officer, a Senior Registrar who knew about Indian customs and traditions and a Hospital Administrator. This small Co-ordinating Group, whose membership never changed, worked together and were capable of assessing situations, making decisions, liaising with other agencies and services and undertaking with other agencies and services and undertaking responsibility for hospital press releases. Apart from individual contact between members, the Group had a standing arrangement to meet every morning and afternoon. In the late evening, the Group, met the Garda, Hospital Pathologists and key staff members for a general review of progress and to decide the tasks and objectives for the following day.

1.3.10 Within a few hours, the Co-ordinating Group realised that the hospital was a world focal point of the international media, and was required to:

a. Accommodate 131 bodies;

b. Provide pathological and Radiological services for each body;

c. Co-operate with the Garda in their forensic work;

d. Cater for relatives of the victims;

e. eet representatives of foreign Governments; and

f. Keep press agencies informed.

Thus began an operation which demanded a quick and dedicated response from all staff working in close cooperation with the Gardai. At the same time, the hospital was required to continue functioning in the delivery of normal in-patient and out-patient services. The Major Accident Plan, apart from alerting staff, provided the framework and basis for many
decisions taken as events evolved. An additional advantage in the practical implementation of the Plan was the fact that the hospital had staff experienced in dealing with previous emergency situations and could marshal the extensive manpower resources available.

1.3.11 The hospital authorities also made the following arrangements:-

a. They briefed Government Ministers and Officials and other dignitaries who visited the hospital. They were taken round the hospital and were explained the arrangements which had been made.

b. Some of the services which were being provided at the hospital were either discontinued or postponed.

c. Bodies were received at the hospital and arrangements were made on their arrival to numerically label and certify as dead all the 131 bodies which were initially received. All the bodies, at that stage, had been individually placed in special purpose body bags. Initially, bodies were placed on tables, but, it was subsequently decided that it would be much easier for all concerned to place the wrapped bodies on polythene covered floors.

d. Arrangements were made for carrying out of the post-mortem examinations. Three Pathologists from other city Hospitals were recruited to augment the existing staff. Dr. Harbison, State Pathologist, was in charge of this aspect of the operation. All the post mortem were completed by 27th June, 1985.

e. For the preservation of the bodies five refrigerated containers with a capacity to hold 140 bodies were hired. These containers were fitted with timber shelving.

f. Government Information Service was located in the Matron's Office.

g. The Army provided troops for the unloading of the bodies from the helicoplers at Cork Airport. They also supplied and erected two large tents for storing bodies after post mortem and embalming. Under Garda escort transport of all the bodies which were recovered was undertaken by the
Army and these arrangements were co-ordinated by Chief Ambulance Officer.

h. Embalming was carried out in the hospital and bodies were then coffined and the coffins with appropriate number plaques were subsequently laid out in the numerical order on the floor when all the post mortems had been completed.

I. All the embalmed bodies were x-rayed (whole body). The examination was completed on 28th June, 1985.

j. A provision was made for a 24 hour extended catering service to meet the needs of staff, Gardai, Army and other personnel involved including visiting relatives.

k. A simple plan was devised for dealing with the relatives. This was a sensitive task bearing in mind the varying religious beliefs, customs and cultures generally of the visiting relatives. Their main function was to provide moral and emotional support to the relatives.

l. As identification progressed, special arrangements were made to assist the relatives. They were met by teams of councellors from the Hospital as soon as they disembarked at Cork Airport and subsequently at the Hospital. The relatives had the same Counsellor and Garda Officer throughout the identification procedure. An interesting development noted was that each family group of relatives, their Counsellor and Garda officers formed a single family unit transcending cultural barriers. On subsequent visits, families appeared lost if their own Counsellor was not immediately available to them. Usually, the Counsellor and the Garda officers accompanied the relatives, at their own request, for visual identification.

m. When plans were being formulated to receive the relatives, it had been hoped to discourage them from coming to the Hospital until such time as progress had been reported on the identification process. Practical experience subsequently proved this strategy to be inappropriate for a number of reasons. Apart from facilitating the collection from relatives of salient information on the victims, the most fundamental reason was the underestimation of the abiding wish of the relatives to be physically and psychologically as close as possible to their deceased dear ones. Moreover, it was the express wish of almost all relatives on arriving at Cork Airport to proceed directly to Cork Regional Hospital; there, they were given an informal talk by Air India and Garda representatives on the progress of the investigation and the methods of identification. Many of the relatives visited the hospital daily and remained there throughout each day.

n. Coach trips were arranged to Bantry Bay for the relatives; Bantry Bay is the nearest landmark from the site of the crash.

Relatives visited the seaside to pay their last respects to the departed souls. These were solemn occasions when each relative prayed in his/her own way. Rose petals and wreaths were immersed in the sea in keeping with Indian traditions. The visit gave them mental satisfaction and in the early days following the crash, helped in diverting their attention while the investigative procedures were being completed.

o. A small number of visiting relatives had personal medical problems and they were treated at out-patient and in-patient levels at the Hospital.

p. Cork/Kerry Tourism Organisation helped to co-ordinate the accommodation of relatives between a number of hotels. Approximately seven hotels were used within a radius of twenty miles of the city for this purpose.

g. A number of press conferences were held. The Chief Executive Officer, directed that press photography and television filming be not allowed within the hospital in deference to the privacy of patients and in respect for the relatives wishes.

r. Responsibility for the identification of bodies rested with the Garda Authorities and the conditions under which bodies were released are summarised as follows :-

(I) Satisfactory identification

(ii) Consent of the Coroner

(iii) Proper authentification of the person claiming each body

All bodies arriving at Cork Regional Hospital had already been numerically labelled by the Garda Authorities. To prevent confusion, the bodies were then given identical numbers under the hospital major accident labelling system and this proved to be very helpful later during identification, investigations and recordings. A routine was established for examining and recording information about each body. Teams consisting of a doctor, nurse, clerical officer and Garda made the necessary examination, labelling and recording each body and such details as :-

a. Sex
b. Adult or child
c. Clothing
d. Jewellery and personal effects
e. Injuries
f. Obvious scars

Death was confimed in all cases. Each body was fingerprinted and photographed by Garda Technical Bureau Staff. Each body was subjected to autopsy, forensic and dental examination. All bodies were embalmed and following embalming, were photographed and x-rayed. This procedure was completed in respect of all the bodies by the evening of the fifth day of the crash. The data from these investigations was collated on an Interpol form (pink) for each body. Similar ante-mortem information was obtained from the relatives about each victim on a separate Interpol form (yellow). When the information on the pink and yellow forms matched beyond doubt, a positive identification was made. It might be noted that the photographs originally taken by the Garda Technical Bureau Officers of each body were matched with photographs of the 131 embalmed bodies. When a positive identification was made, the relatives were shown photographs of the deceased. These photographs were available for inspection by Saturday, 29th June. As positive identification progressed,

personal effects were added to the identification process and finally, visual identification took place. For obvious forensic reasons, positive identification was necessarily slow and meticulous and, in fact, was made more difficult by reason of the fact that only 131 bodies out of the 329 passengers and crew were recovered. All 131 bodies were identified, the first positive identification was made on 27th June and the last on the 6th August. Each coffin had affixed to it a metal plaque clearly indicating the number assigned in the first instance to the body it contained. The bodies when identified were released by the Garda Authorities through the undertaker. The Coroner directed that a reasonable time would have to elapse before unidentified bodies could be disposed off an this was to be by way of burial. The final date for this purpose was fixed for 3rd August, 1985, but, this date was subsequently extended to 6th August, 1985, to coincide with the date of the Civic Commemoration Ceremony.

(s) Bodies of victims for identification were brought individually to separate viewing rooms, suitably decordated with flowers and with incense burning. Visual identification was performed in private by the relatives and moreover, it allowed them to pay their last respects in their own religious beliefs. An adjoining room was also made available where they could grieve in private. Subsequently, it was learnt that these arrangements were much appreciated by the relatives who articulated this appreciation by commenting that the arrangements provided were as near as possible to the funeral rites observed in their domestic communities. The relatives were of the opinion that the special arrangements made conveyed a deep personal and individual response to the dignity of each victim which might otherwise be lost with such a large number of bodies.

(t) Procedures were laid down which were required to be followed and observed for the purposes of preventing infection.

(u) On 6th August, 1985 an interdenominational service was held in the morning. In the evening on that day a Civic Commemoration Ceremony was held which was attended by a large number of persons.

(v) A formal inquest was held by the Coroner in the Courthouse, Cork, which commenced on 17th September, 1985 and ended on 23rd September, 1985. The Coroner's Jury returned a verdict in accordance withmedical and pathological evidence.

ACTION TAKEN BY THE COURT

1.4.1 Despite the fact that Mr. H.S. Khola had been appointed as the Inspector of Accidents under Rule 71 of the Aircraft Rules, the Government thought it proper to appoint Mr.Justice B.N. Kirpal as the Court to investigate into the circumstances of the accident.

1.4.2 The appointment of the Court was made under Rule 75 of the Aircraft Rules, which is as follows :-

"75. Formal Investigation - Where it appears to the Central Government that it is expedient to hold a formal investigation of an accident it may, whether or not an investigation or an inquiry has been made under rule 71 or 74, by order direct a formal investigation to be held and with respect to any such formal investigation the following provisions shall apply namely

(1) The Central Government shall appoint a competent person (hereinafter referred to as "the Court"), to hold the investigation, and may appoint one or more persons possessing legel, aeronautical, engineering, or other special knowledge to act as assessors, it may also direct that the Court and the assessors shall receive such remuneration as it may determine.

(2) The Court shall hold the investigation in open court in such manner and under such conditions as the Court may think fit most effectual for ascertining the causes and circumstances of the accident and for enabling the Court to make the report hereinafter mentioned.

(3) (i) The Court shall have, for the purpose of the investigation, all the powers of a Civil Court under the Code of Civil Procedure, 1908 and without prejudice to those powers the Court may :-

(a) enter and inspect, or authorise any person to enter and inspect, any place or building, the entry or inspection whereof appears to the court reguisite for the purpose of the investigation; and

(b) enforce the attendance of witness and compel the production

of documents and material objects; and every person required by the Court to furnish any information shall be deemed to be legally bound to
do so within the meaning of section 176 of the Indian Penal Code.
(ii) The assessors shall have the same powers of entry and inspection as the Court.
(4) The investigation shall be conducted in such manner that, if a charge is made or likely to be made against any person, that person shall have an opportunity of being present and of making any statement or giving any evidence and producing witness on his behalf.
(5)Every person attending as a witness before the Court shall be allowed such expenses as the Court may consider reasonable:
Provided that, in the case of the owner or hirer of any aircraft concerned in the accident and of any person in his employment or of any other person concerned in the accident, any such expenses may be disallowed if the Court, in its discretion, so directs.
(6)The court shall make a report to the Central Government stating its findings as to the causes of the accident and the circumstances thereof and adding any observations and recommendations which the Court thinks fit to make with a view to the preservation of life and avoidance of similar accidents in future, including, a recommendation for the cancellation, suspension or endorsement of any licence or certificate issued under the rules.
(7)The assessors (if any) shall either sign the report, with or without reservations, or state in writing their dissent therefrom and their reasons for such dissent, and such reservations or dissent and reasons (if any) shall be forwarded to the Central Government with the report. The Central Government may cause any such report and reservation or dissent and reason (if any) to

be made public, wholly or in part, in such manner as it thinks fit."

1.4.3 The Court, which is appointed under Rule 75, does not act as a 'Commission of Inquiry' which is usually appointed under the Commissions of Inquiry Act to inquire into any definite matters of public importance. The role of the Court, on its appointment under Rule 75 of the Aircraft Rules, is essentially that of an Investigator. It is for this reason that no procedure has been prescribed in the Rules which the Court is required to follow. While carrying out its functions, the Court is not only required to comply with the provisions of the Aircraft Act, and the Rules framed thereunder, but it must necessarily also keep in view the provisions of ICAO Annex. 13.

1.4.4. As an Investigator, investigating into an accident, the Court had to perform multi-farious duties and functions. Before referring to them, it would be pertinent to point out that whereas an Inspector of Accidents, who is appointed under Rule 71, would normally be belonging to the Civil Aviation Department and would have all the machinery available to him for conducting the investigation, the Court, when it is appointed to hold an investigation under Rule 75, lacks the basic infrastructure to conduct the investigation of such a magnitude. Assessors are appointed to assist the Court but the actual investigation work cannot be carried out by them. Despite these handicaps, the investigation continued smoothly primarily due to the fact that whenever directions were issued by the Court to any of the participants before it or to the Civil Aviation Department or any other Organisations, the directions of the Court were readily complied with. On a few occasions it also became necessary to require the Assessors to conduct the investigation, which they did with the help of other organisations.

1.4.5 As an Investigator, the first task which was undertaken was to see that the tapes from the Cockpit Voice Recorder, which had been salvaged, were recoverd from the recorders and subsequently analysed. Requisite directions were issued and the tapes were removed from their respective recorders on 16th July, 1985. This operation was carried out at the Air India workshop at Santacruz in the presence of the accredited representatives of Lockheed (manufactures of DFDR), Fairchild (manufacturers of CVR), Boeing Airplane Co., Canadian Air Safety Board (CASB), National Transportation Safety Board, USA (N.T.S.B), Air India and Government of India. The tapes so recovered were subsequently played and analysed.

1.4.6 On an appointment being made under Rule 75 the Court would become incharge of overall investigation of the accident. In that capacity, and in order to effectively discharge its functions, it became necessary for the Court to undertake the following tasks :-

(a) For getting first hand information, the Court had to personally inspect the wreckage which had been recovered and was housed in a boat yard in Cork. While in Cork opportunity was also taken to go to the Cork Regional Hospital and to have discussions with and be briefed by the hospital staff. A trip was also made to Shannon with a view to see and understand the working of the Secondary Radar System which was in use there. On this visit the original ATC tape, which contained communication betwen Kanishka and the ATC, was also heard. As it was suspected that there may be a link between the blast which had taken place at Narita Airport on 23rd June, 1985 and the accident to Air India's flight 182, it was felt necessary to inspect the site of the bomb blast at Narita Airport.

On the aforesaid visit to Tokyo, the site where the blast had taken place was inspected which gave some, though very vague, idea of the detonating power of the blast. While in Tokyo meetings and discussions were also held with the police and Aviation Authorities. The Court also had the advantage of being able to meet members of the team investigating into the Japan Airlines

Flight JL 123 accident which had occurred near Tokyo on 12th August, 1985. Similarities and dissimilarities between the two accidents were, to some extent, noticed and some information was exchanged.
Information was received, that some floating wreckage had been picked on the coast of England and it was possible that some of the places, which were so received, should be subjected to further detailed chemical and metallurgical examination. In order to decide this, it became necessary to visit RADRE, Kent, U.K. As a result of the inspection and the discussions there, it was decided by the Court that the pieces so recovered should be sent to BARC at Bombay for further analysis.
(b) Directions had to be given, from time to time, with regard to the mapping and salvaging of the wreckage which was being effected. It had to be decided as to how, and in what areas, the Scarab should continue to map the wreckage and take video films and still photographs. Based on the information received therefrom and after discussions with the experts, both Indian and foreign, a list was drawn up indicating the items which had to be salvaged. As the weather was likely to be unpredictable, with a possibility of its deteriorating rapidly, a priority list of items to be salvaged had also to be prepared, and this was done. In view of the fact that the Canadian ship John Cabot and the Scarab had a limited capacity, with regard to the size and weight of pieces which could be lifted from the bottom of the ocean, decision had also to be taken with regard to the deployment of another ship. As a consequence thereof a ship 'Kreuzturm' was also engaged in salvage operations.
(c) Directions had also to be given assigning work and duties to different teams of persons. As an Investigator, the Court was incharge of the entire work of investigation which was being carried out in different parts of the world. It not being possible for the Court itself to undertake all the tasks, decisions had to be

taken as to how the investigating work was to progress and who would carry out the directions issued from time to time. For example, immediately after reaching Cork on 25th July, 1985 it was felt necessary that a team should be immediately sent to Canada in an effort to get relevant information from there in connection with the flight AI 182. Accordingly, a team of 3 persons headed by Mr. H.S. Khola was directed to proceed to Canada immediately. As a result of the efforts put in by this team, and with the considerable amount of cooperation, help and assistance rendered by the Canadian Authorities valuable information was received by the Court having direct bearing on the investigation. Yet another example in this regard was of requiring Dr. V. Ramachandran, one of the Assessors and an expert in Metallurgy, to be stationed on board the salvage ships during the recovery operations. The procedure which had to be followed by him was also determined. Information about the progress of the salvage operations was communicated on telephone to the Court at all times of day and night. On receipt of such information further instructions, when ever necessary, used to be issued.

(d) Discussions were held with the Indian experts in order to understand some of the complicated questions which had arisen during the investigation.

In an effort to be able to fully appreciate the effect of decompression, the Court visited the Institute of Aviation Medicine at Bangalore where explsoive decompression was simulated for the Court's benefit. Discussions were also held with other experts of aviation medicine who were also given copies of the post-mortem reports for their opinion. National Aeronautics Laboratory was also visited in Bangalore where meeting was held with experts in aerodynamics, structure and metallurgy. Visits to Bombay where more frequent and necessary so that the Court could get first hand information with regard to the work which was being done at BARC.

The investigation involved looking into matters concerning aviation, electronics, medicine etc. Not being familiar with these branches, the discussions which were held, were of immense help and assistance to the Court who had to understand all the evidence and information which it was gathering.

(e) The accident had attracted world wide attention. Right from the start of the investigation by the Court when the recorders were first opened in Bombay on 16th July, 1985 till the conclusion of the hearing, the Press and the TV were eager for information. It was felt that rather than the media resorting to speculation of getting wrong information, the Court itself or its representative should, as and when necessary, brief the media. In this connection interviews were given, both in India and abroad, which were broadcast over the television and printed in the Press. As a result of this, correct information was disseminated with regard to the progress of the investigation without disclosing the Court's opinion on the evidence which had been received.

(f) Finally, the Court had to conduct the formal investigation in Court. For this purpose it laid down the procedure which would be followed. Rule 75 of the Aircraft Rules required that the investigation would be in open court. It was, however, felt that in this particular case it would be advisable that some evidence should be obtained in Camera.

The Court, accordingly, recommended that necessary amendment should be made in Rule 75 so that the Court was given the power to hold certain proceedings in camera when the circumstances so warranted. The suggestion of the Court was accepted and that resulted in Rule 75(2) being amended and, as a result thereof, the Court was given the power to hold proceedings in camera if the stipulated conditions existed.

COMMENCEMENT OF FORMAL INVESTIGATION

1.5.1 The object of setting up a court to investigate into an accident is primarily to find out the causes and circumstances of the accident and thereafter to make recommendations. Such an investigation is not in the nature of an adversary litigation between the participants before the Court. As such it should be the endeavour of all the participants to assist the Court in arriving at a correct conclusion.

1.5.2 Under Rule 75 of the Aircraft Rules, the procedure which has to be followed in the investigation of an accident is to be determined by the Court itself. While laying down the procedure which is required to be followed, the endeavour of the Court has necessarily to be to adopt such procedure which would help the court in being able to complete its task satisfactorily, and in the shortest possible time. Whenever an accident takes place, it is of utmost importance that the cause of the accident must be ascertained at the earliest so that if any remedial measures are to be taken then those steps should be taken without any undue delay.

1.5.3 In the present case, there were a number of factors which had to be kept in view while determining the procedure whichshould be followed. The accident had occurred over international waters and approximately at a distance of about 5000 miles from the place where the investigation was to be conducted, namely, New Delhi. The ill fated flight itself had commenced from Canada, and this meant that most of the evidence would only be available there. Matters were not simplified by the fact that the debris itself was lying at the bottom of the ocean, 2 miles under water. It became apparent, at the very beginning, that to recover the entire debris would be a superhuman task and it will not be possible to do so within the limited time span which was available.

1.5.4 It was thought that it would be of assistance if all the participants got together so as to determine what procedure should be followed. The procedure had to be such which would give an effective opportunity of hearing to all the participants, without in any way unduly prolonging the investigation.

1.5.5 The Court decided that, in order to obtain the views, it would be necessary and advisable to have a Pre-hearing Conference.

1.5.6 The first decision which had to be taken was as to who were to be given a participants status. Keeping inview the provisions of Annex 13, participants status was given to Governments of Ireland, Canada, USA and India. Similar status was also given to Boeing Airplane Co. and Air India. As there might have been some similarities or dissimilarities between the present accident and the accident of the Japan Airlines Boeing 747-SR and also because there may have been a possibility of the present accident being linked with the explosion which had taken, place at Narita Airport, Tokyo on 23rd June, 1985, an Observer's status was given to the Government of Japan.

1.5.7 Notices for holding of the Pre-hearing Conference on 16th September, 1985 were accordingly issued on 29th August, 1985. The agenda for the Conference was to be as follows :-

a. To make suggestions to the Court for its consideration, regarding the procedure to be followed in the conduct of the formal proceedings in the Court.

b. To draw up a tentative list of witness.

c. To draw up a tentative list of exhibits.

d. To determine the areas to be inquired into

e. To fix a date for the commencement of the public hearing.

f. Any other matter with the permission of the Court.

1.5.8 Except for the Government of Japan, all the other participants were represented at the said Pre-hearing Conference. After discussions had been held between the Court and the Participants, some decisions were arrived at regarding different items of the agenda.

1.5.9 Firstly the following points were framed, indicating the areas to be inquired into by the Court:

a. Whether the accident was caused by a structural failure?

b. Whether the accident was caused by some human effort?

c. Whether the accident was caused by some criminal act?

d. Whether the accident was caused by an external non-criminal act?

e. Based on the evidence on record, what steps should or can be taken so as to ensure greater air safety.

1.5.10 It was further decided that, as suggested by all the participants, at least critical portions of the wreckage should be recovered.

1.5.11 With regard to the recording of the evidence it was decided that evidence will, in the first instance, be taken by filling affidavits or by filling statements alongwith affidavits. Copies of the same were to be supplied to the other participants for their consideration. These affidavits were to be filed on or before 18th October, 1985 and a second Pre-hearing Conference was to take place on 30th October, 1985 at New Delhi when it was to be decided as to which of the persons should be called for cross-examination. It was determined that it is only thereafter that hearing would commence in open court.

1.5.12 A tentative list of witnesses was also drawn up and it was decided that on the next date names of more witnesses may be added and, furthermore, the participants would be free to file any affidavits which they deem fit including affidavits in rebuttal.

1.5.13 Another important decision which was taken at the Pre-hearing Confence was that a Structural Group was formed consisting of (1) Mr. H.S. Khola or his nominee (2) Representative of the Canadian Government (3) Representative of NTSB, USA (4) Representative of Boeing Airplane Co., USA (5) Representative of Air India. This group was entrusted with the task of examining and analysing, initially in Seattle, USA, the video films and the still photographs of the wreckage. This group was also to indicate and decide the items of priorities of wreckage which had to be recovered. The report of this group was required to be submitted by 18th October, 1985. The report of the work done at Seattle was in fact submitted only on 25th October, 1985. This group was also given the liberty to associate any other experts or persons from Boeing or any other Authority. The group was also to inspect the floating wreckage which had already been salvaged and any further wreckage which would be salvaged.

1.5.14 Although the affidavits by way of evidence had to be filed by 18th October, 1985, it was only the Government of Ireland who filed an affidavit by at date. On behalf of the Government of India, an application was filed asking for more time. The reason stated was that the affidavit which had to be filed was to be of Mr. H.S. Khola but he was out of India as he was heading the structures group which was evaluating the video films and photographs at Seattle. The Court had no option but to grant further time to the Union of India to file its affidavits and this necessarily resulted in the adjournment of the Pre-hearing Conference which had been fixed for 30th October 1985.

1.5.15 As the salvage operations were reaching a critical point it became necessary for the Court to go to Cork on 27th October, 1985. Taking advantage of the presence of the Court in Cork, other participants also came there. Besides them, representatives of CP Air and Air Canada also arrived. At one of the informal meetings between the Court and the representatives of the participants, applications were filed by CP Air and the Air Canada, inter alia, praying that they should be permitted to participate in the investigation. It might be mentioned here that CP Air had interlined one of the passangers from Vancouver to AI-182, while Air Canada was the handling agents in Canada of Air India. After hearing the participants it was decided that participant status should also be given to these two viz., CP Air

and Air Canada.
1.5.16 The participant had all filed their affidavits by way of submissions. The Court indicated that formal hearings would be held for the purpose of cross-examining some of the witnesses about three weeks after the receipt of all the reports of the various groups. While in Cork, in the first week of November, 1985 some of the salvaged pieces of the wreckage were brought there. After they were inspected by all the participants and their advisers, who were present in Cork, it was decided by the Court that further detailed metallurgical and other examination of those pieces would be done at BARC, Bombay. In order that there should be no undue delay the Court decided that a Group be constituted consisting of expert representatives of all the participants and also the nominees
of the Court. This group was asked to carry out metallurgical and other examination of some of the critical pieces salvaged and give its report to the Court. The group consituted as a 'Committee of Experts' was as under :-

a. Mr. A.J.W. Melson, Canadian Aviation Safety Board, Canada.
b. Mr. R.K. Phillips, Canadian Pacific Air, Canada.
c. Mr. T. Swift, Federal Aviation, Administration, USA.
d. Mr. R.Q. Taylor, Boeing Commercial Airplane Co., USA.
e. Mr. J.P. Tryzl, Boeing Commercial Airplane Co., USA.
f. Mr. J.F. Wildey II, National Transportation Safety Board USA.
g. Mr. S.N. Seshadri, Bhabha Atomic Research Centre, India (Coordinator).

1.5.17 The parties were informed in Cork that the report of Mr. H.S. Khola, Inspector of Accidents, would be available by about 8th November, 1985. It was then decided that the statements of the first batch of witnesses should be recorded from 20th November, 1985. It was also agreed that if some of the reports of the experts were not received, further examination of the witness may have to postponed.

1.5.18 After receipt of the report from Mr. Khola. on the 8th November, 1985, a notice of the holding of the Public Hearing was issued to all the participants. This notice indicated that the hearing would commence on 20th November, 1985. In the meantime, a Public Notice was also published in the daily "Times of India" in Delhi and Bombay editions on 21st October, 1985 in which it was stated as follows :-

NOTICE AIR INDIA KANISHKA ACCIDFNT INVESTIGATION

The Government of India, vide Notification dated 13th July, 1985, appointed Hon'ble Mr. Justice B.N. Kirpal as a Court to investigate into the accident to Air India's Boeing 747 aircraft VT-EFO (KANISHKA) near the Irish Coast on 23rd June, 1985, when the aircraft was engaged on a scheduled passenger flight from Montreal to Bombay via London and New Delhi.

Any person having direct knowledge, who may desire to make representation concerning the circumstances or causes of the accident, may do so in writing in the form of an affidavit duly attested by an Oath Commissioner or a Notary Public and address the same to the undersigned so as to reach him within 15 days of the publication of this Notice.

S.N. SHARMA SECRETARY COURT OF INVESTIGATION COURT NO.10,DELHI HIGH COURT SHERSHAH ROAD NEW DELHI - 110 003

Pursuant to the aforesaid public notice no affidavit was received from any one.

1.5.19 The public hearing commenced on 20th November, 1985 and the first session concluded on 28th November, 1985. During this period statements of Mr. H.S. Khola, Wing Commander Dr. I.R. Hill and Sgt. Atkinson of R.C.M.P., Canada were recorded.

1.5.20 Till that date, report on the examination of the salvaged pieces had not been received. It was anticipated that the report would be available by mid December, 1985. In order to give the parties sufficient time to study the reports of all the experts it was decided that further evidence would be recorded from 22nd January, 1986.

1.5.21 After the reports were received from BARC; AIB; Farnborrough; NTSB; USA; and Mr. Bernard Caiger of CASB, Canada and the copies of the same had also been received by all the participants, recording of evidence commenced from 22nd January, 1986 and concluded on 30th January, 1986. In all statements of 13 witnesses were recorded.

1.5.22 At this stage it will be pertinent to make a few observations with regard to the procedure which was laid down for recording of evidence etc. As already indicated, most of the evidence was such which was not available in India. As a Court investigating the accident under the provisions of Aircraft Rules, it had no jurisdication to compel attendance of any witness from abroad. The Court also had no jurisdication, either under the Rules or under the provisions of Annex 13, to require any witness to be examined in a country other than the one in which the Court is holding the investigation. The Court was informed that, if called upon, some of the persons who were outside India may not be inclined to testify before the Court.

1.5.23 Faced with the aforesaid difficulty it became necessary, therefore, to evolve a procedure which would enable the Court to get the requisite information. As long as the Court was satisfied that the information which was being received was one which had been truthfully given by a person, it was immaterial as to the manner in which the information was received. It is for this reason that it was decided that evidence will, in the first instance, be given by way of affidavits. It was also provided that the statements could also be filed along with affidavits. This latter course was permitted so as to enable some of the statements, which had been recorded by members of the Royal Canadian Mounted Police, to be placed before the Court. These statements, of course, had to be accompanied, as they were, with the affidavits of the persons who had recorded the statements.

1.5.24 At one stage, by a formal application in writing, Air India had protested against this procedure being followed. By order dated 22nd November, 1985, an objection by Air India to the filing of the statements accompanied by affidavits, was dealt with by the Court in the following words :-

"With regard to the affidavits which have been filed by the Government of Canada, I would only like to observe in the Pre-hearing Conference on 16th September, 1985, it was decided that "Evidence will, in the first instance, 1985 be taken by filing affidavits or by filling of Statements along with affidavits." It was understood that if it is not possible to file affidavits of the persons who are in a position to give information then affidavits may be filed of other persons who may have recorded the statements of the persons who are in a position to give information. This is not an adversary litigation where one of the parties may lose because of lack of proof. One of the objects of setting up a Court to investigate into an accident is to find out the causes of the accident and to make recommendations. It is necessary for this purpose to get information which may be relevant. It is true that strictly speaking the statements which are annexed to the affidavits may not be admissible as evidence in a Court of Law when there is a litigation between the parties but considering limitations which we have, namely, where a Court like the present has no jurisdication to enforce the attendance of any witness who is outside this country and furthermore, the Court has no jurisdication to compel any one to give information, the procedure which was adopted was thought to be the most practical one for obtaining information in connection with the accident. Under the circumstances, the affidavits which have been filed along with the statements which have been annexed thereto which give information with regard to the accident, have to be taken on record."

1.5.25 Another advantage of following the aforesaid procedure was that the time which would have been taken in Court in examining of the witnesses was considerably reduced. After the participants had filed affidavits, the same were to be secrutinised and it was then to be decided as to which of the deponents or persons should be called for examination in Court. Effectiveness of this procedure which was adopted is apparent from the fact that though affidavits by way of evidence were filed in Court, ultimately only 13 witnesses had to be examined in Court and sitings were held in Court only on 14 days.

1.5.26 Written arguments were filed on the forenoon of the 4th February, 1986 and oral arguments were heard in the afternoon of that day. No written arguments or oral submissions were made by the Government of Ireland, CP Air or Boeing Company.

1.5.27 Mr. I.G. Whitehall, councel for the Government of Canada took exception to some of the submissions which were contained in the written submissions filed by Air India. Mr. Whitehall contended that the Court had opined that it will not go into the question of responsibility of the unfortunate accident and therefore, there was no; justification for Air India to include in its written submissions numberous passages which tended to fix responsibilities.

1.5.28 By the order dated 4th February, 1986, it was made clear that it was not the intention of the investigation to apportion blame if any lapse had been committed and, therefore, the Court would ignore any written submissions which tended to apportion blame or responsibility for any lapse of any participants. It might here be mentioned that such a question had earlier arisen while the statement of Sgt. Atkinson was being recorded. The Court had then held that it will not go into the question as to who was responsible for the accident. It was in view of this order that no evidence was led by any of the parties on the question as to who may have been responsible for any possible lapse which could have led to this accident.

2.1 Flight Preparation

2.1.1. Air India Boeing 747 aircraft VT-EFO 'Kanishka' was operating flight AI-181 (Bombay-Delhi-Frankfurt-Toronto-Montreal) on 22nd June, 1985. From Montreal it becomes AI-182 from Mirabel to Heathrow Airport, London enroute to Delhi and Bombay. The aircraft arrived at Toronto from Frankfurt at 1830 Z and was parked at gate No. 107 Terminal 2 at L.N. Pearson International Airport. In accordance with the Canadian regulations, all the passengers and their baggage were off loaded to complete the customs and immigration checks. Transit cards were handed out to 68 transit passengers destined to Montreal who disembarked at Toronto for customs and immigration checks.

2.1.2. The flight from Toronto to Montreal was made up of the following:-

(I) Passengers originating at Toronto and their baggage.

(ii) Transit passengers, and their baggage, continuing their flight to Montreal.

(iii) Two diplomatic bags from Indian Consulate General, Vancouver via Air Canada Cargo Flight, and some Air India Mail.

(iv) Fifth Pod engine and its associated parts.

(v) Interline passengers and their baggage from connecting flights as detailed below:-

a) Air Canada flight AC-102
from Sasktoon - 2 Passengers

b) Air Canada flight AC-106

from Edmonton - 4 Passengers

c) Air Canada flight AC-170
from Winnipeg - 1 Passenger

d) Air Canada flight AC-170
from Winnipeg - 4 Passengers

e) Air Canada flight AC-136
from Vancouver - 10 Passengers

2.1.3. One passenger by name 'M. Singh', checked in at Vancouver on Canadian Pacific flight CP-060 (Vancouver-Toronto) of 22nd June 1985, and got his one piece of baggage interlined to Air India flight AI-181
even though he had no confirmed reservation on AI-181. This passenger, however, did not board the flight CP-060 at Vancouver and also did not check-in for Air India flight AI-181/182 at Toronto.

2.1.4 The checking-in of passengers for Air India flight AI-181/182 at Toronto began at 1830 Z. The checking-in of the passengers was carried out by Air Canada personnel who are the handling agents for Air India, and was supervised by Air India personnel. The Air Canada personnel indicated the computer sequeritial numbers (security numbers) on the passenger boarding card stubs. At about 1930 Z announcement was made for the primary security check of passengers and their hand baggage. The passengers passed through the Door Frame Metal Detector and their hand baggage was checked through X-Ray machine. The passengers were also subjected to physical security check with the help of Hand Held Metal Detectors. The transit passengers to Montreal and their hand baggage were also subjected to these security checks, while their checked in baggage, after clearance by the Canadian Customers authorities was placed by the passengers themselves on the conveyor belt while they were still in sterile area. In this way there was personal identification by the passengers of all checked in baggage, except the baggage which had been interlined to this flight.

2.1.5 The flight was closed for check-in at about 2150 Z. There were 10 'NO SHOWS' and 4 'GO SHOWS'. The security checked passengers remained in the holding area gate No. 107 till boarding was announced at about 2210 Z. At the boarding gate secondary security check of the passengers and their hand baggages was carried out. The passengers were frisked with the help of Hand Held Metal Detectors and their hand baggages were opened and physically checked.

2.1.6 The security numbers on the stubs were circled on the pre-numbered Security Control Sheet to ensure that all the checked-in passengers have boarded the aircraft. Passenger boarding was completed by 2300 Z. Traffic/Sales representative of Air India verified the Security Control Sheet with the number of stubs collected and the number of passengers checked-in. He found that all the 202 passengers, who had checked-in, had boarded the aircraft.

2.1.7 As stated earlier, 68 transit passengers had disembarked at Toronto for completing the customs and immigration checks. However, only 65 of these passengers re-boarded the aircraft as per transit cards collected at the boarding gate. It is in evidence that almost every flight of Air India to Canada, two or three transit passengers do not re-board the flight at Toronto. Some Toronto passengers travelling to India buy their tickets "Montreal-India-Montreal" instead of "Toronto-India-Toronto", for which the fare is higher, and they travel by bus to Montreal to catch the Air India flight to India. On their return journey, when they get down at Toronto for customs and immigration checks, they simply do not re-board the flight even though their reservations are upto Montrteal. These passengers sometimes inform Air India personnel at Toronto about their not re-boarding the aircraft. On 22nd June, 1985, however, no such passenger informed Air India personnel.

2.1.8 There was a crew change at Toronto. The flight and cabin crew members who took over the flight AI-181/182 had been laid over in Toronto for the week prior to the accident flight and were scheduled to take the flight upto London where they were to be relieved by another set of crew. Capt H.S.Narendra was the Commander of the flight, with Capt S.S.Bhinder as co-pilot and Mr.D.D.Dumasia as the Flight Engineer. In addition there were 19 cabin crew members. All the crew members reported together at the airport at 2130 Z. As per the practice existing at that time, the flight crew and cabin crew members were not subjected to frisking checks and their hand baggage were also not security checked. Their checked-in baggage was, howevewr, security checked along with the other checked-in baggage of passengers.

2.1.9 The interline baggage was brought to the international baggage make-up area by the Air Canada staff but, as mentioned earlier, it was not personally identified and matched with the passengers.

2.1.10 The checked-in baggage of the originating passengetrs and crew members of AI-181/182 was sent on a conveyer belt to the baggage make-up area. All the checked-in baggage along with the interline baggage was required to be security checked on the X-ray machine which was located in the baggage make-up area at the end of international belt No.4.

2.1.11 It has been reported that the X-ray machine worked intermittently for some period and at about 2045Z it broke down and there was no picture on the screen. The Machine could not be repaired on that day as it was a week-end and no technician could be contacted. Air India's Security Officer then advised that the rest of the baggage be checked with a PD-4 explosive detector provided by him. He also demonstrated the use of the PD-4 detec- tor to the concerned personnel. It has been reported that about 60 to 70 baggages were checked and cleared by the PD-4 detector.

2.1.12 The security checked baggage was loaded in the containers by the Air Canada personnel. The loading of the baggage in containers was over by about 2230 Z. The ramp personnel of Air Canada carried the container and loaded them in the aircraft.

2.1.13 From March, 1985, after the introduction of Air India flight AI-181 through Toronto, diplomatic bags from Indian Consulate General at Vancouver were being sent to India by Air India flight from Toronto. Accordingly, two diplomatic bags, duly sealed and escorted, were delivered to Air Canada office at Vancouver on 21st June and they arrived at Toronto by Air Canada flight AC-580. One of the bags Sl.No. 49 contained 13 empty large diplomatic bags while the other bag Sl.No.50 contained diplomatic mail. The total weight of the bags was 13.8 Kgs.

2.1.14 In addition to the above, a few envelopes containing some flight documents addressed to Accounts Office, Air India, Bombay, and one envelope addressed to Commercial Headquarters, Air India, Bombay from Air India Town Office in Toronto, were collected by Messrs Mega International.

2.1.15 The aircraft was refueled by CAFAS with 14,602 litres of fuel.

2.1.16 On 8th June No. 1 engine of Air India Boeing 747 aircraft VT-EGC had failed during take off. The failed engine was to be ferried to Bombay on flight AI-181/182 of 22nd June.

2.1.17 The failed engine and the associated parts were placed in Air Canada Engineering Hangar at Toronto airport since June 8,when
the aircraft was brought to the engineering hangar for engine replacement. Air India had requested Air Canada on 15th June for preparing the failed engine for installation as fifth pod

mounting of the aircraft on 22nd June.

2.1.18 On 15th June Air India deputed one of their foremen to Toronto to bring back the failed engine. From 17th to 21st June, Air Canada technicians prepared the failed engine for installation as fifth pod. This preparation involved removal of cowlings, fan blades, locking of compressor rotors etc. Air Canada Engineering/Maintence personnel loaded the aircraft/engine parts on 4 pallets and one container. These pallets and container were then delivered at 0100 Z on 22nd June by Air Canada personnel to Messrs Mega International cargo warehouse at Toronto Airport within restricted airport area. (Messrs Mega International Cargo Warehouse at Toronto Airport within restricted airport area. (Messrs Mega International is the cargo handling agent of Air India at Toronto). The fifth pod engine was transported by Air Canada directly from their premises to the 'Kanishka' aircraft for mounting it on the fifth pod.

2.1.19 Installation of the engine on the fifth pod began immediately on arrival of flight AI-181 at Toronto on 22nd June and the work was completed by 1930 Z. One of the mechanics of Air Canada installed the Mach Air Speed Warning Switch in the Main Equipment Centre as part of the fifth pod engine installation.

2.1.20 The pre-loaded four pallets and one container were brought to the aircraft by M/s Mega International personnel from their warehouse in the afternoon of 22nd June for loading them into the aircraft cargo compartment at positions assigned by the Air Canada load agent. Difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fitting from the aft cargo compartment door cut-out. After removal of the fittings, the cowl could be loaded. All the removed fittings were then reinstalled.

2.1.21. On account of the delay in loading the cowls, departure of the flight was delayed by one hour and twentyfive minutes.

2.1.22 Maintenance Manager of Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft and no snag was observed by him. The commander duly accepted the aircraft.

2.1.23 Senior Flight Despatcher, Air India, Toronto did the flight despatch of AI-181/182 for sectors Toronto-Montreal-London. He briefed the flight crew members about flight plan, weather, Air Traffic Control and fuel requirements. The flight plans for the sectors Toronto-Montreal-London were duly accepted and signed by the Commander.

2.2 Progress of the Flight

2.2.1. The Aircraft took off from Toronto Runway 24L at 0016 Z on 23rd June, 1985. The Maintenance Manager, Security Officer and Passenger Service Supervisor of Air India travelled on board the aircraft for their duties at Montreal. In all there were 270 passengers on board in addition to 22 crew members.

2.2.2. The route from Toironto to Montreal was V-98/ JHL-594/MSS/V 203/FRANX at flight level 290. The flight was uneventful and the aircraft landed at Montreal at 0110 Z. No snag was reported by the flight crew. The aircraft was parked at Cluster 1 Bay No.114.

2.2.3 Sixtyfive passengers destined to Montreal along with the three Air India personnel mentioned above deplaned at Montreal. The remaining 202 passengers, who had joined the flight at Toronto, remained on board the aircraft as transit passengers were not allowed to disembark at Montreal.

2.2.4 Baggage handlers off loaded three containers of baggage, one valuable container and four cargo containers from the aircraft.

2.2.5 Transit Check 'C' of the aircraft was carried out at Montreal. The Flight Engineer also carried out his pre-flight inspection and found that rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to an Air Canada

Technician who flaired the handle and applied the high speed tape. There was no other snag observed during the inspection. The personnel of CAFAS refueled the aircraft with 96,000 litres of fuel. Total fuel on board at the time of take off from Montreal was 104,000 Kgs. which was adequate for 8 hours 40 minutes of flying. The commander accepted the aircraft and signed the 'Certificate of Acceptance' of the aircraft.

2.2.6 At approximately 2130 Z Air Canada personnel opened the passenger check-in counter for flight AI-182 (The flight AI-181 terminates at Montreal and the flight from Montreal to London-Delhi-Bombay is designated as AI-182). The checked-in baggage was sent to the baggage make-up area. Between 2300-2350 Z, a suspect suitcase was identified as the X-Ray showed what appeared to be some wires next to the suitcase opening. The suitcase was placed on the floor next to the X-Ray machine. Subsequently two more suspect suitcases were located. These suitcases were also placed next to the X-Ray machine to await the arrival of the Air India Security Officer who was to arrive on Air India flight AI-181 from Toronto. The remainder of the checked-in baggage, which cleared the security check, was loaded in containers by Air Canada personnel for loading on board the aircraft.

2.2.7 Two diplomatic pouches from the Indian High Commission, Ottawa were brought to Mirabel. After the flight arrived, one of the pouches of Category 'A' weighing 1 Kg. was given to the Flight Purser. The other Category 'B' pouch weighing 9 Kgs. was placed in an valuable container 14R.

2.2.8 No other cargo was accepted for this flight except a small package (weighing less than 1 Kg) containing medicines for cancer treatment of a patient in New Delhi. This parcel was received at 1530 Z on 21st June and was loaded in container 14R by Messrs Mega International on 22nd June, more than 24 hours after its receipt.

2.2.9 Five baggage containers, one valuables container and two empty containers were loaded in the aircraft.
2.2.10 The checked-in passengers with their hand baggage went to the departure sterile area. At the entrance to the departure sterile area security staff used X-Ray units and metal detectors to check passengers and their hand baggages.
2.2.11. At approximately 0100 Z, 23rd June, after the primary security check was completed, the passengers proceeded to boarding gate No.80. At this lcoation the secondary security check was done on passengers using hand held metal detectors. Hand baggages were also subjected to further physical and visual check by them.
2.2.12. A total of 105 passengers boarded the flight AI-182 at Mirabel Airport. It was determined that all the passengers who had checked-in, boarded the aircraft. There was no interline passenger. At Montreal there were five 'NO SHOWS' and two 'GO SHOWS'. In all 307 passengers were on board the aircraft. The flight plan and the load and trim sheet, however, indicated 303 passengers as four of the 6 infants were not included in the passenger list.
2.2.13. The seating distribution of the passengers was as given below:-

Zone/Class Total number of Seats OccupiedÊÊ seats
Zone 'A' -First Class 16 1 Zone 'B'- Club Class 22 - Upper deck - Club class 18 7 Zone 'C' - Economy Class 112 104+ 2 Zone 'D' - Economy Class 86 84+ 1 Zone 'E' - Economy Class 123 105+ 3ÊÊ 377 301+ 6 (Infants)Ê
2.2.14 The seating distribution of the 19 cabin crew members was as follows:-
Two at door L1 and two at door R1
Two at door L2 and two at door R2
Two at door L3 and one at door R3

Two at door L4 and one at door R4
One at door L5 and one at door R5
One in crew rest area, Zone 'A'
One in jump seat upper deck
One crew rest area upper deck.

2.2.15 The three suspected suit cases were not loaded on the aircraft and were detained in the baggage make-up room. After the names of the passengers to whom the suit cases had belonged had been identified the same were transferred to the decompression chamber of E1 A1 Airline where they were examined, with the aid of a Police Explosive Dog, with negative results. The suit cases were kept overnight in the said chamber and when they were opened it was found that they contained no explosive items.

2.2.16. No unclaimed baggage pertaining to the Air India flight was recovered either at Toronto or at Mirabel or Dorval Airport in Montreal.

2.2.17. The flight plan for the sector Montreal to London was filed on telephone by the Air India Flight despatch from Toronto to Dorval ATC Centre. He requested for route SHERBROOKE-COLOR-NAT XRAYBUNTY-MERLY-EXMOR-IBLEY-SAMTN-HAZEL-OCKHAM-LONDON at flight level 290 upto COLOR and flight level 330 thereafter. The reporting points on Track XRAY on that day were COLOR, 47N/50W, 49N/40W, 50N/30W, 51N/20W, 51N/15W, 51N/08W and BUNTY.

2.2.18 The aircraft took off from Montreal at 0218 Z. Its estimated time of arrival at London was 0833 Z. The CVR and the ATC tapes show that the flight was normal and quite uneventful. Suddenly at about 0714 Z, when the flight was being monitored by the Air Traffic Controller at Shannon, with the help of secondary surveillance radar, the aircraft disappeared from the radar scope. Subsequently, the ATC at Shannon got the know that the aircraft had met with an accident and its wreckage was sighted about 110 miles west south-west of Cork, Ireland.

PERSONNEL INFORMATION

2.3.1 Pilot-in-Command (Capt. H.S. Narendra)

2.3.1.1 Cap.t H.S. Narendra (age 561/2 years, date of birth 25th November, 1928) joined Air India on 1st October, 1956. He held ALTP Licence No. 247 valid upto 29th October, 1985 and FRTO No. 478 valid upto 23rd October, 1985. He was released as a Co-pilot on Boeing 707 aircraft on 21st July, 1960 and as a Commander on Boeing 707 aircraft on 17th September, 1964.

2.3.1.2 For conversion as Pilot-in-Command on Boeing 747 aircraft, Capt. Narendra had undergone ground training at Boeing Airplane Company, USA and simulator and aircraft flying training at Bombay in 1972. He completed his route checks for Pilot-in-Command endorsement between December, 72 and January, 73. He became a Commander on Boeing 747 aircraft on 14th February, 1973.

2.3.1.3 Details of Capt. Narendra's flying experience and licence renewal checks are as given below:

a. Total flying experience : 20, 379:15 hours

b. Flying experience on B-747 as
   (i) Pilot-in-Command : 6,364.50 hours
   (ii) Co-pilot : 123:45 hours

c. Day flying experience
   on B-747 aircraft : 3,980:00 hours

d. Night flying experience
   on B-747 aircraft : 2,508:35 hours

e. Flying experience during
   (i) last 6 months: 301:45 hours
   (ii) last 3 months: 159:40 hours
   (iii) last 30 days : 68:45 hours
   (iv) last 7 days : 9:00 hours

He had last flown as Pilot-in-Command on flight AI 181 (Frankfurt to Toronto) on 15th June, 1985.

f. Date of last licence
renewal and IR check : 8 May, 1985

g. Date of last route check : 24 March, 1985

h. Date of last medical
examination at CME,
Delhi : 29 April, 1985

i. Date of last simulator
refresher course : 19 December, 1984

j. Date of ground technical
refresher course : 6/7 May, 1985

k. Date of last flight
safety refresher course : 25 July, 1984

l. Rest period before
operating the accident
flight : 1 week

2.3.1.4 Records indicate that on 29th June, 1966, Captain Narendra was declared medically unfit for 2 months to reduce his weight by 10 Lbs. In February, 1973 he was advised to wear corrective by-focal glasses while flying. In May, 1975 he was again declared medically unfit for 3 months.

2.3.1.5 Capt. Narendra was earlier involved in the following two incidents:

(a) On 25th August, 1984, while operating flight AI-1100 from London to Delhi, there was a deviation of the aircraft by about 170 nautical miles from the track over Rahimyar Khan in Pakistan. He was given necessary INS refresher and Route checks with particular emphasis on cross checking procedure.

(b) On 6th December, 1984, while operating flight AI-124 Delhi-Bombay, the aircraft was observed approaching runway 32 at Bombay Airport when runway in use was 27. Captain Narendra was given simulator training for a series of approaches and landings and visual circuits from right hand and left hands seats for approaches and landings on runway 27 at Bombay

Airport.

2.3.1.6 Captain Narendra was not involved in any accident previously.

2.3.2 Co-pilot (Capt. S.S. Bhinder)

2.3.2.1 Capt. S.S. Bhinder (age 411/2 years, date of birth 30th November, 1943) joined Air India on 12th October, 1977. He held ALTP Licence
No. 940 valid upto 25th July, 1985 and FRTO Licence No. 2290 valid upto 2nd February, 1986.

2.3.2.2 Capt. Bhinder was released as a Co-pilot on Boeing 707 aircraft on 18th November, 1978 and as a Co-pilot on Boeing 747 aircraft on 17th May, 1980.

2.3.2.3 Details of his flying experience and licence renewal checks are as given below:

a. Total flying experience : 7,489:00 hours

b. Experience on B-747
aircraft as Co-pilot : 2,469:30 hours

c. Day flying experience
on B-747 aircraft : 1,426:15 hours

d. Night flying experience
on B-747 aircraft : 1,043:15 hours

e. Flying experience during

(i) last 6 months: 157:45 hours

(ii) last 3 months: 65:00 hours

(iii) last 30 days : 20:15 hours

(iv) last 7 days : 9:00 hours

He had last flown as Co-pilot on flight AI-181 (Frankfurt to Toronto) on 15th June, 1985).

f. Date of last licence
renewal check : 25th March, 1985

g. Date of last IR check : 23rd November, 1984

h. Date of last route check : 9 April, 1985

i. Date of last medical

examination at CME
Delhi : 14 January, 1985
j. Date of last simulator
refresher course : 16 July, 1984
k. Date of last ground technical
refresher course : 8/9 October, 1984
l. Date of last flight
safety refresher course : 3 December, 1984
m. Rest period before operating
the accident flight: 1 week.

2.3.2.4 Records indicate that Capt. Bhinder was not involved in any accident earlier.

2.3.3 Flight Engineer (Mr. D.D. Dumasia)

2.3.3.1 Flight Engineer Mr. D.D. Dumasia (age 57 1/2 years, date of birth 10th October, 1927) joined Air India on 27th December 1954. He held flight Engineer's Licence No. 37 valid upto 6th December, 1985. Mr. Dumasia was released as a Flight Engineer on Boeing 707 airecaft on 16th December, 1963 and on Boeing 747 aircraft on 6th February, 1974. He had a total flying experience of 14,885 hours out of which 5,512:35 hours were on Boeing 747 aircraft.

2.3.3.2 Last medical examination of Mr. Dumasia was completed on 1st October, 1984 at CME Delhi. He had completed simulator refresher course on 14th February, 1985, ground technical refresher course on 14/15th January, 1985 and flight safety refresher course on 13th August, 1984.

2.3.4 Cabin Crew

2.3.4.1 A total of 19 cabin crew members were on duty on Flight AI-181/182 on 23rd June, 1985. Their brief details are as given below:

Sl.No. Names Designation Flight Safety course completed on
1. Mr. S.L. Lazar Inflight Supervisor 1/2 April, 1985 2. Mr.

K.M. Thakur Flight Purser 18 February, 1985 3. Mr. Inder Thakur Flight Purser 9/10 May, 1984 4. Mr. Shukla Flight Purser 23 January, 1985 5. Mr. S.P. Singh Flight Purser 15 January, 1985 6. Mr. N. Vaid Asst. Flight Purser 2/3 May, 1985 7. Mr. B.K. Sena Asst. Flight Purser 3 December, 1984 8. Mr. N. Kashipri Asst. Flight Purser 12/13 Sept., 1984 9. Mr. J.S. Dinshaw Asst. Flight Purser 17/18 Dec., 1984 10. Mr. K.K. Seth Asst. Flight Purser 11/12 February, 1985ÊÊ
11. Miss Raghavan Airhostess 13 July, 1984 12. Miss S. Ghatge Airhostess 10/11 April, 1985 13. Miss R. Bhasin Airhostess 11/12 February, 1985 14. Miss L. Kaj Airhostess 17/18 April, 1985 15. Miss P. Dinshaw Airhostess 17/18 Dec., 1984 16. Miss S. Lasarado Airhostess 15/16 April, 1985 17. Miss E.S. Rodricks Airhostess 10/11 June, 1985 18. Miss S. Gaonkar Airhostess 3/4 April, 1985 19. Miss R.R. Phansekar Airhostess 29/30 April, 1985 AIRCRAFT INFORMATION

2.4.1 General

2.4.1.1. Boeing 747-237B 'Kanishka' aircraft VT-EFO was manufactured by Messrs Boeing Company under Sl.No. 21473. The aircraft was acquired by Air India on 19th June, 1978. Initially, it came with the expert Certificate of Airworthiness No. E-161805. Subsequently, the Certificate of Airworthiness No. 1708 was issued by the Director General of Civil Aviation, India on 5th July, 1978. The C of A was renewed periodically and was valid upto 29th June, 1985. From the beginning of June, 1985, C of A renewal work of the aircraft was in progress. The aircraft had the Certificate of Registration No. 2179 issued by the DGCA on 5th May, 1978. The commercial flight of 'Kanishka' aircraft started on 7th July, 1978.

2.4.1.2 The aircraft was maintained by Air India following the approved maintenance schedules. It had logged 23634:49 hours and had completed 7525 cycles till the time of accident.

2.4.1.3 The aircraft was fitted with four P & W JT9D-7J engines having thrust rating of 48650 pounds. The hours and cycles logged by the engines since new till the time of accident are as given below:

Engine No.1 : P662927-7J - 29,663:26 Hrs (9422 cycles)
Engine No.2 : P695610-7J - 20,810:28 Hrs (6031 cycles)
Engine No.3 : P695602-7J - 21,992:31 Hrs (6564 cycles)
Engine No.4 : P662926-7J - 32,332:15 Hrs (11295 cycles)

2.4.1.4 All the DGCA mandatory modifications and inspections applicable to the subject aircraft had been compiled with. No major component installed on this aircraft and its engines had exceeded the stipulated life period.

2.4.1.5 The last quarter Periodic Check of the aircraft was carried out on 24th May, 1985, at 23274:53 hours and 7439 cycles. Subsequent to this check, two Check 'B' schedules were carried out. The last Check 'B' was carried out on 17th June, 1985, at 23564:14 hours and 7510 cycles and was valid for 200 flying hours.

2.4.1.6 The aircraft had flown 359:56 hours and 86 cycles since last quarter Periodic Check and 70:35 hours and 15 cycles since last Check 'B' till the time of accident.

2.4.1.7 The last Flight Release Certificate was issued on 24th May, 1985 on completion of quarter Periodic Check and was valid for 1100 hours or 150 days elapsed time whichever occurred first. After the last departure from Bombay on 21st June, 1985, the aircraft had flown for 22:34 hours till the time of crash.

2.4.1.8 Mr. Rajendra, Maintenanace Manager, Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft at Toronto on 22nd June, 1985 and no snag was observed by him. No snag was reported by the flight crew during the flight from Toronto to Montreal. Transit Check 'C' of the aircraft for the flight AI-182 was carried out at Montreal by Mr. Rajendra and three Air Canada technicians. The flight engineer also carried out his pre-flight inspection and found that the rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to Mr. P. Bayle, Air Canada technician who faired the handle and applied high speed tape. No other snag was observed during the inspection.

2.4.2 Previous Incidents and Snags

2.4.2.1 A maintenance Group was formed with representatives from Air India and Airworthiness Directorate with Mr. R.K. Paul, Senior Air Safety Officer as the Group Leader to scrutinise the maintenance documents and various defects experienced on this aircraft. The report submitted by the Group (Attachment 'B') indicates that the aircraft was involved in six incidents since the last C of A renewal, details of which are given below

(I) On 13th July, 1984 at Dubai -- flight AI-868 The aircraft returned after aborting take off due to no rise in the EPR and N1 on No.1 engine (Sl.No. 695612). The engine front and rear were checked and found OK. Slight wetness was noticed in the bleed outlets. No external oil leak was noticed. Oil quantity was topped up. The chip detectors and oil filter were found OK. EVC Ph filter was found

OK. EVC linkage wes exercised. The engine was run up and its operation was found satisfactory. The snag was suspected to be due to lack of pressurising air at low N1.

(ii) On 18th July, 1984 at Delhi -- flight AI-105 The right hand side fuselage skin between stations 480 and 500 in line with lower portion of forward cargo door cut-out was damaged by high lift. The same was repaired at Delhi. Permanent repair was carried out at Bombay. The repairs were accomplished using guidelines given in the Boeing Structural Repair Manual.

(iii) On 12th August, 1984, at Rome -- flight AI-135 The aircraft landed with No. 2 engine (Sl.No. 662826) shut down in flight due to oil pressure and oil quantity droping. On motoring the engine, oil leak was observed from metal line between F C O C and L O P switch at the switch end. The line was found cracked which was welded and refitted. The line was subsequently replaced at Bombay.

(iv) On 24th October, 1984, at London -- flight AI-104 There was total loss of No.1 hydraulic system fluid. The fluid leak was traced to inlet pressure adapter of flap control module in the left hand body gear wheel well. Two of the four bolts holding the adaptor on the flap control module had sheared. The hydraulic pump, seal, back-up ring and case drain filter were replaced. The flap control module was replaced when the aircraft arrived at Bombay.

(v) On 14th February, 1985, at Delhi -- flight AI-164 On arrival the leading edge honey comb of the left hand aft trailing edge flap was found damaged about 18 inches in length due foreign object damage. Necessary repair was carried out at Delhi. The aft flap was replaced at Bombay.

(vi) On 28th May, 1985, at Dubai -- flight AI-103 On arrival, the left hand wing to fuselage botton fairing forward rubber seal with strip was found turn off. Temporary repair was carried out at Dubai. Permanent repair was carried out subsequently at Bombay.

2.4.2.2 The flight snags recorded in the flight report books of the aircraft during the 4 1/2 month period prior to the accident were scrutinised by the Maintenance Group and the only significant repetitive defect observed was "R2 door not going to manual". On ground checks by the aircraft maintenance engineers, the operation of the selector was, however, found normal.

2.4.2.3 Prior to operating the accident flight, the aircraft arrived at Toronto from Frankfurt. Capt. R.K. Spencer was the commander of the flight. The flight crew had reported the following three snags:

(I) HF system No. 2 had a lot of distortion

(ii) E P R L indicator unserviceable in 'Go around' mode
(iii) Hydraulic system No.1 pressure indication unserviceable (This snag was carried forward from Delhi).

2.4.2.4 The Auxiliary Power Unit (APU) was unserviceable ex-Bombay and had been released under M E L.

2.4.2.5 For rectification of the above stated snag No.1, Shri Rajendra, Air India's Maintenance Engineer at Totonto checked the connections of the transreceiver and reracked the unit. No snag was reported on this system on Toronto-Montreal sector.

2.4.2.6 Snag No. 2 was carried forward.

2.4.2.7 Regarding the third snag, Mr. Rajendra has stated that the indicator showed 4000 P S I pressure even with no pump running. He therefore, interchanged No.1 and No.3 indicators. The snag, however, persisted. He then replaced transmitter No.1 with a spare transmitter from the aircraft SE box and the snag was rectified. No rectification work was however, recorded by the AME in the Flight Report Book. No snag was reported on this system on Toronto-Montreal sector.

2.4.3 Installation of 5th Pod Engine

2.4.3.1 On 8th June, 1985, No.1 engine of Air India Boeing 747 aircraft VT-EGC operating flight AI-181 failed during take off at Toronto. The aircraft returned and the engine was replaced by a loaned engine from Air Canada. The removed engine was a P & W JT9D-7Q type (Sl. No. P702353-7Q).

2.4.3.2 Air India had planned to bring back the failed engine of VT-EGC aircraft to Bombay, as fifth pod on their flight AI-181/182 of 22/23 June, 1985 and had sent an Engineer along with the necessary kit to Toronto on 15th June, 1985. The engine borrowed from Air Canada on 8th June, 1985, was flown back to Toronto as a fifth pod engine on flight AI-181 of 22nd June, to return it to Air Canada.

2.4.3.3 Shri C.D. Kolhe, Controller of Airworthiness, Bombay examined the aspects relating to installation of the 5th Pod engine, loading of its components and certification of the related work. Shri Kolhe's report indicates that the failed engine and the associated parts were kept in the Air Canada engineering hanger at Toronto airport since June 8 when the aircraft was brought to the hanger for engine replacement. Air India requested Air Canada on 15th June, 1985, for prepairing the failed engine for installation as fifth pod engine on 22nd June. Accordingly, Air Canada's technicians undertook the preparatory work of removing the cowlings, fan blades, panels, locking of compressor, turbine rotors etc. on 17th June, 1985, and completed the work on 21st June, 1985. The fan blades (46 in number) from the failed engine were placed in 12 wooden shipping boxes provided by Air India. These boxes were then loaded in a container. The other components of the failed engine were loaded on 4 pallets.

2.4.3.4 Installation of the fith pod engine was carried out by Air Canada technicians and the individual items on the task card were certified by the individuals who had carried out the work.

2.4.3.5 Some difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fittings from the aft cargo compartment door cut-out. After removal of the fittings, the pallet could be loaded. All the removed fittings were then re-installed. Removal and installation of the fittings was certified by Mr. Rajendra.

2.4.3.6 A question arose whether removal of the door stop fittings could have caused some difficulty in flight. From the video films of the werckage it was found that the complete aft cargo door was intact
and in its position except that it had come adrift slightly. The door was found latched at the bottom. The door was found lying along with the wreckage of the aft portion of the aircraft. This indicates that the door remained in position and did not cause any

problem in flight. In the front cargo compartment, there were 16 containers out of which four were empty. Five containers had baggage of Delhi bound passengers. Container at Position 13L had baggage of the first class and London passengers and container at position 13R had crew baggage. The entire baggage of passengers ex-Montreal was loaded in containers at positions 12R, 21R, 22R, 23R and 24R in the front cargo compartment. Container at position 24L contained fan blades in wooden boxes and the other components of the pod engine. Valuable container was at position 14R.

2.4.3.7 In the aft cargo compartment, there were four pallets containing parts of the fifth pod engine and two containers at positions 44L and 44R containing baggage of Delhi bound passengers. The bulk cargo compartment contained passenger baggage bound for Delhi and Bombay. All the baggage and engine parts in the aft and bulk cargo compartments were loaded at Toronto.

2.4.3.8 The total weight of the fifth pod engine and its items was about 9000 kgs. As a result of carriage of the fifth pod engine, the payload of the flight was considerably reduced on London-Delhi sector.

2.4.3.9 At the time of take off from Montreal the aircraft had 104,000 kgs of fuel on board which was adequate for 08:40 hours of flying as against sector flying time of 06:15 hours. The flight plan fuel was calculated taking Paris as the alternate airport for London.

2.4.3.10 The load and trim sheet from the sector Montreal London was prepared and was duly counter-signed by the commander. The take off weight of the aircraft was 317,877 kgs which was within the maximum take off weight limit of 334,500 kgs. The estimated landing weight of the aircraft was 237,177 kgs which was also within the maximum landing weight limit of 256,279 kgs. The centre of gravity of the aircraft was at 21.3

percent
of MAC at take off and the estimated C G position at the time of landing at London was 25.8 percent of MAC which was within the limits.

2.4.3.11 The load and trim sheet and the flight plan of the aircraft indicated that there was 301+2 passengers on board the aircraft whereas there were actually 301+6 passengers on board. The error occured because four of the six infants were not taken into account.

2.4.4 Corrosion Control Measures

2.4.4.1 Boeing Company have recommended various measure to control corrosion on Boeing 747 aircraft through different documents such as Maintenance Planning Data Document, Corrosion Prevention Manual and Service Bulletins. Compliance of these measures on Air India fleet is accomplished as follows:

(I) Support structure under galleys and lavatories

Boeing Company have recommended repeat inspections of under galley/toilet structure at intervals of 12000 hours. However, in order to detect corrosion at an early stage, these inspections are carried out by Air India at intervals not exceeding 9000 hours.

(ii) Fuselage Lower Bilge Area:

Boeing Company have recommended modifications to provide improved drainage systems by incorporation of various Service Bulletins. All the relevant modification have been completed by Air India on the affected aircraft. In addition to completion of these modifications, repeat inspection of lower bilge area is being carried out to meet the requirements of Boeing Service Bulletins.

(iii) Canted Pressure Deck:

In order to prevent water accomulation and consequent corrosion in the area, Boeing Company have issued SBs 51-2015, 51-2026 and 51-2032. Air India have incorporated Service Bulletins 51-2015, and 51-2032 on all their affected airplanes SB 51-2026 is being complied progressively.

(iv) Cargo Compartments:
Inspection of all the cargo compartment interior structures for corrosion and cracks is being accomplished periodically by Air India after removal of linings and insulation blankets.

(v) Aft Pressure Bulkhead:
During every equalised Periodic Check routine, the aft surface of aft pressure bulkhead is being visually inspected for corrosion condition and security of attachements. The forward surface of the pressure bulkhead, which is covered by aft toilets, is inspected after removal of toilets at intervals not exceeding 9000 hours although the recommended interval by Boeing Company is 12000 hours.

2.4.4.2 Air India has stated that in addition to the above specific measures, aircraft structure particularly the areas below toilets, galleys, cargo compartments, outflow valve area etc. which are prone to corrosion, are inspected for corrosion, cleaned and protected during every equalised Periodic Check. Air India have further stated that no serious corrosion problem has been experienced by them so far on their fleet.

2.4.5 Supplemental Structural Inspection Programme

2.4.5.1 In the case of airplanes which have completed 10,000 flight cycles as on June 30, 1983, Federal Aviation Administration (FAA) U S A and Boeing Company had recommended additional structural inspections known as Supplemental Structural Inspection Programme. In the Air India fleet, the first three 747 aircraft, namely, VT-EBE, VT-EBN and VT-EBO fell in this category and are known as 'Candidate Airplanes'. The subject aircraft (VT-EFO) had completed only 7525 flight cycles at the time of the accident on 23rd June, 1985, and therefore, the Supplemental Structural Inspection Programme was not applicable to this aircraft.

2.4.6 Special Corrosion Inspection of B-747 Aircraft Fleet of Air India

2.4.6.1 In order to examine whether corrosion to the aircraft structure of Kanishka aircraft could have contributed to the accident, a group was constituted by Mr. H.S. Khola, Inspector of Accidents to carry out special corrosion Inspection of all the Boeing 747 aircraft of Air India.

The group consisted of the following members:

(a) Senior Air Safety Officer of the D.G.C.A.

(b) Senior Airworthiness Officer of the D.G.C.A.

(c) Air India's Representative.

2.4.6.2 The inspection was carried out in the following areas:

(a) Below toilets and galleys

(b) Forward and aft cargo compartments belly areas - internally and externally

(c) The forward and aft pressure bulkheads

(d) Canted pressure web area from inside the passenger cabin.

(e) Area around outflow valves

(f) MEC area inside and outside.

2.4.6.3 The inspection reports submitted by the Group show that no corrosion was noticed on the significant primary structural members of the aircraft. Surface corrosion was, however, noticed on some of the members below the toilets and galleys. The corrosion observed during the inspection was of minor nature which is normally expected on such inspection schedule. The Kanishka aircraft was subjected to Periodic Check on 24th May, 1985 at 23,274.53 hours/7,439 cycles and no significant corrosion was observed. Among the Nine 747 aircraft inspected for corrosion, 5 aircraft had logged hours more than the Kanishka aircraft. Three of the aircraft had actually logged nearly double the flying hours. Taking into consideration that the corrosion prevention measures recommended by the Boeing Company were followed by Air India and that even the high life aircraft (45,000 hours approximately) subjected to corrosion inspection at the time when Periodic Check was due i.e. 1100 hours since previous check, had no significant corrosion, it is considered unlikely that Kanishka aircraft, which had logged only 23,275 hours since new and 360 hours since last Periodic Check, had corrosion which could have contributed to the accident.

METEOROLOGICAL INFORMATION

2.5.1 A report on the Meteorological conditions prevailing en-route near the location where the aircraft crashed was provided by the Meteorological Service, Department of Communications, Dublin, Ireland. This report covers a period of one to two hours before and after the time of accident (0714 Z).

2.5.2 From the report it is seen that the surface Synoptic Situation in the vicinity of 51°N, 12.50°W at 0715 Z on 23rd June was as given below:

Surface wind: 250/15 knots

Surface visibility : 10 Kms (occasionally 4 kms in drizzle)

Surface temperature : 13°C

Cloud conditions : Cloud cover in the area was estimated to have been layered upto about FL 100 with a base of 600 feet. There is no evidence of cumulonimbus or thunderstorm activity.

Freezing Level : 700 feet.

2.5.3 With regard to Upper Air situation the report indicates that a mainly West or West North West airflow covered the area of FL 310 The Jet stream was centred at about 48°N. The estimated wind and temperature at FL 310 were 270/65 knots and -47°C. As per the report, at FL 310, 51°N 12.50°W and at 0715 Z any significant clear air turbulence was not expected.

2.5.4 Sunlight condition was prevailing at the time of accident. There were no sigmets valid for the area at that time.

AIDS TO NAVIGATION

2.6.1 The aircraft was equipped with Inertial Navigation System (INS) and was cruising normally at its assigned flight level 310 on track X-ray over Atlantic. It was under the control of Shannon Upper Area Control and was being monitored on the Secondary Surveillance Radar (SSR) located at Mount Gabreal. Till the time of accident, the aircraft was beyond the range of Shannon primary radar.

2.6.2 The aircraft entered Shannon airspace at the correct position and level and remained on the assigned track and flight level till it disappeared from the radar screen.

2.6.3. There is no evidence to indicate that AI-182 experienced any navigational problem during the flight.

COMMUNICATIONS

2.7.1 Two-way communication between the ill-fated aircraft and the ATS units of Canada and Ireland was maintained during the flight from Montreal till the time of crash. The communications were recorded on the ATC tapes. Transcripts of the relevant tapes were provided by the Canadian Aviation Safety Board and the Director of Air Traffic Services, Ireland.

2.7.2 From the Transcript of the conversations, it is observed that two-way communication between AI-182 and the various ATS units was normal. The last R/T contact with the aircraft was at 0709:58 Z when AI-182 informed Shannon UAC that it was squawking 2005. The tape transcript also shows that the aircraft did not transmit any information regarding the emergency on frequency 131.15 MHz on which it was last working with Shannon UAC or on distress frequency 121.5 MHz. Indecipheiable noise was, however, found recorded on the Shannon ATC tape just at the time of crash i.e. 0714:01 Z. Thereafter, repeated calls were made by Shannon UAC to AI-182, but there was no response.

SEARCH AND RESCUE

2.8.1 The report of the Search and Rescue Group gives the details of the Search and Rescue operations. From the report it is seen that at 0730 Z, Shannon UAC informed Marine Rescue Co-ordination centre (MRCC) shannon that AI-182, a Boeing 747 aircraft enroute Montreal-London had disappeared from the Secondary Surveillance Radar (SSR) at 0713 Z in position 51N/ 120W. Shannon UAC requested MRCC Shannon to take emergency section. At 0740 Z MRCC Shannon telephonically explained the situation to Valantia Coast Radio Station (CRS) and requested a PAN Broadcast urgently and to ask any vessels in area to keep sharp lookout and report to Valantia Radio. At 0746 Z Valantia Radio transmitted to all stations PAN message and above advice to ships. The transmission was repeated.

2.8.2 At 0750 Z, an Irish Naval Vessel AISLING reported on R/T to Valantia Radio that it was 54 miles from site of accident and was proceeding to the site. Valantia Radio passed on this information by Telex to MRCC Shannon. Between 0740/ 0750 Z MRCC briefed the Irish Naval Service (INS) Haulbowline, MRCC Swansea, RCC Plymouth and Irish Army Air Corps (IAAC) on the situation. At 0754 Z MRCC relayed a distress message to Shannon Aeradio via the Aeronautical Fixed Telecommunication Network (AFTN)

2.8.3 At 0803 Z Valantia Radio again transmitted the PAN message and the advice to ships. At 0840 Z Cargo vessel M W Laurentian Forest/HBWP (Registered in PANAMA and owned by Federal Commerce of Montreal, Canada) at position 51.09N/ 12.18W reported that it was 22 miles away from distress area and was proceeding there. Laurantian enquired if there were other ships in the area and was informed about position of Aisling. At 0813 Z Valantia Radio informed MRCC Shannon by telex about Laurentain Forest.

2.8.4 Between 0815/0820 Z, MRCC Shannon updated RCC plymouth and they advised that a Nimrod Rescue Aircraft would depart shortly for the area and that SEA KING helicopters were already enroute the Cork Airport initially. Edinburgh RCC advised MRCC Shannon that a Nimrod Rescue Aircraft was also being prepared at Kinloss. At 0820

Shannon Aeradio informed Valantia Radio that there was message from Shanwick Oceanic Control that aircraft were picking up ELT signal in position 51N/15W and 51N/08W and the actual position was beleived to be 51W/1250W. At 0833 Z, Valentia Radio sent message giving the above information and requesting ships in the area to report to Valentia Radio.

2.8.5 At 0842 Z, Ali Baba informed Valentia Radio that it was at position 5125.5N/0825.4W and was listening on 121.5 MHz. At 0850 Z Western Arctic informed Valentia Radio its position 5207N/1151W and that it would proceed in about 20 minutes after bringing in cable. At 0857 Z, High Seas Driller informed Valentia Radio that Vessel Kongstain could be released, ETA 51/2 to 6 hours and they would standby. At 0858 Z, Valentia Radio informed MRCC Shannon about reports from Ali Baba Western Arctic and High Seas Driller.

2.8.6 At 0905 Z, Laurentian forest reported to Valdentia Radio that it was 5 miles from SOS position 51N/12.5 W and it had not sighted anything. Between 0905/0908 Z, three more vessels viz. Atlantic Concern, MV Norman Amstel and MV Tasman reported their positions to Valentia Radio. At 0908 Z, Swansea advised MRCC Shannon that four Seaking helicopters and two Nimrod Aircraft were enroute.

2.8.7 At 0913 Z, Laurentin Forest reported to Valentia Radio that they had sighted what looked like 2 rafts about 2 miles away. At 0914 Valentia Radio informed MRCC Shannon about the report from Laurentian Forest.

2.8.8 At 0918 Z, Laurentian Forest reported to Valentia Radio that it had sighted wreckage in water at position 5101.9N/ 1242.5W and the liferafts were not inflated. Valentia Radio passed the message to MRCC Shannon at 0920 and also sent transmission about wreckage sighting. Lifeboats Valentia and Baltimore reported to Valentia Radio that they were proceeding to the position of wreckage.

2.8.9 At 0937 Z, Laurentian Forest reported that it had sighted 3 bodies in water. Valentia Radio informed the same to MRCC Shannon at 0940 Z. At 0945 Z, MRCC Shannon and MRCC Swansea decided that
for security and operational reasons Cork Airport would be the primary operational base and ATC Cork were informed of this decision.

2.8.10 At 0953 Z, S MYROLI informed Valentia Radio that it was 80 miles north of position and had a group of 10 to 20 French vessesls and desired to know if they should proceed to site. After consulting Laurentian Forest, S MYROLI was advised that it was not necessary. Valentia Radio kept on giving Mayday relay frequently.

2.8.11 At 1045 Z, a prohibited flying area was established with a radius of 40 N Miles from the datum point from sea level to 5000 feet. Falmouth Coast Guard reqested Valentia Radio the position of all ships in the distress area and those proceeding so that each vessel could be designated to search a particular area.

2.8.12 At 1126 Z, Laurentian Forest reported Valentia Radio that it had located numerous bodies in water and Seaking helicopter was hovering there. Valantia Radio Transmitted this information to all stations.

2.8.13 At 1133 Z, Valentia Radio informed Coast Guard Falmouth the position and ETA of various ships and also of the Lifeabouts Valentia and Beltimore. At 1150 Z, RRC Plymouth requested MRCC Shannon that "Le Aisling" assume duty as "On Scene Commander Surface Unit". At 1204 Z, information was received by Valentia Radio that 8 Spannish Trawlers were proceeding to distress position of AI-182 and their ETAs were between 1630/2000 Z. At 1246 Z, Star Orion informed Valentia Radio that it would be able to refuel any vessel in medium or small quantities at the accident site. Valentia Radio informed MRCC Shannon and Falmouth about the Spanish Vessels and

Star Orion.

2.8.14 Falmouth requested Valentia Radio at 1303 to advise Laurentian Forest to inform Aisling that 8 Spanish trawlers would arrive in search area between 1600 Z and 2000 Z and Aisling should deploy trawlers in conjunction with lifeboats to recover bodies as it would be easier to recover than from large vessels. Valentia Radio sent the above message.

2.8.15 Laurentian Forest informed Valentia Radio at 1307 Z that 10 bodies were on Aisling, 4 on Helo, and they had some alongside and had launched lifeboats to pick them up. Valentia Radio informed the same to MRCC Shannon and Falmouth. At 1338Z, MRCC Shannon requested Valentia Radio to include the following in their broadcast:

"Vessels within 100 N Miles of datum 5101.9N/1242.5W are requested to proceed to search area and contact Aisling/EIYP. Any vessels recovering bodies or wreckage are requested to retain them on board and inform MRCC Falmouth of total number of bodies recovered."

2.8.16 Valentia Radio transmitted the above message at 1340 Z to all stations and also informed MRCC Shannon. At 1503 Z Aisling informed Valentia Radio that they had recovered 56 bodies. MRCC Shannon requested Valentia Radio to advise Aisling that if they could locate "Black Box", they should drop buoy. Valentia Radio advised Aisling accordingly. At 1530 Z, on advice from MRCC Shannon, Valentia Radio asked Baltimore, Courtmaesherry and Ballycotton lifeboats to return to base. At 1633 Aisling requested Valentia Radio to inform Falmouth that they were unable to transfer bodies to Valentia Lifeboat as latter was returning to base owing to fuel shortage. At 1659, Laurentia Forest informed Valentia Radio that 66 bodies had been picked up by then. Aisling advised Valentia Radio that Valentia lifeboat was returning with four bodies.

2.8.17 At 1721 Z Falmouth requested Valentia Radio to relay

following to all surface units at scene:
1. One mimrod remaining on scene overnight.
2. All other air units will be recalled at 2200 Z. One Helo remains at 15 minutes notice at Cork
3. Air Search recommences at 240400 Z.
4. All Civil surface units will be released by 2200 and may proceed on passage. Bodies should be landed at Irish Post for transfer to receiving station at Cork Airport.
5. Warship Challenger, Emer and Aisling acknowledge".

2.8.18 At 1723 Z Aisling informed Valentia Radio that they saw 3 Spanish vessels approaching and they were using Ch.16 which Aisling was using for co-ordination with RESCUE 52 and requested that Spanish Vessels be asked to stay outside 5 miles radius. Spanish Agent was told about Aisling request.

2.8.19. Valentia lifeboat informed Valentia Radio that they were heading for home (Valientia) at reduced spead of 11 knots and they had five bodies on board. At 1822 Z, Aisling requested Valentia Radio information on 'Black Box' that might help its location. Aisling was advised of ELT signal on 121.5 MHz. At 1840 Z Cork ATC Advised MRCC Shannon that a total of 64 bodies were in Cork.

2.8.20 At 1920 Z, MRCC Shannon downgraded the 'MAYDAY' Broadcast to 'PAN' (Urgency) Broadcast, Aisling informed Valentia Radio that 79 bodies had been recovered. At 1958 Z Laurentian Forest informed Valentia Radio that they were proceeding to Dublin. Valentia Radio thanked them for assistance.

2.8.21 At 2000 Z, MRCC Swansea advised MRCC Shannon that main air search would cease at 2200 Z and would recommence at 240400 Z. The overnight search would continue with one Nimrod providing air cover for the surface search by three warships. Vessels transiting the area were requested to keep a sharp look out and to report to HMS Challenger.

2.8.22 By 0300 Z on 24th June, four Seaking helicopters had deported from Cork to resume the airborne search. At that time the search area covered a six nautical mile radius of position 5059.2 N/1225.3W and the vessels Le Emer and HMS Challenger were requested to search this area. HMS Challenger was the coordinator of the surface search and Nimrod Rescue 02 was on-Scene-Commander.

2.8.23 At 0450 Z Rescue 02 reported sighting of wreckage in position 5101 M/1245 W. Between 0505 and 0543, three USAF Chinook helicopters departed from Cork Airport to join the search. At 0556, MRCC
Swansea confirmed that there were 329 people on board the aircraft (Earlier reportes had idicated 325 people on board).

2.8.24 A continuous search was maintained throughtout the day (24th June) but only one further body and numerous pieces of wreckage were recovered. An extensive surface search was also maintained throughout the day and instructions were passed by MRCC Shannon to Valentia Radio requestiong all shipping to recover any wreckage or bodies sighted.

2.8.25 At 0900 Z, Capt. G Mc. Stay of Department of Communications advised MRCC Shannon that Aisling was bound for Cork, ETA 1300 Z and he (Capt. Mc Stay) was assuming responsibility for collection of wreckage. MRCC were also advised by Mr. Gregory of Britoil that their two vessels 'Constine' and 'Star Orion' were enroute to Foynes having picked up quantities of wreckage.

2.8.26 At 1740 Z, SRCC Plymouth advised Shannon that the Search will terminate at 242200 Z, at 1800 Z Falmouth MRCC advised MRCC Shannon to direct the Portisheal and Valentia Radios to concel Urgency Broadcast from 242000 and to release HMS Challenger and Le Aisling from the search at 242000 hours. All the aircraft were released at 24000. It was also decided that Le Emer would remain at the area. At 242003 Z, a message was transmitted to all stations on R/T and W/T that air and sea search was being terminated at 242000 Z and all the participant were thanked for their assistance.

INJURIES TO PERSONS

3.1.1 Post mortem examination was carried out by Irish Authorities at Cork. At that time Wing Commandor Dr. LR. Hill was also present. Subsequently Air Vice Marshall Kunzru also reached Cork. Both of them were members of the Medical Group which had been constituted by Mr. H.S. Khola.

3.1.2 By then 131 bodies had been recovered. None of the bodies of the flying crew were revocered. The bodies which were recovered represented 39.8 per cent of the victims. The exact seating position of passengers is not certain, because it is known if the passengers had changed their seats after the take off of the aircraft from Montreal. On the information which is available, the passengers were supposed to have been as follows:-

Passengers: Seats Occupied Bodies Available identified
Zone A 16 1 0 Zone B 22 0 0 Upper Deck 18 7 0 Zone D 112 104 + 2 29 Zone D 86 84 + 1 38 Zone E 123 105 + 3 50 Sub-Total 377 301 +(6 infants) 117 Crew: Flight Deck 3 3 0 Cabin 19 19 5 Total 399 329 122ÊÊ

3.1.3 The Post-mortem reports were examined by Wing Commander Dr. Hill. He submitted two reports being Exhibits H-1 and H-2. He was also examined in Court as Witness No. 2. Dr. Hill who had developed a system which would indicate the severity of the accident and the injuries suffered. He used a scale from 0 to 4, with naught being no injury and 4 being a fatal lesion. Though there is some amount of subjectivity involved in the system, nevertheless categorising the injuries according to the sacle does give an overall picture of what had happened to the victims. After adding up all the injury scale for a particular body, Dr. Hill in his Report Exhibit H-1 divided the injuries as under:-

No. of victims Mild injury (0-49) total 34.4% 45% Moderate injury (50-99) 38.9% 51% Severe Injury (100-149) 25.2% 33% Catestrophic Injury (150 +) 1.5% 2 Total 100.1% 131 3.1.4   A further break up showing the overall injury score of the recovered victims is as follows:

Minor Moderate Severe   Zone No. % % No. % % No. % % Total C 8 6.1 17.8 9 6.9 17.7 4 3.1 11.4 21 D 9 6.9 20 15 11.5 29.4 9 6.9 25.7 33 E 15 11.5 33.3 15 11.5 29.4 14 10.7 40 44 Unknown 13 9.9 28.9 12 9.2 23.5 8 6.1 22.9 33 Total 145 34.4 100 51 39.1 100% 35 26.8 100% 131   3.1.5 The reports submitted by Dr.Hill further indicted as follows

(a) There were 30 children recovered and they showed less overall injury. The average severity of injury increases from zone C to E and is significantly less in C than in Zones D and E.

(b) Flail pattern injuries were exhibited by eight bodies, five of these were in Zones E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

(c) There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evently distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

(d) Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 Zone D, 11 inZone E, 2 crew and 1 unknown), and 16 had little or no clothing.

(e) Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

(f) There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

(g) There is a general absence of signs indicating the wearing of lap belts.

(h) Pathological examination failed to reveal any injuries indicative of a fire or explosion.

3.1.6 In his testimony in Court, Wing Commander Dr. I.R. Hill further stated that the significance of flail injuries being suffered by some of the passengers was that it indicated that the aircraft had broken in mid-air at an altitude and that the victims had come out of the aeroplane at an altitude. He further explained that if an explosion had occurred in the cargo hold, it was possible that the bodies may not show any sign of explosion. It may here be mentioned that the forensic examination of the bodies do not disclose any evidence of an explosion. Furthermore, the seating pattern also shows that none of the bodies from Zone A or B was recovered, in fact as per the seating plan Zone B was supposed to have been unoccupied. This Zone is directly above the forward cargo compartment.

3.1.7 Dr. Hill further stated that the pattern of the accident as suggested by the injuries indicated that it was a complex affair and there were at least two phases of injuries, one in the air and the other at water impact. In answer to a specific question that if there was an explosive device in the cargo hold then could the passengers who were seated have suffered such injuries, the answer of Dr. Hill was that "it is possible". According to him, the pattern of injuries indicated that if there was an explosion in the aircraft it was more likely that the explosion had occurred in the rear cargo compartment than in the front cargo compartment. This conclusion was apparently based on the fact that, according to him, in zone E of the aircraft there were larger vertical load type injuries. Dr. Hill was also asked if he had to make any suggestions which would minimise injuries to passangers in the event of an accident. In answer, the witness made his suggestion in the following words

"There are very complicated things one would have to do such as rearward facing seats; having safety belts which incorporated restraint for the upper part of the body; increasing the space between aircraft seats; incorporating shocks absorbing system within the seat and using materials which do not break easily like plastic. We would also need fuel systems which would not immediately set on fire and furnishing which would be resistant to burining, and also passengers should not carry into the aeroplanes large amount of hand bags which only get in way in the event of evacuation, and I personally feel that the carriage of large amount of alchohol both in the passengers and in the aeroplane is a hazard to flight and safety. Finally the passengers should take heed of the flight safety instructions given to them by the crew of the aeroplane".

3.1.8 Air Vice Marshal Kunzru, witness No. 10 in his report dated 14th November, 1985, Ex.A-48, gave his comments not only on the post-mortem reports but also on the statement of Wing Commander Dr. I.R. Hill. With regard to the post-mortem examination, the comment of AVM Kunzru was as follows:

"All victims have been stated in the PM reports to have died of Multiple injuries. However two of the dead, one infant and one child, are reported to have dies of Asphyxia. There is no doubt about the asphyxial death of the infant. In the case of the other child (Body No. 93) there could be doubt because the findings could also be caused due to the child undergoing tumbling or spinning with the anchor point at the ankles. Three other victims undoubtedly died of drowning. There was no evidence of significant Lap-belt injuries.

Considering rupture of the ear-drum, without injury to skull, as a criterion to indicate rapid decompression, two cases may be

considered to fall in this category.
Histological examination has been carried out only in 57 bodies out of 131. Lung examination on almost all of them showed decelerative changes. Six bodies (Nos. 6,22,70,103,121 and 131) showed presence of Bone Marrow Embolism in Lung Sections. Though not of much significance in this accident, this finding does indicate survicval after a bony injury for an undefined period of time No evidence of fire burns or explosive material, other than Kerosene burns on some bodies, which I had myself seen at Cork, could be found. Kerosene burns in such acidents is a fairly common findings and is of no significance".
AVM Kunzru generally agreed with the crash injury analysis on the victims which had been furnished by Wing Commander Dr. Hill. He, however, gave the following comments with regard to hypoxia, decompression and decelerative changes:
"Hypoxia : The main Post Mortem findings in hypoxia is generalised congestion if the hypoxia is of the type described as "hypoxic hypoxia". In other causes of hypoxia of more severe degree such as "histotoxic hypoxia", "asphyxia" or "drowning" additional histological findings such as petechial haemorrhages and generalised congestion, and lung findings such as haemorrhage and extrusion of alvoolar phagocytos are seen.
Decompression : The term used by Dr. Hill is "Decompression". It is presumed that he means "Rapid/Explosive Decompression" which occurs within one Sec. and not "decompression sickness" which takes a minimum of 5 to 7 mnts to occur even at 31,000 ft. altitude and which in this case can positively be ruled out.
The Post-Mortem and histological signs of rapid Decompressions are :-
(a) Possibility of rupture of Ear drums without any injury to the skull.
*(b) Patchy Lung Haemorrhages
*(c) Emphysomatus changes

*(These occur more commonly in those cases where the individual was in the phase of breathing-in at the time of decompression.

3.1.9 If it is assumed that the aircraft suddenly broke up in Mid-Air at an altitude of 31,000 ft. the bodies will be at once exposed to hypoxia and rapid decompression and as a consequence will suffer body changes as mentioned above. As the aircraft/occupants start descending, they will be exposed to increasing amounts of Oxygen and as soon as ;they come down below 15,000 ft. and then below 10,000 ft. the effect of hypoxia rapidly diminishes. Finally, the aircraft/individuals come down and hit the ground/water with a very heavy impact, thus submitting the individuals to extremely severe G-loads of decelarative type.

Decelerative Changes : Decelerative impact brings about well established changes in the lungs besides many other associated injuries. It is relevant to note the decelerative lung changes which are :-

(a) Patchy haemorrhages in Lung.
(b) Marked Emphysomatus Changes.
(c) Extrusion of alvoolar Phagocytes
(d) Desqummation of bronchcolar epitherium.

"Comparative study of the PM/histological findings of hypoxia, Decompression and Decelerative Lung injuries reveal that they are more or less similar. Decelerative injury being the most severe of the three and last to occur tends to so modify the Post-Mortem and Histological findings that it becomes extremely difficult and some times impossible to isolate one from the other."

3.1.10 AVM Kunzru was, therefore, of the opinion that in this accident evidence of hypoxia/decompression (except in 2 cases) had not been confirmed or established.

3.1.11 The difference of opinion between Wing Commander

Dr. hill and AVM Kunzru, with regard to evidence of hypoxia and decompression, is of no significance in the present case. What is important to note, however, is that they have agreed that the injury pattern does indicate break up of the aircraft in mid-air and that the occupants of Zone E had suffered the greatest amount of injuries as compared to the occupants of the other zones.

MAPPING, WRECKAGE DISTRIBUTION AND SALVAGE

3.2.1 Introduction

3.2.1.1 Oceanographic charts indicated that the depth of sea in the crash area was about 6700 feet and the site appeared to be a flat sea bed, without any valleys or hills. The immediate necessity after rescuing/searching crash victims, was to locate and recover the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR). The operation was unique of its kind and had never been undertaken earlier in the world at this depth of the sea. It required an equipment which could home on the transmitted signals from the underwater locater acoustic beacons fitted on DFDR/ CVR, identify the units, clear them from attachments/wreckages, grab them and bring them to the surface.

3.2.1.2 The pressure exerted by the water at 6700 feet below mean sea level is extremely high and the temperature is very low. No light penetrates to that depth and it is pitch dark. Scarab I fitted on French Ship "Leon Thevenin" which had undertaken the challenging job of locating DFDR and CVR, and recovering the same, was not designed to operate at 6700 feet depth. Its maximum design operating depth was only 6000 feet. However, it was decided to exceed the design operating depth for this emergency operation.

3.2.1.3 By using the preliminary information of probable area of location OF CVR and DFDR as indicated by ship 'Gardline Locator', the Scarab I was Lowered in the sea to locate and recover these units which it accomplished on 10.7.85 and 11.7.85 respectively.

3.2.1.4 Prior to recovery of DFDR/CVR by the ship 'Leon Thevenin', sufficient spade work was done by the ship 'Gardline Locator' (A ship provided by Accident Investigation Branch, U.K.) and 'Le Aoife' (an Irish Naval Ship). The survey of the crash area, carried out with the help of side-scan sonars fitted on these ships, had indicated a general distribution of the wreckage and a rough idea about the sizes of the parts. Each part of the wreckage was called a target. The method used for survey was triangulation with multiple passes through the crash site.

3.2.1.5 Next phase was the task of :

(a) Locating hundreds of pieces of wreckage by the combined use of sonar and video monitors.

(b) Video and still photography of the pieces of wreckage.

(c) Plotting the distribution of the wreckage.

All this was to be carried out under the directions of the Court.

3.2.2 Scarab

3.2.2.1 The means (vehicles/equipment) proposed to be used in the locating, mapping and video photography of the wreckage were the CCGS John Cabot and SCARAB II.

3.2.2.2 The John Cabot is an ice breaker of the Canadian Coast Guard. Since utilisation as an ice breaker is seasonal, the John Cabot is also equipped for submarine cable laying. In order to enlarge its capabilities in this regard, the John Cabot is equipped to have on its deck the Scarab and to operate it. Thus the John Cabot can be used for repair of submarine cables. The John Cabot has complete facilities for operation, maintenance and repair of the Scarab. This includes a Control Hut, a Test Room, Workshop, Stores etc. The John Cabot has considerable experience in work on deep sea bed.

3.2.2.3 The SCARAB II is a submersible craft assisting repair and burial of cables. As will be clear from the following details, the Scarab is not ipso facto a submarine. It is a total system for carrying out its complex functions.

3.2.2.4 The SCARAB II is a state-of-the-art system designed and built for tethered unmanned work at ocean depths of upto 6000 feet. Scarab's standard equipment are :

Two rugged manipulators.

A complete optical suite.

Six thrusters of 5 hp each.

CTFM Sonar.

Navigation System.

3.2.2.5 The manipulators have a choice of grippers/claws/ cutters etc. of any required description and size. The Scarab has three TV cameras mounted on separate pan/tilt mechanism to allow real time observation and video tape documentation. A 35 mm still camera was also installed and used in the present work. There was a choice of quartz-iodide flood lights to provide illumination.

3.2.2.6 The location and control of the Scarab is accomplished through a phased array navigation system.

3.2.2.7 The Scarab was equipped with a 360° high resolution Sonar with a range of 1000 meters. The Sonar was also capable of interrogating and detecting 37 KHz and 27 KHz pingers. It can function independently of the ship's facilities and is equipped with power generators and semiautomatic handling equipment.

3.2.2.8 The John Cabot can salvage items, but it is not a salvage ship as it does not have the specialised high capacity cranes, derricks etc. required for salvage of large objects. Further, it does not have deck space for keeping large salvaged items like the wings, fuselage or tail surfaces of an aircraft as large as a 747. The John Cabot was, therefore, adequate and fully satisfactory for the work envisaged in this phase of the programme, as salvage of large items was not planned in this phase. The task was, as mentioned earlier, locating, mapping and photography of the hundreds of pieces of wreckage. (The salvage work was part of the next phase of the programme).

3.2.3 Control and Monitoring of Operations

3.2.3.1 It was realised that the operation proposed would pose problems of control, monitoring and logistics.

3.2.3.2 Consider : A ship operating on the high seas in international waters on the task of locating, mapping and video photographing the hundreds of pieces of wreckage. The state of art system for Sonar location and photography (Scarab) used by the ship for handling this task. The group located on shore in charge of the operations. Finally, the Court in Delhi was in overall charge of the operatins.

3.2.3.3 It was realised that a proper line of control and communication was essential if the operations were to be smooth and successful.

3.2.3.4 Therefore it was decided that the following would be the chain of command :

Court Investigating the Accident
(Mr. Justice B.N. Kripal)
Control Centre at Cork
(Court's representative)
CCGS John Cabot
(Commanding Officer)
Scarab
(Project Manager)

3.2.3.5 Because of the multiplicity of agencies involved in the operations, the need was felt for a proper delineation of power at all levels. It was, therefore, decided that :

a. Overall responsibility for the operations would rest with the Indian authority viz. the Court. This would cover the identification and definition of assignment of the overall tasks, laying down of the priorities, overall control of the coverage of the operation and, finally, the time schedule for the operation.

b. Decisions taken at the Control Centre, flowing from the above, were to be taken solely by the Court's representative. The experts from CASB, NTSB and Boeing were free to give their views and recommendations, but the final decisions were to be left to the Court's representative. Examples of such matters are : Track of the survey, areas to be covered by John Cabot, assignment of priorities for specific tasks, amount of time to be devoted to any piece of wreckage, whether any item of wreckage is to be picked up, etc.

c. Operation Control of John Cabot would be in the hands of the Canadian Coast Guard Officer in the Control Centre, who would co-ordinate with the Commanding Officer of John Cabot. This would cover decision on feasibility or otherwise of operations under adverse weather conditions, manner of covering the area, method of retrieving any wreckage, etc.

d. Decisions relating to the Scarab (i.e. whether the weather was suitable for Scarab operations, whether the size, weight etc. of an item would permit its being picked up by Scarab, etc.) would be left to the Scarab Project Manager on Board John Cabot.

3.2.3.6 It might appear at first sight that in the above system excessive power was delegated at certain levels to the detriment of overall control. Any such impression would not be correct. In actual fact, because of proper delegation of responsibility and power at different levels, the operations were carried out with extraordinary efficiency, smoothness and coordination, In this connection, it is relevant to point out that the operations were not a uni-disciplinary one. The operation (aircraft accident investigation) was totally dependent on experts from other disciplines, like naval (coast guard) operations, deep sea photograph, salvage from sea bed etc. It was therefore, decided that for smooth and efficient operations, adequate power and responsibility should be delegated at all levels, particularly to specialists engaged in the different areas of work as above.

3.2.3.7 It was also considered that adequate communication was a sine qua non for smooth operation. Therefore, the following communication facilities were established :

Control Centre at Cork Airport

Telex

Telephones (2)

3.2.3.8 The ship John Cabot had both telex and telephone facility. These links were through satellite (IN MARSAT). The Control Centre was in continuous communication contact with John Cabot through telex and telephones. In order to establish a reliable and satisfactory line of communication it was decided that instructions or communication from Control Centre to the Indian experts on John Cabot would follow the path as under :

Control Centre

Court's representative --- Canadian Coast
Guard Officer

John Cabot

Indian experts --- Commanding Officer

3.2.3.9 It was felt that this would eliminate any possibility of inconsistent or contradictory orders/messages going to John Cabot.

3.2.3.10 With a view to have an ordered system of communications between the control centre and John Cabot (which is essential for proper control and monitoring of the operations), it was decided that John Cabot would sent to the Control Centre daily Situation Reports (SITREPS) at specified times viz. 0800 hrs, 1200 hrs, 1600 hrs and 2000 hrs. This however did not preclude the despatch of telexes by both Control Centre and John Cabot at any other time.

3.2.3.11 In order to inform all agencies of the above system of Control and Communication a number of meetings were held. These were on 12.8.85 and 3.9.85 on board John Cabot and on a number of occasions at the Control Centre. The purpose of these meetings was not only to inform all concerned about the specific task, the programme and the line of control and communication but also to sort out differences and to understand the technical and operational difficulties faced by the personnel on the spot and to find a way out.

3.2.4 Daily Monitoring of Progress

3.2.4.1 It may be relevant to point out here that search, location and video photography work was to be carried out round the clock. Thus a considerable volume of data would be coming into Control Centre. This required regular, almost hourly, monitoring, study and analysis for

(a) proper understanding of the data collected and (b) advising John Cabot of any changes in its programme, such as additional photography on an item etc. For this purpose (i) SITREPS were filed in the Control Centre (ii) all data (description, latitude and longitude) obtained on every target was tabulated and the cumulative list updated daily.

3.2.4.2 The location of the targets was plotted on charts every 4 hours. This was in addition to the plotting of targets carried out on John Cabot.

3.2.4.3 Every day (including holidays and week ends) all the officers posted at Control Centre assembled at about 0900 hrs. They studied the SITREPS received at 0800 hrs and any other telexes received from John Cabot in the night. The lists of targets were updated and the new targets plotted on the charts. John Cabot generally also sent brief remarks such as description, nature of failure/damage, dimensions etc. Discussions were held on the significance of the targets and their implications. Instructions if any to be telexed to John Cabot were also discussed. Similarly SITREPS received at 1200 hrs and 1600 hrs were studied.

3.2.5 Monitoring at Cork

3.2.5.1 The Scarab provided video tapes and still photographs. In the initial stages (upto 9.8.1985) the John Cabot was operating in peripheral areas and therefore few targets were found. Hence the output of videotapes was small. In fact upto 9.8.85, only about 10 targets were found and only 3 video tapes were used up. But later, when John Cabot came close to and into the crucial areas, video tapes were recorded at a fast rate. Further, still photography facility on the Scrab was activated at about this time. Therefore, arrangements were made periodically to obtain the video tapes and films from John Cabot. Video tapes and still photographs (these required to be processed) were transported from John Cabot to Cork Control Centre.

3.2.5.2 About 50 video tapes and nearly 3000 still photographs (positives and transparencies) provided the visual information on the targets.

Arrangements had to be made at Cork for such viewing and study of the video tapes and still photographs. Video equipment (TV monitor plus VCR) suitable for viewing the video tapes had to be arranged.

3.2.5.3 The still photography used special professional quality colour film (35 mm), each roll having 800 frames. The film was diapositive. These had to be developed and transparencies obtained from them. Thereafter negatives and prints had to be made. Special equipment for viewing the transparencies had to be provided for continuous work. The video tapes, transparencies and prints provided the principal means of monitoring of the results of the operation.

3.2.6 Operations

3.2.6.1 The Charts prepared by 'Gardline Locator' were on a different type of grid system, and had to be translated into LAT-LONG system, for use by John Cabot. For the convenience of search/mapping operation the search area was divided into 4 blocks viz. Block 1, Block 2, Block 3 and Block 4.

3.2.6.2 The navigation system used by John Cabot is PULSE-8 system. This system needs the transponders to be placed on the sea bed. These transponders help in getting the correct fix of a target and in obtaining relative positions of the targets on the sea bed which is highly useful for revisit for the purpose of rephotography or recovery. Initially 4 transponders were placed, and subsequently the number was increased as the search operation was continued. The strategic locations for placing the transponders was decided by considering :

(a) frequencies of relative transponders,

(b) distances required between relative transponders,

(c) wreckage distribution suggested by side scan sonar plots of Eithena and Garline Locator, and

(d) size of search area.

These transponders were calibrated to match the navigation system of the ship.

3.2.6.3 In order to obtain the maximum information from search, it was decided that the Scarab search paths should be as follows :

(a) Normally the search paths should be east to west, or west to east within the individual blocks.

(b) The pattern of search should be a parallel search method.

(c) Distances between the parallel paths to be 1,200 feet (i.e. 2 cable widths), for effective use of sonar fitted on the Scarab.

(d) If Scarab deviates from its planned path for photography or recovery, it should return to its planned path for further search.

(e) In each block, the search was to be made, at least 1/2 mile (North or South) beyond the last target sighted, so as to ensure no target is missed out from the given block.

3.2.6.4 However, when there was a need to modify the search pattern, due to wreckage distribution in particular areas, the following changes were made:

(a) Expanding box type search pattern was used in Block 1.

(b) Some North to South and South to North passes were made in Block 3.
(c) In Block 3 northern end, the distances between the search passes was reduced to 600 feet i.e. 1 cable width.
However, these deviations were made basically to improve the reliability of search in specific areas, as demanded by peculiar distribution of aircraft wreckage.

3.2.6.5 To facilitate identification of the wreckage located by Scarab it was necessary to position aircraft maintenance personnel on board the ship. As the aircraft structure was badly torn, mutilated and distorted, serious difficulty was anticipated in identification of small pieces of structure. It was therefore essential that these maintenance personnel were provided with aircraft photographs, manufacturing drawings, parts catalogue, wiring diagram manuals and maintenance manuals. Since carriage of such voluminous literature was not praticable, 3M micro film reader printer
machines with micro film cassettes of the above literature were produced and installed on the ship. In case of difficulty of locating any particular information, the engineers were advised to contact Cork Search Centre by telex or telephone who, in turn, could seek the desired information from the manufacturers.

3.2.7 Wreckage Distribution

3.2.7.1 The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and

may have moved horizontally in sea currents before settling at the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled. Although badly damaged, sections 41, 42 and 44, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been mapped or photographed. Section 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the western most identified aircraft component located at lat 51°02.90'N and long 12°50.1'N. The wreckage extended in a line about 110 degrees to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern. A third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southwest orientation. One of the operating engines was displaced 0.5 nautical mile to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components
and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

3.2.7.2 Details of the various targets which were identified by the Structures Group is contained in Appendix 1 of this Report.

3.2.8 The Break up Pattern

3.2.8.1 The forward fuselage section of the aircraft was found inverted and badly broken into many pieces, the major pieces being :

(I) Section of fuselage right side below cockpit windows containing part of the name 'Kanishka' (in Hindi) and 3 passenger windows (Target No. 192)

(ii) Portion of upper skin between B S 360 and B S 520 below window belt right side, up and over crown. This portion includes the crew door and last letter of the "Air India" (in Hindi) logo (Target No. 192).

(iii) Section of fuselage between B S 510 to B S 700, including the passenger window belt right side, up and over crown to include upper deck windows left side (Target No. 218).

(iv) Section of fuselage between B S 720 to B S 840 including left side passenger window belt, up and over crown to right side passenger window belt. Forward and upper edges of L H No.2 door cutout can be seen (Target No. 193).

(v) Large section of fuselage between B S 1000 to B S 1460 including left side passenger window belt, up and over crown to right side passenger window belt. This section was found lying on its right side (Target No. 137).

(vi) The lower portion of the fuselage skin/frame between the nose and B S 1000 was damaged past recognition except for a small portion with the forwarded cargo door (Target No.204) and another portion containing the aft access door cutout at B S 810 (Target No. 362).

3.2.8.2 The aft fuselage was found in the following major pieces :

(I) Section of RH fuselage skin between B S 1640 and B S 1940 below the window belt up to the crown (Target No. 321).

(ii) The RH fuselage bottom skin between B S 1820 (forward edge of C2 door) and B S 2060 and between two stringers above the door cutout to just below stringer 46 lap joint (Target No. 40).

(iii) The lower fuselage skin with stringers between B S 1480 and B S 1846 about 100 inches wide approximately (Target No. 7).

(iv) The LH fuselage skin panel between B S 1740 and B S 1880 about 110 inches wide (Target No. 11).

(v) The LH fuselage skin between B S 1460 and B S 1800 width 80 inches including No. 4L door and passenger windows (Target No. 28).

(vi) The RH fuselage skin between B S 1660 and B S 1920, from below window belt up to the crown including the 4R door cutout (Target No. 321).

(vii) A fuselage lower skin panel (containing out flow valve) between B S 2120 and B S 2240 and 120 inches wide (Target No. 320).

(viii) A fuselage LH skin panel (containing 5 windows with "T -" part of registration) between B S 1980and B S 2080 between stringers 19L and 24L (Target No. 369 and 26).

(ix) A fuselage LH skin panel between B S 1460 and B S 1800 with 8 stringers below the bottom of the door and 3 stringers above the top of the door (Target No. 28).

3.2.8.3 The tail portion of the fuselage was found in the following pieces:

(I) The lower fuselage skin between B S 2412 and B S 2598 about 20 stringers wide (Target No. 371).

(ii) The vertical fin with rudders attached was lying on the ground by itself with a portion of B S 2517 frame. This includes a small portion of the aft pressure bulkhead (Target No.37).

(iii) The horizontal tail with elevators attached was lying on ocean floor with the jack screw and drive motor attached (Target No. 31).

(iv) The fuselage tail cone aft of B S 2669 was found basically intact and lying separately (Target No. 27).

3.2.9 Extent of Damage

Photographic and Video Interpretation of Wreckage

Photographic Interpretation

3.2.9.1 All wreckage sighted was recorded on video tapes and all major items were recorded on 35 mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage pattern. For example, the sine wave bending of target 7 appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into acount.

3.2.9.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

3.2.9.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gears were in the 'up' position at the time of impact.

3.2.9.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

3.2.9.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

3.2.9.6 Section 42

Portions of Section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers. All cargo doors were found intact and attached to the fuselage structure, except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different from that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back on to the sea bed. An attempt to relocate the door was unsuccessful.

3.2.9.7 Section 44

Section 44 containing the aircraft structure between B S 1000 and B S 1480 including that area where the fuselage and wings were mated

was located and identified. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gears were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

3.2.9.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northern most area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

3.2.9.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of B S 1480 and, for purposes of this report, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

3.2.9.10 The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were positively identified (targets 35, 37, 73 and 296). Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognisable as having come from a specific area of the aircraft.

3.2.9.11 Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from B S 1600 to B S 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

3.2.9.12 The tail cone and the auxillary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

3.2.9.13 A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure.

3.2.9.14 The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

3.2.9.15 The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates° to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabiliser was missing and the auxilliary spar was exposed. There was localized damage to the right-hand root of the loading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

3.2.9.16 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from section 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42 and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat belts were not fastened.

3.2.10 Salvage Operations

3.2.10.1 During recovery operation the video tapes as well as photographs of the wreckage to be recovered, were supplied to the personnel on board the ship for facilitating identification and recovery of correct targets.

3.2.10.2 Whenever any component/part of the aircraft wreckage was salvaged it was essential to immediately subject the same to inspection and to identify the damage sustained during recovery operation. In order to oversee this critical operation, the Court deputed one of its Assessors, Dr. V. Ramachandran, to be on board the ships. Under his supervision, the components/parts were thoroughly washed with fresh water, dried and treated with corrosion inhibiting compounds. A detailed inspection was thereafter carried out, observations recorded and the targets were appropriately labelled and their numbers were painted thereon. A laboratory microscope was taken on board by Dr Ramachandran.

With that, fragments of significance were segregated for further investigation. Indeed some of these fragments did give important clues.
3.2.10.3 All the investigating personnel on board the ship were provided with leather gloves, fisherman's shoes, raincoat, life floating suits, writing and labelling material, camera with coloured films, etc. Sufficient number of "body bags" were positioned on each ship to cater for the eventuality of recovery of bodies with the wreckage. This precaution helped when a body did come along with wreckage on 25.10.1985.
3.2.10.4 The ship John Cabot completed the operation of locating, mapping and photography of the wreckage and returned to Cork on 1.10.85 at 2020 hours. The next phase of operation was to recover the significant wreckage parts which would be useful for deciding the cause of the crash.
3.2.10.5 Subsequent to the accident to Japan Airlines Boeing 747 aircraft, suspected to have been caused by failure of the repair to the rear pressure bulkhead, NTSB and FAA decided to fund the U.S. Navy for a two week operation over the seas for recovery of significant pieces of wreckage. For this purpose, U.S. Navy appointed Commander J.R. Buckingham, a deep sea salvage expert, to head the recovery operation. An offshore supply vessel M.V. Kreuzturm, of Canada was hired by U.S. Navy to recover the wreckage with the help of Scarab on John Cabot. One nylon lift line together with winch and ram were installed on the ship prior to its sailing to Cork where it arrived on 4th October, 1985. One crane was installed on the ship Kreuzturm in Cork.
3.2.10.6 One inch dia Kevlar lines coated with black plastic for abrasion resistance and braided with Dacron lining were used by John Cabot as primary lift lines.
3.2.10.7 The structure group after studying the photographic data, had formulated a list of 32 targets for recovery on 3.10.85. A systemwise priority list proposed by the Court of Inquiry was

received through Dr V. Ramachandran on 4.10.85. Using these two lists, and taking into account the operating restrictions imposed by two ship operation, a final list of targets was prepared for recovery by the ships, assigning a priority number to each target. However, as the recovery operation progressed, changes in priority list were made to achieve optimum utilisation of the ships.

3.2.10.8 A meeting was held at 1400 hrs. on 4.10.85 on board CCGS John Cabot to establish/clarify the priorities for the wreckage recovery operation and coordination between John Cabot, Kreuzturm and Cork Search Centre. All the personnel involved in the recovery operation were shown the slides and photographs of the targets which were chosen for recovery on priority basis. The method and procedure of the recovery operation was discussed in detail and finalised. Another meeting was convened on 6.10.85
to clarify the doubts and to present the picture albums containing various photographs of targets to be recovered. The mode of attaching grippers/grabbers to the targets at strong points was clarified. A serialised list of priorities was prepared based on the mode of operation indicated by the the crew of John Cabot and Kreuzturm. Dr Ramachandran was given the authority to make on-the-spot decisions during the salvage operations.

3.2.10.9 A detail log of the activities of the ships John Cabot and Kreuzturm which started the recovery operation of 10.10.85, reveals the following :

(a) The Scarab working independently recovered the following

(1) Basket at target 192 containing copilot's chair, 2 suitcases and radar antenna (12.10.85)

(2) Target 8 - Lower fuselage skin of aft cargo compartment. (11.10.85).

(3) Target 245 - Forward belly skin just aft of radome (16.10.85).

(4) Target 350 - Economy class seats and carpet (23.10.85).
(5) Target 296 - Piece of aft pressure bulkhead.
(b) The Scarab after attaching the grippers, bridal cable and lift line to the targets buoyed off the same to Kreuzturm which recovered the following targets :
(1) Target 362/396 - Forward cargo fuselage skin from station 700 to 840 and STR 41L to 43R. (16.10.85).
(2) Target 193 - Fueselage skin from station 720 to 860 and passenger door 2L (17.10.85)
(3) Target 223 - Nose landing gear pressure deck web and stiffeners, container pieces (staion 260-340)(19.10.85).
(4) Target 181 - Wing skin with forward cargo compartment SLIPPED OFF WITH GRIPPERS (21.10.85) AND WAS LOST.
(5) Target 399/358 - Fuselage skin from station 780 to 940 and STR 7R to 35R with 2R door (25.10.85). A body entrapped in target 399/358 was recovered. Another body which came upto surface with the wreckage fell
off into sea and was lost while hauling the wreckage on board. The recovered body was identified as of Dr. Mathew Alexander, a Canadian passenger and was brought to Cork by Fisherman's vessel "Orion" at 0130 hrs. on 28.10.85 and was sent for Post Mortem etc.
(6) Target 7 - Aft cargo compartment fuselage skin from station 1480 to 1860 (26.10.85).
(7) Target 47/50 - Aft cargo floor structure with roller tracks, frames, latch etc. from station 1600 to 1760 (27.10.85).
(8) Target 117 - Three rows of coach class seats with passenger cabin floor boards, broken floor beam (28.10.85).
(9) Target 35 - Aft Pressure Bulkhead piece (30.10.85).

3.2.10.10 The Scarab experienced malfunctions with its arms, Sonar equipment, multiplex system, junction box, microprocessor unit, etc. off and on during the above period of operation. Fouling of lift line with umbilical cord was also experienced in the early stages of operation. Since the assigned recovery by Kreuzturm was over by 30.10.85, and as the Scarab became unserviceable due to breakdown of its power suppluy, the OSV MV Kreuzturm was directed to return to Cork to off-load the recovered wreckage and its operation was terminated, (Indian Government had funded the cost of operation of M.V. Kreuzturm from 21.10.85 onwards).

3.2.10.11 Since the Scrab continued to remain unserviceable, the ship John Cabot was called back to Cork. It anchored in Cork at 1100 hrs. on 5.11.85. All the wreckage on board the ship was transported to the boat yard, in the afternoon.

3.2.10.12 After detailed macro photography of the recovered wreckage, the experts group mentioned in section 1.5.16 prepared a detailed factual report after carefully inspecting each of the targets recovered. It was decided to send the wreckage to Bombay for which necessary crates were then prepared and the large pieces of wreckage were cut along the lines indicated by the experts group to facilitate their packing.

3.2.10.13 RCMP investigators carried out a close visual and microscopic examination of the fragments recovered with the wreckage, suitcases, seats and cushions, etc. For further laboratory analysis. Dr A.D. Beveridge collected a few samples.

3.2.10.14 The Scarab appeared to be serviceable on 19.11.85 and the ship John Cabot sailed for completion of recovery of left over targets, on 20.11.85. However, the serviceability of Scarab proved elusive, it became inoperable on 21.11.85 and the ship returned to Cork at 1700 hrs on 25.11.85.

3.2.10.15 Efforts were made to repair Scarab so that the ship John Cabot could sail again in order to salvage as many pieces as possible. It was fortunate that the weather had not deteriorated. Some of the important but small pieces which had to be recovered had been placed in a basket at the bottom of the ocean. The ship sailed out again after Scarab had been repared. The basket was sought to be lifted, but, unfortunately, when it reached near the surface of the sea it overturned and the contents of the basket spilled and were never traced again.

3.2.10.16 At this juncture it was decided that the salvage operations should be terminated. The ship returned and sailed for home in the first week of December 1985.

3.2.11 Examination of Wreckage

3.2.11.1 Floating Wreckage

Soon after the accident, a number of light weight parts of the aircraft were found floating over a wide area at the crash site. These were picked up by the ships engaged in rescue operations and were brought to Cork where they were kept in the boat yard. The floating wreckage recovery continued for four days i.e. upto 26th June.

3.2.11.2 Some of the wreckage items were subsequently washed to the west coast of Ireland. These were picked up by the Irish Police and were brought to Cork. Some wreckage items were taken by a ship to Halifax, Canada. These were flown to Cork by the Canadian Aviation Safety Board. With the assitance of Air India engineers, the wreckage items were identified, labelled, photographed and laid out in the boat yard hangar for examination.

3.2.11.3 The wreckage was initially examined at Cork by the Structures, Power Plant and Systems Group. It was subsequently transported to Bombay for further examination. A few wreckage items which were taken by the Spanish trawlers to Madrid were also transported to Bombay. Some wreckage items had washed to the west coast of England. These were collected by the Accident Investigation Branch of UK and were transported to Cork and then to Bombay.

3.2.11.4 The floating wreckage recovered constituted approximately 3 to 5 per cent of the aircraft structure. The major items of the wreckage recovered were :

Various leading edge skin panels of LH nd RH wing, LH wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canon fairings aft end pieces, landing gear wheel wall doors, pieces of elevator and aileron, toilet doors, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggages, suitcases etc. and three empty oxygen bottles.

3.2.11.5 The Structures Group which had been constituted by the Court examined the floating wreckage and submitted its report. From the report the following significant information about the damage to major items of the floating wreckage is noted :

(I) VT-EFO aircraft was carrying a -7Q engine on 5th pod and a -7Q 5th pod kit in the aft cargo compartment. It had therefore, in all 14 engine fan cowls (eight working engine fan cowls plus two 5th pod engine fan cowls plus two -7T engine kit fan cowls in the aft cargo compartment plus two -7Q engine fan cowls in the aft cargo compartment). Out of these 14 fan cowls, 9 cowls (6 of working engines plus 2 of -7J kit plus one of 7Q kit) and two additional pieces of fan cowls were found. Five of the fan cowls of working engines show
folding damage lines at approximately 3 O'Clock and 9 O'Clock positions. The number 3 engine inboard fan cowl has severe impact damage on its leading edge and has small inward to outward puncture holes (not penetrating through outer skin) in the lower centre region. The two fan cowls of -7J 5th pod kit stowed in the aft cargo compartment exhibit severe damage. One of these cowls is broken in two pieces. One of the pieces is cut at one corner in an arc of about 20 inches diameter and its external skin is pealed back. The external surfaces of all the three pieces have considereable scratches, tears and holes from outside to inside. None of the punctures penetrates the inner skin. Some punctures are also present from inside to outside but none of these penetrates the outer skin.

(ii) Out of the 12 spoilers, seven (number 2, 3, 5, 7, 8, 9 and 12) have been retrieved. Of these, six have their actuators attached to them in fully retracted position. Six spoilers have splits in their lower skin with split edges curled into the cores of honeycomb. Number 8 spoiler (located just inboard of number 3 engine) has a concentrated local impact damage on front spar and trailing edge beam from forward to aft and up direction over a span of 2 feet starting from outboard of spoiler actuator.

(iii) The left hand wing tip assembly with a part of H F Antenna was retrieved. No burning/discolouration marks around lightning arrester of H F system were noticed. The rib inboard of the lightning arrester was found intact. There were no burn marks anywhere on the panel.

(iv) The right hand wing leading edge top panel inboard of number 3 engine with a position of kruger flap frame along with bull nose attached was recovered. The bull nose was found crushed from top in the area just below the stay rod and the lower surface of stay rod has scratch marks from front to rear.

(v) The right hand wing root leading edge (inboard of W S 268.81) shows an impact damage at the leading edge. Bottom skin and internal structure are torn away. The leading edge skin is caved in over a span of about 3 feet and shows signs of heavy body impact in air. The impact damage shows signs of downward and backward movement of the impacting body.

(vi) A 3' x 2' piece of right hand inboard trailing edge fore flap with accordian seal was recovered. The inboard 8" portion of leading edge was found damaged by impact of an object going from lower forward to upper aft.

(vii) All the floor panels recovered from upper deck and main cabin indicate that these were detached from their attachments in an upward direction from all sides.

(viii) One main deck blow out door located between B S 2040 and 2140 left hand side was available. Out of its four metal clips,

one clip was broken off with 2 nylon rivet heads sheared.
(ix) The cockpit entry door and the side bulkhead panel were found fairly intact but had come out of their attachment.
(x) Twelve toilet doors, out of a total of 16, were available and were found fairly intact, but had come out of their attachments.
(xi) The available cabin interior panels and overhead bins of the main deck and upper deck have only minor damage.
(xii) The woodent boxes which contained the fan blades of 5th pod engine and were loaded in container at position 24L in the forward cargo compartment were found broken apart with no burn marks.

3.2.11.6 Wreckage Salvaged from Sea

The wreckage salvaged from the sea was visually examined at Cork by the Committee of Experts as mentioned in section 1.5.16 and the observations thereon recorded. Subsequently detailed metallurgical examination was carried out at the Bhabha Atomic Research Centre, Bombay by
Dr. M.K. Asundi and Dr. G.E. Prasad of B.A.R.C., Mr. S. Radhakrishnan and Dr. R.V. Krishnan of National Aeronautical Laboratory and Mr. B.K. Athawale of the Explosives Research and Development Laboratory, under the guidance of Dr. V. Ramachandran. During this examination, representatives of CASB, CP Air and Boeing were present in the first week. These represntatives left Bombay while the metallurgical examination was being carried out. The metallurgical examination was continued and the aforesaid group submitted the metallurgical report to the Court in December, 1985.

3.2.11.7 Although all the recovered wreckage was examined, only those items exhibiting characteristics which provide some evidence as to what may have happened to the aircraft during its final moments of flight are discussed herein below :

3.2.11.8 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from B S 1480 to 1850 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear and the torn edge was buckled in waves, like the trace of a sine wave. One the right side, between the one quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at B S 1480. The skin tear located at about B S 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distored and elongated.

3.2.11.9 This panel was examined by the committee of experts at BARC and according to their report the keel beam trunnion fitting beneath the outer chord of the station 1480 bulkhead had fractured at the aft set of bolt holes. The fracture surface of the right side of the trunnion fitting was clean. As per the report, it was typical of overload failure in tension. The fracture surface of the left side of the trunnion fitting was covered with corrosion products, especially, at one corner, due to sea water. After cleaning this area by the recommended techniques, scanning electron microscopy revealed morphology of overload fracture consisting of dimples. Away from this corner also the fracture was similar as being due to overload. There was no evidence of there having been any fatigue failure.

3.2.11.10 At B.A.R.C., a sample was cut from the corroded corner of the failed left side trunnion fitting and metallographic examination was carried out on the same. The said examination showed on a face perpendicular to the corroded fracture surface, pits due to corrosion by sea water. The basic microstructure was however free from intergranular cracking. It was thus concluded by the experts that the material in the region corroded by sea water had not suffered stress corrosion cracking which generally manifests as intergranular cracking.

3.2.11.11 A piece of the trunnion fitting was cut and the hardness and electrical conductivity values were measured by the said experts. As per their report, the electrical conductivity values were within the specified limits.

3.2.11.12 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from B S 1860 to 1960 and from stringer 46L to 46R. The forward end of target 8 matched with the aft end of Target 7. A region of fracture along the rivet holes near stringer 46L was marked for SEM examination. SEM examination after cleaning revealed that the fracture was characterised by dimples along its length, including areas adjacent to the edges of the rivet holes. These features are consistent with an overload mode of failure.

3.2.11.13 According to the metallurgical report, there was no evidence of fatigue failure on this target.

3.2.11.14 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 O'Clock position, the piece from 12 to 1 O'Clock position had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 O'Clock position the outer edge showed sinusoidal buckling, and the edge sector at 9 O'Clock position was partially collapsed and its edge was turned under. Samples taken for optical stereo microscope and SEM examination revealed that the fracture characteristics were consistent with an ovrload mode of failure.

3.2.11.15 According to the metallurgical report, there was no evidence of fatigue or any other mode of failure.

3.2.11.16 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occuped the 7 to 9 O'Clock position. Optical and SEM examination were undertaken on this item.

3.2.11.17 The fracture alont the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

3.2.11.18 Representative fracture samples were cut from the left-hand side and circumferential fracture edges of the fracture surfaces. Optial and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

3.2.11.19 Target 47 - Aft Cargo Floor Structure

This portion of the aft cargo compartment was located between B S 1600 and B S 1760. No significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

3.2.11.20 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between B S 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

3.2.11.21 In the metallurgical report it is stated that on an examination of this target it was also found that on the underside of this
floor near the forward end, a number of dents and impact marks were observed. This region appeared to have suffered shrapnel penetration. This area was radiographed but no metallic fragment was detected.

3.2.11.22 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segement was located between B S 720 and 840.

The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

3.2.11.23 Target 399 - Fuselage around 2R Door

This target is shown in Fig. 399-1. A detailed description is given below :

TARGET 399 Fuselage Station 780 to 940 in the longitudinal direction and stringer 7R down
to stringer 35R circumferentially.

This piece contained five window frames, one in the 2R passenger entry door. Three of the window frames, including the door window frame, still contained window panes. Little overall deformation was found in the stringers and skin above the door. The structure did contain a significant amount of damage and fractures in the skin and stringers beneath the window level. In the area beneath the level of the windows, the original convex outward shape of the surface had been deformed into an inward concave shape. Further inward concavity was found in the skin between many of the stringers below stringer 28R. The skin at the forward edge of the piece was folded outward and back between stringers 25R and 30R. Over most of the remaining edges of the piece a relatively small amount of overall deformation was noted in the skin adjacent to the edge separations. Twelve holes or damage areas were numbered and are further described.

No.1 : Hole, 5 inches by 9 inches with two large flaps and one smaller curl, all folded outward. Reversing slant fractures, small area missing.

No.2 : Hole, 2 inches by 3/4 inch, one flap folded outward, reversing slant fractures, one curled sliver, no missing metal.

No.3 : Triangular shaped hole about 2 inches on each side. One flap, folding inward, with one area with a serrated edge. No missing metal, extensive cracking away from corners of the hole, reversing slant fracture.

No.4 : Tear area, 8 inches overall, with deformation inward in the centre of the area. Reversing slant fracture.

No.5 : Fracture area with two legs measuring 14 inches and about 24 inches. Small triangular shaped piece missing from a position slightly above stringer 27R. Inward fold noted near the joint of the legs. An area of 45° scuff marks extend onto this fold.

No.6 : Hole about 2.5 inches by 3 inches with a flap folded outward, reversing slant fracture. Approximately half the metal from the hole is missing.

No.7 : Hole about 3 inches by 1 inch, all metal from the hole is missing. Fracture edges are deformed outward.

No.8 : Forward edge of the skin is deformed into an "S" shaped flap. Three inward curls noted on an edge.

No.9 : Inwardly deformed flap of metal between stringers 11R and 12R at a frame splice separation. No evidence of an impact on the outside surface.

No.10 : Door lower sill fractured and deformed downward at the aft edge of the door.

No.11 : Frame 860 missing above stringer 14R. Upper auxilliary frame of the door has its inner chord and web missing at station 860. A 10 inch piece of stringer 12R is missing aft of station 860.

No.12 : Attached piece of floor panel (beneath door) has one half of a seat track attached. The floor panel is perforated and the lower surface skin is torn.

3.2.11.24 Much of the damage on this target was on the skin and stringers beneath the window level, i.e., on the starboard side of the front cargo hold. The inside and outside surface of the skin in this region are shown in Fig. 399-2 and 399-3 respectively. There were 12 holes or damaged areas on the skin as described above, generally with petals bending outwards. The curl on a flap around hole no.1 shown in Figh 399-4 has one full turn.
This curl is in the outward direction. Cracks were also noticed

around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.

3.2.11.25 When this target was recovered from the sea, along with it came a large number, a few hundreds, of tiny fragments and medium size pieces, All of the fragmets were recovered from the area below the passenger entry door 2R. One of the medium size pieces recovered with this target was a floor stantion, about 35 inches long, shown in Fig. 399-5. It is a square tube. It had the mark station 880 painted on its inner face, i.e. facing the centre line of the cargo hold. The part number printed on this station is 69B06115 12 and the assembly number is ASSY 65B06115-942 E3664 1/31/78*. It was confirmed that this stantion belongs to the starboard side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the station. Fig. 399-6 is a print from the radiograph of this station. The inward curling can be seen clearly in this figure. Curling of the metal in this manner is a shock wave effect.

3.2.11.26 A piece near the fracture edge of this stantion was cut, and examined metallographically. Fig. 399-7 and 399-8 show the micro-structure of this piece. Twins are seen in the grains close to the fracture edge. The normal microstructure of the stantion material is free from twins as shown in Fig. 399-9.

3.2.11.27 Fig. 399-10 shows a collection of small fragments recovered along with target 399. There were some curved fragments with small radius of curvature (A). Reverse slant fracture (B) was noticed in some of the skin pieces. A piece 3/4" x 1/2" and 3/16" thick was found to have three blunt spikes at the edge (C). This piece was metallographicaly polished on the longitudinal edge. The microstructre of the piece is shown in Fig. 399-11. It may be seen that the grains in this fragment also contain a large number of twins.

3.2.11.28 Target 362/396 Forward Cargo Skin

This piece indluded the station 815 electronic access door, portions of seven longitudinal stringers to the left of bottom centre and five longitudinal stringers to the right of bottom centre. The original shape of the piece (convex in the circumferential direction) had been deformed to a concave inward overall shape. Multiple separations were found in the skin as well as in the underlying stringers. Further inward concavity was found in the skin between most of the stringers.

3.2.11.29 The two sides of this piece are shown in Fig. 362-1 and 362-2. This piece has 25 holes or damaged areas in most of which there are multiple petals curling outwards. These holes are numbered 1 to 3, 4a, 4b, 4c and 5 to 23. These are described below. Unless otherwise noted, holes did not have any material missing :

No.1 : Hole with a large flap of skin, reversing slant fracture.

No.2 : Hole with multiple curls, reverse slant fracture.

No.3 : Hole with multiple flaps and curls, reversing slant fracture, one area of spikes (ragged sawtooth)

No.4A : One large flap, reverse slant fracture, one area of spikes.

No.4B : Hole with two flaps.

No.4C : Hole with two flaps, one area of spikes

No.5 : HOle with two flaps.

No.6 : Braching tear from the left side of the piece, reversing slant fracture.

No.7 : Hole, with one flap, one curl and one area of spikes.

No.8 : Very large tear from the left side of the piece with multiple flaps and curls, reversing slant fracture and at least two areas of spikes.

No.9 : Hole with multiple flaps, one curl.

No. 10 : 2.5 inch tear

No.11 : One flap

No. 12 : Grip hole, plus a curl with spikes on both sides of the curl.

No.13 : "U" shaped notch with gouge marks in the inboard/ outboard direction. Three curls are nearby with one are of spikes. Gouges found on a nearby stringer and on a nearby flap.

No. 14 : Nearly circular hole, 0.3 inch to 0.4 inch in diameter. Small metal lipping on outside surface of the skin. Most of the metal from the hole is missing.

No. 15 : Hole in the skin beneath the first stringer to the left of centre bottom. Small piece missing.

No. 16 : Hole in the stringer above hole No. 15. Most of the metal from this hole is missing.

No. 17 : Hole through the second stringer to the left of centre bottom, 0.4 inch in diameter. The hole encompassed a rivet which attached the stringer to the outer skin. Small pieces of metal missing.

No. 18 : Hole at the aft end of the piece between the third and fourth stringers to the left of centre bottom. The hole consisted of a circular portion (0.4 inch diameter), plus a folded lip extending away from the hole. The metal from the circular area was missing.

No. 19 : Hole with metal folded from the outside to the inside, about 0.6 inch by 1.5 inch. Flap adjacent to the hole contained a heavy gouge mark on the outside surface of the skin.

No. 20 : Hole containing a piece of extruded angle.

No. 21 : Hole containing a piece of extruded angle.

No. 22 : Hole with one flap.

No. 23 : Hole about 0.3 inch in diameter, with tears away from the hole. Small piece missing.

3.2.11.30 Fig. 362-3 to 362-7 show a few of these holes. There were also cracks or tears around some of the holes. The curls around some of the holes had nearly one full turn. In the large tear between body stations 700 and 740 and stringers between 41L and 45L, there were many pronounced curls as shown in Fig. 362-8. On the edges of the petals around several holes, reverse slant fracture was seen at a number of places. This slant fracture is at an angle of about 45° to the skin surface, the fracture continuing in the same general direction but with the slope of the slant fracture reversing frequently.

3.2.11.31 Sharp spikes were observed at the edges of the holes or at the edges of the petals around the holes No. 3, 4A, 4C, 7, 8 (at two locations), 12, 13 and 16. Some of the spikes are shown in Fig. 362-9 to 362-12. One of the holes, No. 14, on the skin was nearly elliptical with metal completely missing, as shown in Fig. 362-13. On the inside surface of the skin, paint surrounding this hole was missing. Hole No. 16 was through the hat section stringer, as shown in Fig. 362-14. In this, most of the metal was missing. On the inside of the hat section, the fracture edge of this hole had spikes, as shown in Fig. 362-15. Hole No. 17 was through the stringer and the skin, as shown in 362-16.

3.2.11.32 Through holes No. 20 and 21, extruded angles were found stuck inside, as shown in Fig. 362-17 and 362-18 respectively. In the petal around hole No. 20, there was an impact mark by hit from the angle as seen in Fig. 362-19 photographed after removing the angle. Such a mark was not present in the petals around other holes.

3.2.11.33 On the skin adjacent to hole No. 13 gouge marks were noticed, Fig. 362-20. These marks were on the inside surface of the skin. To check whether these could be due to rubbing by the bridal cable of Scarab during the recovery operations, a sample of bridal cable was obtained from "John Cabot" and gouge marks were produced by pressing this cable against an aluminium sheet. The gouge marks thus produced, as shown in Fig. 362-21, appear to be different from those observed near hole No. 13.

3.2.11.34 A piece surrounding hole No. 14 was cut out and examined in a Jeol 840 scanning electron microscope at the Naval Chemical and Metallurgical Laboratory, Bombay. Fig. 362-22 and 362-23 are the scanning electron micrographs showing the inside surface and outside surface of the skin around this hole. Flow of metal from inside to outside can be seen from these figures. Energy dispersive x-ray analysis was carried out on the edges of this hole. Only the elements present in this alloy and sea water residue were detected.

3.2.11.35 A portion of the skin containing part of hole No. 14 was cut, polished on the thickness side of the skin and examined in a metallurgical microscope. Fig. 362-24 shows the microstructure of this region. The flow of metal along the edge of the hole can be seen from the shape of the deformed grains near the hole. This can be compared with the bulk of the grains shown in Fig. 362-25, away from the hole. In addition, in Fig. 362-24, a series of twin bands can be seen in some of the grains near the hole. Fig. 362-26 shows these bands at a higher magnification. Normal deformation rates at various temperatures do not produce such twinning in aluminium or its alloys. It may be noted that this microstructural feature is absent in the microstructure of the skin, away from hole No. 14, Fig. 362-25.

3.2.11.36 Metallography was also carried out on a petal around hole No.7 and on a curl with spikes around hole No. 12. The microstructures indicate twins, however they could not be recorded due to their poor contrast.

3.2.11.37 Small pieces containing the spikes around holes No. 12 and 16 were cut and energy dispersive x-ray chemical analysis on the region of spikes in both was carried out in the Jeol 840 SEM. Only elements present in the alloys and sea water residue were detected.

3.2.11.38 A number of small fragments were found along with the forward cargo skin in target 362. Amongst them was a piece from the web of a roller tray. This has pronounced curling of the edges towards the drive wheel, Fig. 362-27.

3.2.11.39 Another small fragment was found from the above target. This piece, identified as specimen No. 12 in box No. 1, target 362, has a number of spikes along the edge. A scanning electron micrograph of the spikes is shown in Fig. 362-28. The sides of the spikes on SEM examination revealed elongated dimples as shown in Fig. 362-29, characteristic of shear mode of fracture. Metallography was carried out on the thickness side of this specimen. Fig. 362-30 and 362-31 show the microstructure near the apex of the spike and at the root of the spike respectively. Extensive twinning can be seen in these regions of the spikes.

3.2.11.40 Another fragment recovered with target 362 and identified as specimen No. 8 in box No. 1, also showed extensive twinning. The microstructure is recorded in Fig. 362-32.

3.2.11.41 Reference has also to be made to two other reports concerning wreckage.

3.2.11.42 The floating wreckage recovered was initially examined at Cork. On 25th June, Mr. Eric Newton a retired investigator of AIB, UK, was requested to examine the floating wreckage recovered and other materials with specific reference to the possibility of explosive sabotage having taken place. Mr. Newton examined the floating wreckage, passenger clothings and the other materials recovered from the crash victims The findings of Mr. Newton on the material available at that time are summarised below:

a. Taking the scatter of the wreckage and bodies into consideration and the condition of the limited wreckage recovered indicates that the aircraft had broken up in flight before impact with the sea.

b. Detailed examination of the structural wreckage recovered did not reveal any evidence of collision with another aircraft. Nothing was found suggestive of an external missile attack.

c. There was no evidence of fire internal or external.

d. There was no evidence of lightning strike.

e. Examination of all available structural parts recovered, did not reveal any evidence of significant corrosion, metal fatigue or other material defects. All fractures and failures were consistent with overstressing material and crash impact forces

f. Examination of clothing from the bodies did not show any explosive fractures or any signs of burning. The seat cushions and head cushions also did not show any explosive characteristics.

g. The damage to the suitcases (14 large and 29 small) which were examined was due to impact crash forces. The presence of 14 large suitcases could, however, indicate that one of the baggage containers had been broken to permit these suitcases to escape.

h. A number of lavatory doors and structure also did not show any damage consistent with explosion. The flight deck door showed no explosion damage inside or outside.

i The circumstatnial evidence strongly suggests a sudden and unexpected disaster occurred in flight.

j. There was no significant fire or explosion in the flight deck, first and tourist passenger cabin including several lavatories and the rear bulk cargo hold.

3.2.11.43 The other report dated 30th November, 1985 is of Mr. V.J. Clancy. Mr. Clancey had examined the wreckage and had also taken part, though only for a few days, in the metallurgical examination which was being conducted at BARC, Bombay.

3.2.11.44 Mr. Clancey examined practically all the items of wreckage which had been brought to BARC and in his report he has dealt with all of them. His report contained a description of the recovered items and also his comments thereon.

3.2.11.45 With regard to the aforesaid target 362, he observed that there were about 20 holes in it clearly resulting from penetrations from inside.

3.2.11.46 He further stated that:

"In addition to the fact that perforation was from inside there are certain features which suggest that they were made by high velocity fragments such as are produced by an explosion. These features are:

(a) Presence of toothed or spiked edges at some parts of the metal which had petalled out from the perforations.

"Tardif and Sterling (Canadian Aeronautics and Space Journal, 1969, 16, 1, 19-27) obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.

(b) Presence of marked curling, in some cases of more than 360°, of some of the petals.

Tradif and Sterling stated that such curling was a feature of explosively produced fragments.

(c) The virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal.

(d) The virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object. This suggested that the production of at least many of the perforations were separate independent events.

(e) One perforation (identified as No. 14) resembles a "bullet hole", that is cleanly punched out - a type of hole usually associated with a high velocity missile.

"There is evidence that the forward part of this item had been folded back inwards along the line of station 760 and then bent back again along a line slightly forward of this station.

"Such folding, may be violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.

"One hole identified as No. 13, was almost certainly caused by a slipping wire rope used as a sling.

"Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken by me of this area
and are being examined by R.A.R.D.E. for evidence of fire or explosives".

3.2.11.47 There were several hundred small fragments which were recovered from the same general area as Target 362. While dealing with these Mr. Clancey observed that the production of a large number of small fragments is generally regarded as indicative of an explosion. One piece out of this was isolated, which was about one inch square of sheet alloy, and it was noted by Mr. Clancey that this piece had characteristic spikes on one edge similar to those described by Tardif and Sterling. (This piece is the same as shown in Fig. 362-28).

3.2.11.48 Mr. Clancey also examined a few suit cases which had been recovered. One particular suit case to which reference was made by him was of red plastic material with blue lining. With regard to this he stated that the damaged lining, severely tattered, resembles that of one found after an explosion in an aircraft in Angola. In that case microscopic examination showed definite evidence of damage by an explosion.

3.2.11.49 The later part of the report of Mr. Clancey contained his opinion. With regard to Target 362 his opinion was as follows:

"The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

"Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

"A more detailed study, metallurgical and fractographic, is required.

"The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

"The single "bullet hole", No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

"If the forward part of this item was forcefully and rapidly folded back to impact on the other part it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility".

3.2.11.50 The opinion of Mr. Clancey about the small fragments was as follows:

"The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.

"The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

3.2.11.51 It appeared to the Court that the report of Mr. Clancey required certain clarifications. It was suggested to Boeing Commercial Airplane Company by the Court that Mr.

Clancey should appear as a witness. The Court received a message to the effect that Mr. Clancey felt that he could not add anything useful to his report.

3.2.11.52 A close examination of the report of Mr. Clancey shows that the opinion expressed by him in the later part of the report is at considerable variance with the observations contained in the earlier part of the report. Particularly with regard to Target 362 and the small fragments, Mr. Clancey has stated in his observations that there was strong
evidence of explosion. In his opinion, however, he has stated that more detailed study is required. It is interesting to note that though Mr. Clancey has referred to the opinion of Tardif and Sterling, he has not chosen to contradict the conclusions arrived by them. Mr. Clancey has also not stated as to what could possibly have caused the special features which were noted on Target 362.

3.2.11.53 We find the metallurgical report inspires more confidence. Not only is reference and reliance made in the report to other expert opinions contained in various articles written by experts all over the world, certain explosion experiments were also carried out by the experts which led them to the same conclusion.

3.2.11.54 The particulars of the experiments so carried out and the results obtained therefrom have been stated in their report as follows:

EXPLOSION EXPERIMENTS

"To determine the damage by high velocity fragments or shock waves on a structure similar to the one in aircraft cargo hold, the following experiments were conducted on November 30 and December 1, 1985 at the Explosives Research and Development Laboratory, Pune, using plastic explosive (PEKI) and different mixtures of plastic explosive and TNT. The explosive was kept in a box made of sheet metal of 6" x 6" x 6" of 1/16" thickness.

This box was kept inside another box made of sheet metal 2' x 2' x 2' of .04 or .06" thickness. The boxes were made of 2024 aluminium alloy sheets used for aircraft skin. To the inner surface of the outer box, hat section stringers similar to those used in the aircraft were riveted. The quantity of explosive used in the inner box was varied from 60 g to 100 g. The explosive was detonated with an electrical detonator. After the explosions the fragments and the panels were collected and examined.
"Experiments were also conducted to produce explosive damage on skin panels, individual hat section stringers and individual stantion tubes. In the case of stantion tubes experiments were carried out placing the explosive charge both inside and outside. The quantity of explosive used was varied from 5 g to 50 g.
"Various types of damages were recorded on all the targets. These include punched holes, petaling and curling around holes, spikes at fracture edges, curved fragments with small radius of curvature and reverse slant fracture. Fig. EXP-1 shows a collection of fragments. The features mentioned above are shown in Fig. EXP-2 to EXP-7. It may be noticed that the features produced by experimental explosion were similar to the features observed largely in target 362 of the wreckage. The small fragments had features similar to those in the fragments from targets 362 and 399.
"Metallography was carried out in (a) a specimen surrounding a punched hole in the skin (b) a specimen surrounding a hole in the stringer, (c) a curl in the stantion and (d) spikes in a fragment. In all these cases, the grains adjacent to the area of explosive damage are having twins. Two typical microstructures are shown in Fig. EXP-8 and EXP-9. Away from these areas the microstructure is normal. Thus it is confirmed that twinning in the microstructure of these structural members is a unique feature of explosive fracture, not produced by any other measns known so far."

3.2.11.55 The findings in the said metallurgical report are also strengthened by the observations of Eric Newton in the article "Investigating Explosive Sabotage in Aircraft" published in the International Journal of Aviation Safety, March 1985, p. 43. Mr. Newton is an acknowledged authority in the detection of explosive sabotage in aircraft. The conclusions contained in the article are based on his review of incidents of explosion between 1946 and 1984 which were known to him. Some of the conclusions arrived at by him which were relevant in the present case are when he states "Generally speaking, the smaller the fragment, higher the velocity of the detonation. Minute fragmentation is indicative of high explosive having been used, and provides clues to the focal point or region of the explosion. The mode of break up of the aircraft itself and its sequence of failure is usually very complicated and quite without the logic dictated by normal aerodynamic overstressing".

3.2.11.56 Mr. Newton has also observed that curling, cork-screwing, and saw tooth edges may also be indicative of an explosion though such fractures by themselves may not be conclusive evidence that an explosion was involved. Firmer evidence, according to him, was of fusing
of metal, scorching, pitting and blast effect. He further states that "Perhaps the most conclusive material evidence to be found on metal specimens is cratering, very often in groups, often minute and numerous".

3.2.11.57 Mr. Newton also refers to the positive explosive signatures which remain on a detonation in an aircraft. These positive singatures, according to him, are as follows:

"(a) The formation of distinctive surface effects such as pitting or very small craters formed in metal surfaces, caused by extremely high velocity impacts from small particles of explosive material. Such craters, when viewed under the microscope, have raised and rolled over edges and often have explosive residue in the bottom of the crater.

"(b) Small fragments of metal, some less than 1 mm in diameter, which, under the scanning electron microscope, reveal features such as rolled edges, hot gas washing (orange peel effect, surface melting and pitting and general evidence of heat; such features have been proved and observed following explosive experiments with known explosives). Supporting strong evidence would be if such fragments (normally found embedded in structures, furnishing or suitcases) were found embedded in a body where evidence of burning of tissue is present at the puncture entry and where the fragment came to rest.

"(c) As well as surface effects on metal fragments produced by explosives there are deformation mechanisms which are peculiar to high rates of strain at normal temperature. At normal rates of strain metals deform by usual mechanism associated with dislocation movement. However, because this process in an explosion is thermally activated at very high rates of strain, there is insufficient time for the normal process to occur. In some metals such as copper, iron and steel, deformation in the crystals of the metal takes place by 'twinning', that is to say by parallel lines or cracks cutting across the crystal. Such a phenomenon can occur only if the specimen has been subjected to extreme shock wave loading at velocities in the order of 8000 m/sec. Such specimens, usually distorted must be selected with care, prepared in a metallurgical laboratory, polished, mounted
and microscopically examined. Where such twinning of the crystals is found it establishes (a) that the specimen was close to the seat of the explosion and (b) that a military type explosive had been used with a detonating velocity of 8000 m/sec or more. Twinning is rarely produced when shock impact loadings are below 8000 m/sec.

"The above features, singly or combined, are considered to be proof positive evidence of a detonation of a high explosive; they could not be produced in any other way."

3.2.11.58 The metallurgical report indicates that the microscopic examination (conducted by them) discloses such features being present which had been described as positive signatures of the detonation of an explosive device in an aircraft by Mr. Newton. Furthermore, twinning effect has also been noticed at a number of places - around holes and in fragments. These have been categorised by Mr. Newton as positive signature of an explosion.

3.2.11.59 In the primary zone of explosion, metallic structures disintegrate into numerous tiny fragments and usually these fragments contain the above mentioned distinct signatures of explosion. In the present case the explosive damage had occurred at an altitude of 31000 feet when the aircraft was flying over the ocean. The fragments that formed due to explosion must have been scattered over a wide area and it is impossible to locate and recover all of them from the ocean bed. Nevertheless, some of the fragments which were recovered along with the targets 362 and 399 do contain signatures of explosive fracture.

3.2.11.60 From the aforesaid discussion it would, therefore, be safe to conclude that the examination of targets 362 and 399 clearly reveals that there had been a detonation of an explosive device on the Kanishka aircraft and that detonation has taken place not too far away from where these targets had been located.

FIRE

3.3.1 There is no evidence that there was any fire on board the aircraft before it met with the accident.

3.3.2 Amongst the floating wreckage, however, was found, what was later on identified as, a spares equipment box belonging to this aircraft. This box was charred on one side and partially on the bottom. The depth of charring suggested that the burning time was three to four minutes. This box contained some sand and small shellfish. The flesh from the shelfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

FLIGHT RECORDERS

3.4.1 Recovery of Flight Recorders

3.4.1.1 Recovery of the flight recorders was a very difficult and challenging job. At the site of accident, depth of water is about 6700 feet. The job involved fixing the location of recorders and then retrieving them. For this purpose three ships viz. Guardline Locator (a ship provided by Accident Investigation Branch of U.K.), Le Aoife (an Irish Naval Ship) and Leon Thevenin (a French Cable laying ship, charterd by the Government of India) were utilised. Guardline Locator and Le Aoife were solely for fixing the positions of recorders and also had the capability to lift the recorders with the help of its scarab.

3.4.1.2 Both the Cockpit Voice Recorder and the Digital Flight Data Recorder were fitted with Dukane Underwater Acoustic Beacons (Pingers) which enabled establishing the location of flight recorders under water. The Beacons are designed to provide a signal at 37.5 ñ 1 Khz frequency that can be heard for approximately 2 miles in any direction for 30 days after water entry. Its high strength case permits operation in water depth to 20,000 feet. Its pulse repetition rate is not less than 0.9 pulse per second.

3.4.1.3 On 4th July, 1985, Guardline Locator reported strong possibility of two separate sound sources of frequencies between 39 KHz and 42 KHz. On 5th July, Guardline Locator gave coordinates of an area, which it believed contained the pinger. Guardline Locator later reported that using a Dukane Hand Locator, it had located pinger (2) at 5102.6N, 1248.6W. Leon Thevenin then concentrated its search in this area for retrieving the recorders.

3.4.1.4 In response to a query, Messrs Dukane Corporation advised that Pinger transducer is made of ceramic and if cracked during impact, its frequency could be elevated. The pulse rate should, however, be uneffected. Keeping this in mind, the Leon Thevenin increased its Sonar Band one upper frequency limit from 40 KHz to 45 KHz.

3.4.1.5 On 9th July at about 2300 hours the Scarab of Leon Thevenin located the Cockpit Voice Recorder at 5102.67N, 1248.93W and the recorder was brought on the deck at 0747 hrs on 10th July. The CVR was kept in a drum filled with water. The scarab was again lowered on 10th July in the same area and at about 2130 hours faint signals were picked up on Sonar. By about 2200 hours the signals became louder and the pulse rate frequency was calculated to be 72 transmissions per minute. At about 2230 hours the DFDR was also located at 5103.10N, 1249.59W and it was brought on deck at 0245 Z on 11th July.

3.4.1.6 The DFDR was also placed alongside the CVR in the drum filled with water. Leon Thevenin was then advised to return to Cork with the Flight Recorders. Leon Thevenin reached Cork on the morning of 12th July and the flight recorders were placed in two specially fabricated water tight steel containers filled with water. The recorders were then carried to Bombay on the same day by Mr. Satendra Singh, Reginal Controller of Air Safety, Bombay, accompanied by Mr. Vishwanath of Air India for preparing read-outs and transcript of the recorders. Necessary precautions were taken to ensure that the data recorded was not affected during transportation to Bombay.

3.4.1.7 Both the recorders reached Bombay on the morning of 13th July and were kept in the office of the Regional Controller of Air Safety under Armed Police Guard.

3.4.2 Description of Flight Recorders

3.4.2.1 Kanishka was equipped with a Fairchild A-100 Cockpit Voice Recorder Serial No. 5809 and a Lockheed 209E Digital Flight Data Recorder Serial No. 1282. These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the rear pressure bulkhead.

3.4.2.2 The CVR records all crew communications and sounds in the cockpit on a continuous tape loop which has a tape speed of 1-7/8 inches per second. The Recorder has two heads, one head which erases the previous recording and the second which records the current information and thus the last 30 minutes of recorded signals are retained, the previous being automatically erased. It continuously records convervations/sounds from 4 different sources on the following four separate channels:

Channel 1 : Radio channel of pilot

Channel 2 : Radio channel of flight engineer

Channel 3 : Cockpit Area Mike

Channel 4: Radio channel of co-pilot.

3.4.2.3 The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor. Adjacent to this unit was a Lockheed Model 280 Quick Access Recorder that recorded the same serial digital signals on to a 50 hour cassette.

3.4.2.4 The DFDR records 52 basic parameters on a magnetic tape. The tape preserves records of the last 25 hours. The serial digital signal has a bit rate of 768 bits per second and is recorded at a tape speed of 0.37 inches per second.

3.4.3 Examination of Flight Recorders and Tapes

3.4.3.1 General

The recorders brought to Bombay from Cork were opened on 16th July, 1985 at the Air India's Facilities in Bombay in the presence of the Court and Assessors. A team of foreign experts including one each representatives from both the Recorder Manufacturers, three from National Transportation Safety Board, one from Canadian Aviation Safety Board and one from NRC Flight Recorder Playback Centre, Canada were present when the tapes were taken out of the recorders. Apart from them, representatives of the Government of India and Air India were also present.

3.4.3.2 Cockpit Voice Recorder

When the unit was removed from its shipping and storage container, some mechanical damage was immediately evident. The top of the cover had been deformed inwards, probably due to initial external

strong attachments for the horizontally mounted Underwater Acoustic Beacon. The plate had torn away from the light structure behind it. The cause of the damage was not obvious. The light outer cover was removed by cutting it open with hand shears and pliers.

3.4.3.3 When the armoured and insulated containment was opened, the tape transport was found to be in relatively good condition and the tape physically undamaged. Eighteen inches of the tape was pulled from the centre of the tape stack and the tape cut near the stack well clear of the end of recording. The tape was then removed from the recorder, transferred to standard tape reels, laboriously cleaned several times with distilled water and dried with lint free absorbent material.

3.4.3.4 Digital Flight Data Recorder

When the recorder was removed from its shipping and storage container, it was noted that there was very little external damage. A cover on the rear section was removed and it was observed that, when viewed from the front of the recorder, the right hand edges of the four rearmost printed circuit cards were displaced towards the front of the recorder. The left hand edges were restrained by plug-in connectors to the boards. The rearmost card, that controls track selection on the tape, and the one in front of it, had bowed along the right-hand edges and popped out of their plastic guides in the top and bottom of the recorder. Deflection of the other two cards had occurred following failure of the attachments of the right hand ends of the plastic guides to the chassis. The damage could have been caused by a high lontitudinal decelaration, as would occur if the front face of the recorder impacted the water.

3.4.3.5 When the tape deck was opened, it was found that the tape was intact but had become dislodged from the last tape guide when the tape was moving in the direction of the odd-numbered tracks and had also jumped out of the adjacent end-of-tape sensor. One edge of the tape had been stretched in this area. The drive belt to the tape transport was still in its correct position. The tape was stuck to the third tape guide in the odd-numbered track direction and suffered some damage when it was finally detached from it. This was repeaired with a splicing tape.

3.4.3.6 The location of the record heads was marked on the back of the tape with a waterproof felt pen. It was noted that there was slightly more tape on the supply reel for the odd tracks than on the other reel. The tape reels and tape were removed from the recorder, keeping the tape wet with distilled water, and the tape transferred to the standard reels for meticulous cleaning. During the cleaning process, it was found that the edge of the tape had also been stretched locally 336 inches down- stream from the splice repair in the odd track direction. The tape was dried by patting it with absorbent lint-free material before loading it into a serviceable recorder as this was the only means by which it could be replayed at the Air India base.

3.4.3.7 The circuit card controlling track selection was removed from the accident recorder and the status of the latching relays checked to determine the last track on which recording was being made. It was found that the relay states indicated Track 1, but since this requires all relays to be set in the same condition, it was considered possible that they had been mechanically set on water impact. The card was subsequently inserted to another recorder and the Track 1 setting confirmed on a test bench.

3.4.3.8 When a change in track selection was attempted, it was found that the relays would not switch, probably due to the effects of salt water corrosion or high water pressure. It was decided that Track 1 would be considered as the most likely one to contain the accident data with the possibility that it could have occurred on any of the other tracks. When the data was recored, the accident information was found some distance past the mid-point of Track 1.

3.4.4. Recovery of Information

3.4.4.1 Cockpit Voice Recorder Tape

The spool was removed from the CVR and was washed with distilled water, dried and loaded on to another spool. The cleaned and dried tape was taken to the Bhabha Atomic Research Centre (BARC), and a copy
of the tape was prepared which was used for preparing transcript and carrying out further analysis. The transcript of the CVR conversation is given in Appendix 2.

3.4.4.2 Shannon Air Traffic Control Tape

A copy of this tape that contains all radio communications between the aircraft and Shannon was provided to the Indian Authorities by the Air Traffic Control Authorities, Shannon. The recording also included the short series of unusual sounds that occurred about the time of the accident.

3.4.4.3 When the CVR and the ATC tapes were played it was found that some adjustment in speed was necessary so as to synchronize the two. This adjustment was independently carried out by different experts who analysed the CVR tapes.

3.4.4.4 Digitial Flight Data Recorder Tape

The Lockheed representative had brought a Lockheed Model 235 Copy Recorder from his plant. This unit copies all the 25 hours of data from the recorder by running it at high speed for only two passes of the tape, an operation lasting only 16 minutes. A copy tape was made by this procedure before embarking on the standard Air India recovery procedure to serve as a back-up tape in the event of physical damage to the original tape in subsequent playback.

3.4.4.5 Air India playback equipment for the DFDR required that the tape be re-installed in another DFDR in which it was driven at high speed. In the standard playback procedure, the tape was first run to the beginning of Track 1 through 6 sequentially on to a computer tape followed by a repeat of Track 1. The computer tape was then taken to Air India's main computing facility where selected information was printed out in engineering units.

3.4.4.6 The first printouts showed that the accident was recorded on Track 1, as indicated by the latching relays, and suggested a rather abrupt end to the recording. There was a loss in bit synchronization in word 26 of the last Subframe 3 of data that was followed by a normal Subframe 4. Prior to the loss in bit synchronization, all measurements appeared normal. Plans were made to borrow the high speed oscillograph recorder previously used to studythe final CVR signals from BARC to examine the end of the recorded serial digital signal in detail.

3.4.4.7 Meanwhile, the critical section of the tape and the heads of the playback recorder were re-cleaned and a second transfer of data on to the computer tape was made. Printouts from this computer tape showed no significant difference from the first one.

3.4.4.8 The recorder was then opened and the tape positioned about 1.5 inches before the final resting place of the tape that was clearly indicated by head imprints on the magnetic oxide coating side. A high speed oscillograph record of a few seconds of data was made and visually decoded. It was found that the recorded GMT was 21 hr 16 min. This time corresponded to 15 min or about 333 inches of the tape after start of the oldest recording downstream of the accident.

3.4.4.9 The tape was then re-positioned using a Lockheed analogue playback unit, that had a display of the recorded time and a stopwatch was used to locate the accident timing. Two oscillograph copies of the end of the serial digital data were made, the second one having more data preceding the end. Visual reading of the traces confirmed that recording became erratic and irrecoverable at the end of Word 26 in Subframe 3 at the recorded time of 07 h : 14m : 35s. The erratic signal continued for about 0.27 inches of the tape before switching back to the data recorded 25 hours earlier.

3.4.4.10 Examination of the printouts confirmed a suspicion that the complete Subframe 4 of data following the partial Subframe 3, was data from 32 seconds earlier that had not been cleared from the data buffer in the computer and that Word 26 of the Subframe 3 was the last normal measurement provided by the recorder.

3.4.4.11 The end of recording occurred at the point on the tape at which some damage had been observed during the cleaning process. It was apparent that, after the end of the recording, the tape had run on for 336 inches before finally coming to rest.

3.4.4.12 A copy tape of the DFDR tape was made at Bombay and taken to Ottawa. Data from the accident flight, the preceeding Toronto-to-Montreal flight and part of the cruise conditions of the earlier flight to Toronto were transcribed on to the computer tape. The tape was edited to minimize errors and converted to engineering units using standards calibration. Time histories of all parameters for periods of interest were plotted. In addition, chart records were made of all parameters in raw data form for the total duration of the last lap of the flight.

3.4.4.13 The DFDR read out shows that the aircraft was cruising at an altitude of 31,000 ft. and a computed air speed of 296 knots till it suddently stopped recording at 07:14:35 GMT recorded time.

3.4.5 Reports received by the Court

3.4.5.1 The CVR was taken to B.A.R.C. This tape was played by the CVR group a number of times and hard copies of the time information were also prepared using an ultra violet (UV) Recorder. The group consisted of Mr. Satendra Singh, Regional Controller of Air Safety of D.G.C.A., Mr. S.N. Seshadri of BARC, Mr. Paul C. Turner of NTSB, USA, Mr. John G. Young of NTSB, USA and Mr. P. dE Niverville of CASB, Canada. On 18th July, 1985 this group made the following observations after playing the aforesaid tape (UV recording of CVR is at Fig. 1) :-

"The first visible rising signal volume was observed on channel number three the CAM channel It reaches a maximum in about 50 milliseconds. At this time noticeable disturbances are observable on the other three channels. A smaller disturbance is observable on channels 2 and 4 earlier than observable on channel 1. A major disturbance is observed to begin approx. ninety milliseconds following the initial observation on channel number 3 (CAM), on channels 1,2 and 4. Following this point at 75 milliseconds the CAM signal subsides to a lower level but much higher than observed ambient (prior to disturbance) where it remains for approximately 375 milliseconds from initiation when it ceases. Channel four goes off at the same time. Channel 1 goes off twenty five milliseconds earlier. Channel two is inconclusive and had a different pattern. All four channels exhibit a disturbance at approx. 450 milliseconds. The cockpit voice recorder power then shuts off at 650 milliseconds.

The Shannon area control centre tape made the night of the accident was examined and printed. It shows a signal was received at approximately the time the aircraft disappeared from radar. It isn't conclusive at this time that the signal originated from the accident aircraft. The signal was received in pulses for approximately five seconds."

3.4.5.2 The tape was again played on 19th July, 1985 and a further report was prepared which was signed by the aforesaid persons and Mr. B. Caiger of NRC, Canada. In this report it was stated as follows:-

"The Shannon area control centre tape was again printed at .05"/ second per inch speed from approximately 22 sec. before the first broadcast from the accident aircraft at 0709.58 until Radio carrier with indecipherable modulation can be heard at 0714:01. The print contains a time encoded signal.

A similar print was made from the CVR channel 4 (Co-Pilot's) of the same audio as received on the ATC tape. Although the tape speed is different, the events when corrected for tape speed errors occur at the same time. It appears that the ATC recording contains the beginning of the aircraft breaking until power is lost to the transmitter since channel one and channel four (Capt + Co-pilot's radio) appear to contain a transmitted signal on the CVR. It is probable that the ATC signal at 0714:01 coincides with the final quarter second of CVR radio channels".

3.4.5.3 On the date i.e. 19th July, 1985, Mr. Paul Turner of NTSB also gave an additional report which is to the following effect :-

"During my observations of numerous cockpit voice recorders I have heard and observed a number of aircraft breakages due to various causes. In this case the explosive sound on the CAM channels occurs prior to any electrical disturbance observable on the selector panel signals. Electrical disturbances can generally be seen prior to audio signal when explosive sounds originate at any significant measureable distance from the microphone (15 feet) and in the area where there is significant electrical systems. It is my opinion that an explosive event occurred close to the cockpit. The CAM signal which follows the explosive event shows a very much higher noice level than cockpit ambient 85 db, indicating to me the cockpit area was penetrated and opened to the atmosphere. The selector panel signals show signatures similar to those of an aircraft breaking up and are apparantly caused by electrical systems disturbance (circuit breaker blowing, fuse switching etc.). The lack of Mayday call and apparent inadvertant signal from the cockpit crew incapacitation. The transmitter coming on due to breakup is phenomena observed previously.

This contains only my personal opinion and in no way should be considered a final determination of cause without corroborating evidence".

3.4.5.4 Copies of the tapes were also sent to some of the participants who wanted to carry out independent analysis.

3.4.5.5 With regard to DFDR the Court received reports from Dr. Caroll Roberts of NTSB and report dated 11th November of Mr. B. Caiger.

3.4.5.6 With regard to CVR the Court received reports from Mr. B. Caiger dated 11th November, 1985, report dated November, 1985 of Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K., report dated 31st August, 1985 of Mr. S.N. Seshadri of BARC, Bombay.

3.4.6 Court Observations

3.4.6.1 Digital Flight Data Recorder

The reports of Dr. Caroll Roberts and Mr. Caiger which also coincide with the report submitted by Mr. Satendra Singh disclose that the DFDR showed no evidence of abnormal values of any of the many parameters being monitored upto a point at which the recorded data signal became irregular for a fraction of a second and recording ceased. Both the DFDR and the CVR stopped at the same time.

3.4.6.2 The short period of irregular digital data that occupied only 0.27 inches of tape, most probably indicates that the recorder was subjected to a sharp angular acceleration in the left wing down sense about the aircraft longitudinal axis.

3.4.6.3 According to Mr. Caiger's report the possibility that the digital recorder was subjected to a sharp disturbance more rapid than violent motion of the aircraft lends some credence to the possibility of a detonatiaon of an explosive device in the aircraft. The other alternative, according to Mr. Caiger, which could have led to this was that the Flight Data Acquisition Unit in the main electronics bay .or its power supply were suddenly disturbed. As the Lockheed Quick Access Recorder was not recovered from the wreckage, this possibility could not be investigated further. A perusal of the DFDR print out, however, shows that whereas there was a speed limit of 290 knots (.81 Mach) of the aircraft due to carriage of the 5th pod engine, in actual fact the aircraft's speed during cruise varied from 287 to 296 knots. Mr. H.S. Khola asked the Boeing Airplane Company to examine the effect of aircraft cruising at a speed of 296 knots with a 5th pod engine installed on it. The Boeing company sent a reply, inter alia, stating as follows:

"The operating speed limit of Air India 747-237B, JT9D-7J with fifth engine pod was 290 knots indicated airspeed, with an altitude limit of 35,200 feet. Flight testing of this model airplane configuration was successfully accomplished to a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, with no adverse effects.

In the event that the operating speed placard was exceeded an increase in perceptible vibration levels would be felt. As the dive Mach number (0.92) is approached the buffet vibration would increase to level that could become objectional to the flight crew, but would not he bazardous".

3.4.6.4 It would thus be clear that if no adverse effects could have been noticed with a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, there was little likelihbood of the aircraft having been subjected to any adverse effect by reason of the speed varying from 287 to 296 knots while it was cruising at a height of about 31,000 feet.

3.4.6.5 Cockpit Voice Recorder

The Court received four reports of the CVR tape analysis. These reports were of Mr. B. Caiger, Mr. R.A. Davis, Mr. S.N. Seshadri and Mr. Paul C. Turner. Whereas the first three experts appeared and deposed in Court, Mr. Paul Turner did not come.

3.4.6.6. There were certain aspects of the report of Mr. Turner which required clarification. After the Court had failed to secure his presence, it sent a questionnaire to Mr. Turner for his answers thereto. It is indeed unfortunate that till now no reply has been received. It is in this background that the report dated 13th November, 1985 of Mr. Turner and the reports of other experts have to be judged and analysed.

3.4.6.7 Mr. B. Caiger's Report and Deposition

Mr. Caiger has said in his report that the Cockpit Area Microphone signal was studied in detail. According to him, in an aircraft, sound can be transmitted by multiplicity of paths. If an explosive device was located close to the microphone then the short wave from the disturbance would cause a sharp rise in pressure which was not noticed. From more remote location, however, structurally transmitted sounds could reach the microphone first and induce more complex signals. According to Mr. Caiger, at this time he did not have any evidence from occurrences of this nature that would permit any meaningful comparisons or conclusions.

3.4.6.8 Mr. Caiger obtained from the manufacturers details of Automatic Gain Control (AGC) on the cockpit area microphone. According to the information so provided it was indicated that the decrease in amplitude of the recorded noise over about 33 msec after the peak level was reached 40 msec from the start of the disturbance is most probably due to the AGC and that the actual envelope of the pressure levels at the microphone continued to increase until 90 msec from the start before establishing at about four times the recorded level until the 160 msec point when the recorded amplitude started to decrease rapidly. Mr. Caiger could not find any explanation for this marked reduction. Mr. Caiger further recorded that the large amplitude lower frequency signature, that immdediately followed this reduction, is similar to signatures observed by the manufacturer when there was an abrupt break in the line from the cockpit area microphone pre-amplifier output to the voice recorder. No similar signature was observed in tests on the crew audio channels when the appropriate lines to the recorder were similarly interrupted.

3.4.6.9 The observation of Mr. Caiger with regard to ATC tape was as follows :-

"The ATC recording that followed the cockpit area microphone sounds appears at first to contain a series of short intermittant sounds. Closer study reveals that the background noise only returns to its steady level for about 160 msec immediately after the first low level noise and again for about 85 msec just over halfway through the 5.4 sec duration of the recordings. At the end of all routine radio transmissions, a damped sine wave transmitter keying signature is observed with a frequency in the region of 450 Hz. In the accident recordings, only two of these are observed".

"Listening to the sounds, it also appears that a human cry occurs near the end of the recordings. Spectral analysis of these sounds and comparison with voice limitations reveals that the accident sounds do not contain all the pitch harmonic frequencies normally associated with such voice sounds. The origin of all the sounds has not been identified."

3.4.6.10 From the aforesaid investigation Mr. Caiger concluded that :-

"From the voice and data recorders, Air India Flight 182 was proceeding normally enroute from Montreal to London, England at an altitude of 31,000 feet and a computed airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound the cause of which has not yet been identified. The sound continued for about 0.35 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder".

"The initial waveform of the cockpit area microphone signal is not consistant with the sharp pressure rise expected with detonation of an explosive device close to the flight deck but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, we cannot at this time exclude the possibility that it originated from such a device elsewhere in the aircraft".

"Within 1 to 2 seconds of the first detection of the loud sound on the cockpit area microphone, a series of unidentified noises were recorded on the Shannon ATC tape. These extended over a period of 5.4 seconds and are assumed to have origniated from VT-EFO. They gave the impression of abnormal conditions on the flight deck".

3.4.6.11 In his evidence in court, Mr. Caiger explained about Automatic Gain Control. He stated that the CAM channel of the CVR had an Automatic Gain Gontrol in a pre-amplifier that is installed close to the microphone. This AGC is designed to prevent excessively loud signals from saturating the microphone and the associated electronics. He further stated that from the tests conducted by the manufacturers it could be concluded that most likely at 45 msec. point the AGC came into effect which gradually reduced the signal over the next 33 msec. before letting it stabilise at a roughly constant value. This figure of 33 msec. was taken by Mr. Caiger not by carrying out any experiment himself but it was provided to him by the manufacturers. He also stated that there was no positive indication of structural failure

being evident from the flight
recorders. Mr. Caiger was asked to explain as to what was the reason for loud sound to which reference had been made in his report. In answer to the said question from the Court he said that there could be a number of reasons. The detonation of an explosive device not close to the microphone was one possibility, the occurrence of some type of structural failure was another possibility. He was further of the opinion that at the present stage of development in structural acoustics, he did not think it was possible to come up with any reasonable estimate of the location of either explosive device or some type of possible structural failure. When asked for his opinion about the sequence of events which he could determine by looking at the sound spectrum, he said as follows:

"From the study that we have made which have of course been augmented by studies done by several other groups it would appear that there was a very sharp bang that was detected by the CAM. Approximately one-third of a second after this happened the line from the CAM to the CVR was disconnected but intermitant power supply was still being sent to the voice recorder for approximately one and a half seconds. During this 1-1/2 seconds period sounds were being transmitted from the 'Kanishka' aircraft that tend to suggest that the aircraft was in some distress. Though it is difficult to be specific about the basis on which we assesss the state of the aircraft, this signal ceased after a period of 5.4 seconds and we have no more audio information concerning the aircraft from that point onwards."

3.4.6.12 Mr. R.A. Davis's Report and Deposition

Mr. R.A. Davis in his report on the analysis of CVR has stated that he did not have with him a faithful copy of the original CVR tape. The tape supplied to his contained signals which warranted investigation but any measurement could be hampered by a decreased signal to noise ratio due to the copying process. Mr.

Davis however analysed the tape which admittedly according to him was not of good quality. Mr. Davis in his report states that he carried out a spectrum analysis of the different channels of the CVR. The spectra did contain the sound of a bang. He however, could not find any significant low frequency content in the spectrum which according to him, would have been expected if the sound was of a high explosive detonation.

3.4.6.13 While carrying out detailed study of the tape he also looked out for any evidence of various audio warning signals which may have been buried in the noise. One such audio warning which could have been detected was that of pressurisation warning. Mr. Davis stated that this warning possessed a very defined frequency spectrum which was not present in the signal of the CVR of Kanishka. With regard to this he, however, stated that absence of this signal was not surprising as any decompression would take a finite time before reaching the warning level. Mr. Davis further observed that the presence of warnings due to attititude display disagreement, excessive speed and fire were investigated but with negative results.

3.4.6.14 During the course of investigations, Mr. Davis had compared Kanishka CVR recording with the recordings of an explosive decompression on a DC-10, a bomb in the freight hold of a B-737 and a gun shot on the flight deck of a B-737. According to Mr. Davis the spectrum of VCR tape of B-737 showed a much low frequency content with very little content at upper frequencies. This bomb, in the forward baggage hold of B-737, had exploded while the aircraft was at a low level and therefore the CVR did not have the sound accompanied with that of depressurization. That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a high explosive device, then the spectra should have shown large low frequency content, but this was absent. He further opined that, even if there was a possibility of a bomb remote from the flight deck and of a low power, even then the characteristics of a bomb would still be apparent in the time record. He also analysed the spectrum of the sound of the hand gun shot on a B-737 flight deck and according to him the said signal was sharp edged and did not compare with that of Kanishka's signal.

3.4.6.15 Mr. Davis also analysed the sounds recorded on the ATC tape. He concluded that the sounds emanated from Air India's Kanishka aircraft. According to him the transmission from the ATC is "chopped" until at approximately 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound was similar to that heard in other accidents where there had been a rapid increase in airspeed.

In the noise which continues until the end of the transmission is heard a crying sound. This was originally thought to be a human cry. He, however, noted that a human cry would contain more harmonics than was noticed in this case. It was also reported by Mr. Davis that knocking sounds which were heard during the transmission were initially thought to be due to hand-held microphone vibration. This was discounted because of the frequency of the sounds. He noticed that almost identical sounds were heard on the DC-10 CVR after the decompression had occured and the source of that sound had not been identified. On the DC-10 the pressurization audio warning commenced 2.2 seconds after the decompression. Analysing the ATC tape Mr. Davis observed that no such warning was identified during the open microphone transmission.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-

"It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182.

"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.

"Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. Such a situation would be most unusual, if not unique, in that we have never failed to detect sounds of structural failure, decompression, explosives etc., on any accident CVR, even though the event occurred at the rear of the aircraft. If such a device was used on AI 182 it is considered that it would have to be a very small device in order not to be detected (unlikely in itself). Such a device would be unlikely to cause the sudden total destruction which occurred in this instance. It is considered that a device of sufficient power to produce this effect could not fail to be detected on the CVR. The B-747 explosions referred to earlier, blew holes several feet wide in the structure but the crew were still able to control and operate the aircraft.

"It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

3.4.6.17 In reply to a question it was stated by Mr. Davis, when he was examined in Court, that it was true that there was no evidence that rapid decompression was caused by any structural failure. In an answer to another question, as to whether in his opinion there is a low frequency content present in every situation whereever there has been a high explosive device detonated, Mr. Davis answered in the affirmative, he however added that "But we do not have sufficient numbers to indicate that that would always be the case". Mr. Davis, however, agreed that DC-10 aircraft was quite dissimilar to Boeing 747, and the sound of an explosive decompression in the aft cargo hold of a DC-10 would not be identical to an explosive decompression in the aft cargo hold of a Boeing 747.

3.4.6.18 Mr. Davis further agreed that he was looking for low frequencies in Kanishka tape, but he did not know what type of low frequencies should be looked out for because there was no available data anywhere in the world for the sound of a bomb explosion in a Boeing 747. Mr. Davis was however emphatic in saying that he could not measure the distance of the origin of the sound from the cockpit area mike. In his report, and also in the earlier part of the examination, Mr. Davis had referred to the absence of low frequency component in the spectrum and had sought to conclude that such absence showed that there was no detonation of a high explosive device. In an answer to the question put by the Court however, Mr. Davis appeared to have altered his stand. This is evident from the following deposition of Mr. Davis :-

"Court Ques Am I to understand that there must necessarily be a low frequency whenever an explosion occurs?

Ans. No. What we thought was there would be. There was only one sample of explosion in B-737. But we would need more accidents of that nature to able to say that yes we must have a low frequency component.

Court Ques: Am I to understand that the absence of a low frequency component would not therefore necessarily mean that the sound was not that of an explosion?

Ans. Because of the absence of a low frequency component we would not be able to say positively that there was an explosion or it was not explosion."

Court Ques : Would the frequency of a particular type of sound change depending upon the environment in which that sound occurs?

Ans Yes.

Court Ques If an event results in low frequency sounds in one type of environment, can it mean that the same event can result

in a high frequency sound in a different environment?
Ans. That must be possible".
3.4.6.19 Mr. S.N. Seshadri's Report and Deposition
A detailed analysis of the CVR and the ATC tapes was also carried out by Mr. S.N. Seshadri at BARC. For the purposes of comparison, CVR tapes of Iranian Air Force Boeing 747 accident as well as that of Indian Airlines Boeing 737 accident were also analysed at BARC.
3.4.6.20 The original CVR tape of Kanishka was played on a 4 channel tape recorder modified to run at 1-7/8" per second. The output of this tape recorder was copied faithfully on an eight channel HP 3968A instrumentation tape recorder. Channels 1 to 4 were used for recording the CVR data and channels 5 for recording a time marker. For further processing and signal analysis this copy of the original tape was used.
3.4.6.21 The observations of the data so recorded, as contained in the said report inter-alia are as follows :
"Repeated and careful listening to all the four channels revealed the presence of explosive sounds on all these channels occuring nearly
at the end at the same time. Speech information is present on channels 3 and 4 during the last few minutes. Channel 1 does not contain any speech data during this period. Channel 2 contains indecipherable speech data about 20 to 25 seconds before the explosive sound".
"It was decided to analyse in detail the tape data during the final few seconds within which significant audio and electrical changes were observed to be present. Data from all the four channels were displayed on a Tektronix 2-channel storage oscilloscope Model 466 for initial observations. Based on this study the relevant portion of the tape was selected for more intensive snalysis. Simultanious ultraviolet recording of all the four channels on this portion of the tape was next carried out".

The following observations are relevant.

1. Channel 3, which corresponds to the area mike shows the first indication of a rising audio signal. This instant is termed, for conveniece, as zero time reference. The signal level rises from the ambient level in the cockpit by about 18.5 db in approximately 45 milliseconds. The signal then starts falling and stablises at a level about 10 db higher than the ambient level before zero time. The signal continues to remain at this level for about 275 milliseconds. The total duration of the signal from zero reference is thus about 360 milliseconds.

2. Channels 1 and 2, which are the radio channels of the pilot and the flight engineer respectively, show start of electrical disturbance signals 45 milliseconds from zero time at which the audio signal on channel 3 is at its maximum. These signals, which have do minant frequencies in the range of 70 to 210 Hz, persist for about 100 milliseconds on both channels. Subsequent to this, channel 1, shows an audio burst lasting about 200 milliseconds. Channel 2 shows a delayed audio burst lasting 25 milliseconds, 220 milliseconds from zero time, or in other words, 175 milliseconds after the peak signal from channel 3. A low amplitude tail appears after this burst and lasts around 40 milliseconds. Channel 4 which is the co-pilot's radio channel shows an electrical disturbance commencing at 85 milliseconds from zero time and lasting around 60 milliseconds. The frequency distribution during this period is similar to those on channels 1 and 2. This is followed
by an audio burst of 230 milliseconds duration. The frequency spectra of the audio portions of channels 1,2 and 4 are reasonably similar."

3.4.6.22 "Correlation of Events of ATC Shannon Tape and Channel 4 of CVR tape :

"It was observed that during the last few minutes before the stoppage of the CVR, information recorded on the ATC tape and channel 4 of the CVR tape are identical. However, the ATC tape contains a series of audio bursts approximately corresponding to the instant at which a single explosive sound is recorded on channel 4. Thus a doubt arose whether the series of audio bursts recorded on the ATC tape had originated from channel 4 of Kanishka CVR since these are not recorded on the CVR tape. In order to obtain an answer to this it was necessary to check with very good accuracy the simultaneity of the explosive sound on channel 4 and the series of audio bursts on the ATC. The procedure followed for the same is given below.

"The ATC Shannon tape and the CVR tape were run on two independent tape recorders. It was found that the speeds of the two tapes were mismatched. In order to match speeds the earliest speech signal on both the tapes.

"Seven seventy that checks maintain three five zero" was used as the reference point. The speech signals which mostly contain the conversation between the co-pilot and ATC Shannon lasts for about 146 seconds. Channel four was kept ready for starting exactly at the reference point. The ATC was next played starting well before the reference point. The tape recorder playing channel 4 was started manually exactly at the time when the reference point on the ATC was audible. By noting the time of ending of the conversation on both the tapes which corresponds to

"Right Sir squaking two zero zero five one eight two" the speed of the recorder playing the ATC tape was corrected by pitch control to approach the speed of CVR tape. The process was repeated a number of times till audibly the speeds were matched. The two tapes were next synchronously played and both the channels were simultaneously recorded on a third recorder to a point well after the explosive sound on channel 4. This tape was used for all further analysis.

"The first significant observation was that the explosive sound on channel 4 coincided with the beginning of the series of audio bursts on the ATC tape as heard by the ear. It was thus clear that both the recordings correspond to those generated by Kanishka during its last moments.

"To confirm this preliminary conclusion which was judged solely by the ear, accurate instrumented tests were carried out. The two channels were simultaneously recorded on an ultraviolet recorder at the four speeds, 0.1"/sec, 1"/sec, 10"/sec and 160"/sec for study of synchronism as well as frequency details. It was noticed that the two waveforms were not exactly suynchronised though by the ear they appeared to be so. In order to find out exactly the difference in synchronisation the following tests were done:

UV recordings at 16" per second were taken at three representative points relating to the communication of ATC with Kanishka. These points correspond to speech portions at 070838 "Five eh Squawking and eh Air India", at 070958 "Right Sir Squawking" and near the blast on channel 4. It was found that the ATC was running slightly faster. At the first point the ATC was leading by 90 milliseconds, and at the second point by 130 milliseconds. The time interval between these points is about 80 sec. By extrapolating this lead to the time of the blast which occurs about 243 sec. from the second point, it is clear that the lead of the ATC with respect to channel 4 at this point will be given by 130 + (130-90) (243/80) which is approximately 250 milliseconds. This error is very small."

"Thus one can conclude that the sounds recorded on the ATC Shannon tape are those which emanated from Kanishka during its last seconds."

3.4.6.23 "Frequency Analysis:

Mr. Seshadri also carried out frequency analysis of the CVR and the ATC tapes. His opinion with regard to the same was the follows:

"Significant audio and electrical disturbances were observed in

the final few seconds of the CVR tape. It was therefore decided to analyse all the four channels for their frequency contents at the various places
in this pertinent region. For Fourier analysis of each signal, digitized time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

3.4.6.24 "The frequency analysis of electrical disturbances in channels 1,2 and 4 indicate presence of low frequencies in the region of 20 Hz to 600 Hz. The dominant frequencies are in the range of 70 Hz to 210 Hz.

3.4.6.25 "The frequency spectrum of the background noise in channel 3 just before the explosive sound has a broad band spectrum with some dominant frequencies in the region of 650 Hz to 1550 Hz. At the bang, many additional frequencies appear. The frequency spectrum of bang on channel 3 indicates an increase in the bandwidth.

3.4.6.26 "The frequency spectrum of channel 1 at the bang position indicates a fairly broad spectrum with dominant frequencies in the range of 150 Hz to 1 KHz. Channel 2 displays a frequency spectrum at the bang position in which low frequencies are dominant. It has a significant frequency range between 20 Hz to about 1 KHz. The frequency spectrum of channel 4 at the bang is wide-band with a broad peak in the range of 150 Hz to 800 Hz.

3.4.6.27 "At the beginning of the crackling sound, the frequency spectrum shows narrow band peaks around 1.6 KHz. About 90 and 300 milliseconds later, the spectrum changes with additional peaks appearing around 400 Hz, 600 Hz and 1150 Hz. Frequency analysis was also carried out at 600, 800 and 1000 milliseconds before the start of the crackling sound."

3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal

time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

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3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal
peaks to its maximum of 18.5 db above ambient level in about 45 milliseconds. A loud audible blast is heard when this channel is played at this point. An analysis of the frequency spectra before this loud blast and during the blast shows a definite change in the frequency composition. From all the above results it can be concluded that an explosion occurred in the aircraft. The exact position in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the Cockpit judging from the rise time of 45 milliseconds.

3.4.6.29 "Explosive sounds on all the four radio channels preceded by electrical disturbance reinforce the evidence provided by channel 3.

3.4.6.30 The synchronised recording and detailed analysis of the ATC and channel 4 confirm that the sounds recorded in the ATC Shannon tape are undoubtedly attributable to the transmissions from AI 182 Kanishka during its last moments. The sounds indicate possible breaking up of the aircraft in mid air and the air blast which follows a decompression. A very detailed UV recording does not indicate the presence of a second explosion."

3.4.6.31 "Copies of CVR tapes of well understood air crashes pertaining to an Indian Airlines Boeing 737 in 1979 and Iranian Air Force Boeing 747 in 1976 were analysed for possible reference in connection with the analysis of the CVR tape of Kanishka.

3.4.6.32 "A definite explosion near the Cockpit was the cause of the crash of the Indian Airlines Boeing 737. An explosive sound recorded on the Cockpit Area Mike shows a rise time of about 8 milliseconds which corresponds to a distance of about 8 feet. This indicates that the rise time is a measure of the distance from the Cockpit Area Mike at which an explosion has occurred.

3.4.6.33 "The Iranian Air Force Boeing 747 broke up in mid air. Analysis of the CVR tape clearly indicates that the frequency spectra of the electrical disturbances are similar to those obtained for Kanishka. Thus the series of audio bursts recorded on the ATC Shannon tape have been most probably generated by the break-up of kanishka in midair.

3.4.6.34 Mr. Seshadri was also examined in Court on 27th January, 1986. In his deposition he very succintly explained some aspects of the work which was done by him. He also dealt with the aspect of AGC to which reference has been made by Mr. R.A. Davis and Mr. Paul Turner in their reports. The relevant part of the testimony in this connection is as follows :-

"We wanted to make sure that the CVR recording and the ATC corresponded to the same aircraft Kanishka. When we played the tapes for the first time we found that there was a difference of about 1 second. Though this figure may be tolerable because of the accuracy of the tape speeds, we wanted to investigate further to make really sure that the ATC corresponded to Kanishka. For this purpose we had simultaneously "recorded channel 4 of the CVR and the ATC on a single tape on 2 channels after synchronising the common speech signals to the best of our ability by the ear. We started with the first speech which was available on both the tapes, namely, "770 that checks maintain 350". This was a conversation with the TWA aircraft which is available on both channel 4 and the ATC. The last sound which is recorded common to CVR and ATC is the speech of the co-pilot who says "right Sir, squaking 2005 182". After this recording though by the ear the explosive sounds on the ATC. as well as the CVR seemed to match, we wanted to check it in more detail. For this purpose we had detailed UV recordings of different portions of the synchronised tapes pertaining to the conversation between ATC and Kanishka. This was done and we noticed that the ATC was running slightly fast. We had about 80 seconds reference time of conservation from Air India Boeing Kanishka and the ATC for reference and we had to extrapolate the information in this section for another 243 seconds at which time the explosive sound occurs. During the beginning of this 80 seconds reference period, we find that the ATC was leading by 90 milli-seconds and at the end of 80 seconds the lead of ATC was 130 milli-seconds. Thus, in 80 seconds, the ATC had gained 40 milliseconds.

"This extrapolated to 243 seconds and gives a figure of 250milliseconds. This is how we arrived at the conclusion that both are synchronised within 250 milliseconds. I would like to bring to the notice of the Court that we have taken great pains to confirm this information by reapeating the tests a number of times. We did not take the 400 cycle signal available on the tape as the time reference. We took for reference the bunching of signals produced by the conversation and the gaps in between the convervation which are very clear on both tapes. Hence we are sure that our results are right. The UV recording which was made has been filed along with my report.

"The main channel which was examined was the CAM channel. This was agreed to by all the experts who were present during the first analysis of the tape at the BARC between 16th and 20th July, 1985. One of the most noticeable things is that channel 3 which corresponds to cockpit area shows the first sign of disturbance. Let us say for reference that the disturbance starts at 0 time. In about 45 milliseconds the signal rises to a peak value which is approximately 18.5 db above the ambient level before the commencement of the signal. After this point the signal decays roughly exponentially in about 40 milliseconds to be almost a steady level which is 10 db above the ambient level before the explosive sound. From this we could draw conclusions. Assuming that an explosion occurred on the aircraft. The explosion produces a shock wave with a steep wave front which travels in air as well as through the aluminium body and the speed of travel will depend upon the distance of the explosive from the point of observation. It will depend on the cube root of the explosive and it will also depend on the ratio of the distance to the cube root of the weight of the explosive. The shock wave is very fast. It can travel at about 10 times the speed of sound. Also when the shock wave hits the aluminium body of the aircraft the vibrating panels which are defined by the stringers and longerons transmit the sound to the CAM location. Because the speed of sound in aluminium is about 19,200 feet per second which is 16 to 18 times that of the speed of sound in air and the shock velocity is also about 10 to 12 times. This signal will be received

"first by the CAM. Nevertheless the shock wave gets attenuated diffracted and refracted during its travels to the cockpit. Hence the signal received at the cockpit will be an attenuated signal and this small signal we have taken as instantaneous with the time of explosion. As the time passes the sound waves travel from the explosion site reinforcing the sound in the cockpit area thereby there is a rise time. Then when all the complete sound information is transmitted we get the peak of the signal and thus the rise time corresponds to the delay between the first rise in signal to the peak as compared to the speed of sound. One may ask the question what is the speed of sound because the aircraft has an explosion and is exposed to the outside environment but since the de-pressurization of the aircraft through the explosive fracture will take a minimum of a few seconds, we can reasonably assume that the pressure of the air in the aircraft corresponds to about 5000 to 6000 feet of altitude. At this presure and temperature, the sound velocity is roughly 1000 feet per second and from the 45 milliseconds delay we concluded that the explosion should have occurred about 40 to 50 feet from the cockpit. A question may be asked that the decay of the signal might be due to the AGC of the CVR coming into action. Mr. Turner, who is an acknowledged expert in the field of CVR has reported that Messrs Fairchild tested the cockpit voice recorders with a 10 db rise and fall of signals at the threshold of AGC and they got a result indicating a decay time of 33 milliseconds. The fall in the waveform of Channel 3 is about 40 milliseconds and is well near 33 milliseconds, so an argument may be advanced that the sound continued to remain steady and the fall in the signal level was effected by the AGC. In order to confirm this we tested the Cockpit Voice Recorder which was identical to the one which was on Kanishka by applying 1 KHz waveform of rectuangular modulation. To our surprise, we found that the decay time roughly was 130 milliseconds as compared to 33 milliseconds given by Mr. Turner. We repeated the tests with an initial background and without any background at all. We further tested with ramp waveforms, in other words, "slowly rising and falling waveforms of triangular shape with modulations of 1000 cycle carrier. This also confirms our finding. In order to clarify how the tests were performed so that others can judge whether it was a realistic test, I will explain the procedure. The modulated waveform was produced by a signal generator. This was fed to an amplifier. The amplifier output was fed to a loudspeaker. The output of the amplifier was checked to ensure that there was no distortion. Thus the signal going into the loudspeaker is the same modulated signal which has been applied at the input of the amplifier. This sound coming from the loudspeaker was recorded on the CVR through the CAM in the laboratory. This is how the test was performed. We were given a CVR tape by the Department of Civil Aviation purported to be that of an explosion which occurred on a Boeing 737 aircraft which crash- landed at

Madras. We did the CVR analysis of this aircraft. We first recorded the output of the CVR of Indian Airlines CAM channel on a UV recorder. We found the rise time to be very small. This was of the order of a few milliseconds, about 8 milliseconds or so. We have been told that the explosion occurred just by the side of the front toilet i.e. just behind the cockpit. This to some extent confirms that the rise time is related to the distance of the explosion from the detecting CAM. The next thing that we did was the frequency analysis of this waveform. Mr. Davis has indicated in his report that if an explosion occurs on board the aircraft there should be low frequencies present. When we analysed the frequencies of the Kaniskha aircraft Channel 3, we did not find very low frequencies in case of an explosion abroad the aircraft. When we analysed the Boeing 737 tape we did not find any low frequencies in the signals. The report of Mr. Davis also provides the frequency analysis of a pistol shot which has been fired in the cockpit of the aeroplane. This also shows no low frequency components. So our conclusion, that it is not essential for low frequencies to be present in case of an explosion abroad an aircraft, was confirmed. I will go a step further to say that the frequency received by an area mike which responds to an explosive action abroad the aircraft will contain frequencies of the structure of the defracted " and dragging shock wave, the resonant frequencies of the aluminium panels defined by the longerons and the stiffening channel members and also some frequencies which may be of objects that the shock wave encounters in its path. It is, therefore, impossible to calculate the frequency spectrum that one would expect in the cockpit due to an explosion taking place in the aircraft".

3.4.6.35 In answer to a question Mr. Seshadri categorically stated that the word "explosion" in his report meant "a bomb, a very fast device".

3.4.6.36 Mr. Paul C. Turner's Report

Lastly, a reference may be made to the report dated 13th November, 1985 of Mr. Paul C. Turner. The evaluation of Mr. Turner of the analysis done by him of the CVR and the ATC tapes, as contained in the said report, was as follows:-

"With the foregoing as background, we can make several observations. The CVR record on the CAM channel, captain's channel and flight engineer's channel show that they were all affected at about the same time; the copilot's perhaps 20 milliseconds later. Major disturbances which are recognized as electrical system disturbances can be seen to begin about 60 milliseconds after the initial disturbance. This approximates the time it would take for the electrical system protective circuitry to become active.

3.4.6.37 "A steep wave front which would be indicative of a shock wave cannot be seen on the CAM channel sound spectrum; however, the spectrum analaysis shows that impulse type sounds occurred at the beginning of the event recorded on the CAM channel of the CVR. Since audio signals propagate through aluminium approximately 16 times the speed of sound in air, the CAM channel would probably have been affected by structurally transmitted noise before being affected by airborne noise. The geometry of the aircraft was such that structure borne disturbances could be recorded before the airborne transmitted information appeared at the cockpit microphone and an air transmitted shock wave or steep wave front may not be evident on the CVR.

3.4.6.38 The captain's and copilot's selector box channels recorded signals which appeared to be electrically inducted and similar to those seen on the Huete Boeing 747 breakups. These are then followed by a signal resembling audio frequency noises similar to an open microphone in a noisy environment or the opening of a receiver squelch. Both effects have been seen during aircraft breakups. The audio noise on the captain's and copilot's channels appears to have come from a different source. The flight engineer's channel does not contain audio noise. A spectral diagram of the copilot's and captain's channel noises just show broad band noise across the spectrum. The signal frequncies extend beyond the frequency range of a microphone both on the high and the low end. It does not fit the normal microphone envelope. Spectral diagrams of the event on the CAM channel show the normal microphone preamplifier envelope summed with wide band signal of unspecified origin. Since the signal quits abruptly with a doublet, it indicates that the interference was added upstream of the CVR and was not just reflected in the CVR power supply.

3.4.6.39 "The CVR record shows a signal stayed on for about 200 milliseconds when it appears that the power may have been interrupted to both the radio channel and the CAM channel of the CVR at the same time. It further appears that the signals to the CVR were probably interrupted at 360 milliseconds from the initial disturbance possibly by severance of the signal wires. It further appears from the action of the erase head and record that the main electrical system began to fail at this point and the CVR bus voltage value dropped to a value below 70 volts but not below 20 volts. This fluctuating voltage continued intermittently for a minimum of 1-1/4 seconds at which time the voltage evidently dropped to some value below 20 volts and the recorder ceased to operate. The power for operation of the No. 1 VHF transmitter can be explained by the operation of the standby bus and battery and connection of the No. 1 VHF radio to this standby bus.

3.4.6.40 "The necking down of the signal to a low value shows that no signal was coming to the CVR from the CAM preamplifier. The lack of a signal on the radio channels, which do not need to be erased before being recorded, further suggest that the wires were severed or "that the transmission to Cork began after what appeared to be the loss of the primary electrical system approximately 1-1/2 seconds following the event. Standby power would have become available upon loss of the primary power, the number one VHF would have become available, and CVR would have ceased to operate.

3.4.6.41 "The action of the erase circuitry in the CVR suggests that the fluctuating voltage seen was coming from the main electrical system bus. Anything else causing this fluctuating voltage down stream of the CVR circuit breaker would probably blow it.

3.4.6.42 "The signal received in Ireland indicated that a radio, most probably this aircraft's No. 1 VHF transmitter, stayed operational for about 5.4 seconds following the event at which time the entire aircraft electrical system ceased to function. This assumes that the No. 1 transmitter ceased to operate due to standby bus failure.

3.4.6.43 "In the conclusion, it appears that a catastrophic event occurred on Kanishka. It was reflected in all channels of the CVR and the CVR power supply at the same time. The main electrical bus began to fail within 0.35 second and the standby bus survived for only 6 seconds more at which time the aircraft's electrical system ceased to function. It appears that the event occurred in a manner to affect the cockpit area microphone operation severely and to force operation of the automatic gain control on the CVR. This loud noise continued for the life of the aircraft's main electrical system as reflected in the CVR.

3.4.6.44 "The mechanism of how the ATC transmission was made from Kanishka to Cork is unclear. The sound was not recorded on the CVR, indepentent studies by Canadian and British investigators have the Cork ATC call originating approximately 1-1/2 seconds following the event on the CVR. This is about the time that standby power would have become available to the No. 1 VHF.

3.4.6.45 "This report should be viewed as an accident investigation tool only and used in conjunction with other evidence gathered during the investigation.

3.4.6.46 "The United States Noard/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

3.4.6.47 It is pertinent to note that according to Mr. Turner there was "catastrophic event" which had occurrred on Kanishka. He has, however, not elucidated as to what this event was.

3.4.6.48 After the receipt of the report, the Court requested the NTSB that Mr. Turner should come and depose. It is unfortunate that permission was not granted to him. Faced with this situation and as it was thought necessary that some clarification was called for, the Court sent a telex to Mr. Turner whereby he was asked to give replies to the queries contained therein. He was requested that the reply be sent by 27th January 1986. A copy of the telex was also forwarded to the American Embassy at New Delhi for sending the same to NTSB by way of confirmation. Previously all communications addressed to NTSB were being routed through American Embassy. No reply has been received by the Court till this day either from NTSB or from Mr. Paul Turner. According to paragraph 5.14 of Annex 13 the State is required, on request from the State conducting the investigation of an accident, to provide to that State with all the relevant information available to it. It was, therefore, obligatory on the NTSB to have seen that the information sought for by the Court by way of answers to the queries was supplied.

3.4.6.49 Court Evaluation

From the reports of all the experts and the testimonies of M/s Caiger, Davis and Seshadri it is clear, and it is agreed to by all of them, that there was a breakup of the aircraft in mid-air. The experts also agreed that the sounds recorded on the ATC Shannon

tape at 0714:01 Z emanated from the Kanishka aircraft.
3.4.6.50 Mr. Caiger has not said either in the report or in his statement as to what was the cause of the bang. Mr. Davis, on the other hand, is categorical in stating in his report that there was explosive decompression (meaning rapid decompression) on the aircraft. He has, however,
stated in the report that there is no evidence of an explosive device. The main reason for his coming to this conclusion is that he had not been able to find low frequencies in the spectra of the CVR of Kanishka. Mr. Seshadri, on the other hand is equally vehement in concluding that an explosive device had detonated in the front cargo hold of Kanishka.
3.4.6.51 It may be that the frequency spectrum of Kanishka CVR did not contain low frequencies but, as has been admitted by Mr. Davis himself in answer to a Court question, it is not necessary that in the case of every detonation there must necessarily be low frequencies in the spectrum. Frequency spectra of 'Kanishka CVR before 'bang' and at the 'bang' position are shown in Figs. 2 & 3, indicating presence of additional high frequncies at the bang. Indeed in the case of Indian Airlines Boeing 737, which admittedly was a case where there was an explosion of a device within about 8 feet of the CAM, the frequency analysis showed absence of low frequencies. Frequency spectrum of Indian Airlines Boeing 737 CVR is shown at Fig. 4. Merely, because therefore, there were no low frequencies present would not mean that there was no detonating device on board the Kanishka. The CVR of Indian Airlines Boeing 737 has not been analysed either by Mr. Caiger or Mr. Davis. The analysis was, however, conducted by Mr. Seshadri and as is evident from his report, there were marked similarities between the spectra of Indian Airlines 737 and Air India's Kanishka CVR. One of the important reasons for coming to this conclusion, which has been indicated by Mr. Seshadri, is the rise time of the bang signal.

From the analysis of the Indian Airlines Boeing 737 tape it was observed that it had taken 8 milliseconds for the peak to be reached. It was also seen that the explosive device was approximately 8 feet away from the cockpit area mike. Keeping this in view Mr. Seshadri observed that in the case of Kanishka the peak of the bang signal was reached in about 40 milliseconds. He, therefore, concluded that the origin of the bang sound was about 40 feet away from the cockpit area mike.

3.4.6.52 It would be pertinent to note that even according to the report of Mr. Davis the rise time in the case of Kanishka, which has been given for the peak is about 40 milliseconds. He, however, does not attach much importance to this because according to him after about 40 ms automatic gain control would become effective.

3.4.6.53 Mr. Davis has no personal experience of the time which it would take for the Automatic Gain Control to take effect. He has got the figures from the manufacturer. Mr. Davis admitted that the time which it will take for the AGC to be effective is not indicated in any published document of the manufacturer.

3.4.6.54 Mr. Seshadri, however, personally carried out the experiments on a Boeing 747 by using an instrument similar to what was on board Kanishka. From the testimony of Mr. Seshadri it is apparent that the results which he got were different. As per his testimony, for the AGC to be effective it will take 130 ms. If this be so then it may be possible to conclude that in the case of Kanishka the peak was reached in 40 ms. and thereafter the signal decayed and the signal was in no way effected by the AGC.

3.4.6.55 A reference may also be made, at this stage, the frequency spectrum of the sound of the hand gun which was fired on a boeing 737 flight deck. Frequency spectrum prepared by Mr. R.A. Davis is shown at Fig. 5. He has stated that the rise time for reaching the peak is almost instantaneous. Same is the case with regard to the frequency spectrum prepared by him of a bomb in a B-737 aircraft where the bomb had been placed in the freight hold which is shown in Fig. 6. A perusal of that spectrum also shows that the peak was reached in approximately 5 ms. The forward freight hold compartment of Boeing 737 is much more than five feet away from the cockpit area mike. If the theory of Mr. Seshadri was to be applied then as per the frequency analysis of this Boeing 737 bomb, the distance from the area mike could not have been more than 5 ft. It is, however, known, as per the report of Davis, that the bomb was actually in the freight hold which would mean not nearer than about 25 feet.

3.4.6.56 From what has been stated in the various reports, as well as in the testimony of the 3 experts who apperared in the Court, the only safe conclusion which can be drawn is that possibly enough study has not been done, due to lack of adequate data, which can lead one to the conclusion as to the exact nature of the sound and the distance from which it originated.

3.4.6.57 The fact that a bang was heard is evident to the ear when the CVR as well as the ATC tapes are played. The bang could have been caused by a rapid decompression but it could also have been caused by an explsoive device. One fact which has, however, to be noticed is that the sound from the explosion must necessarily emanate a few milliseconds or seconds earlier than the sound of rapid decompression because the explosion must necessarily occur before a hole is made, which results in decompression. In the event of there being an explosive detonation then the sound from there must reach the area mike first before the sound of decompression is received by it. The sound may travel either through the air or through the structure of the aircraft, but if there is no explosion of a device, but there is nevertheless an explosive decompression for some other reason, then it is that sound which will reach the area mike. To my mind it will be difficult to say, merely by looking at the spectra of the sound, that the bang recorded on the CVR tape was from an explosive device.

3.4.6.58 There are various hypothesis and theories which the experts have to investigate before any acceptable conclusions are arrived at. It so happens that in the present case we have the opinions of four experts, but they do not agree with one another on some material aspects. Two of the experts, namely, Mr. Caiger and Mr. Davis are categorical in saying that it is not possible to measure the distance of the origin of the sound on the cockpit area mike, whereas Mr. Seshadri has come to a different conclusion. Mr. Paul Turner in his report dated 13th November, 1985 in silent on this aspect, though in his earlier report dated 19th July, 1985 he had categorically said that there was an explosive device close to the cockpit.

3.4.6.59 With regard to the nature of the sound also we have 3 different opinions. Mr. Caiger is unable to give the nature of the sound, Mr. Davis says it is rapid decompression while Mr. Seshadri says it is a sound of an explosive device followed by decompression.

3.4.6.60 In the absence of any other technical literature on the subject, it is not possible for this Court to come to the conclusion as to which of the Experts is right. The only conclusion which can, however,
be arrived at is that the aircraft had broken in midair and that there has been a rapid decompression in the aircraft. Just as it is not possible to say that the spectrum discloses that the bang is due to an explosive device similarly, and as has also been admitted by Mr. Caiger and Mr. Davis, it is not possible to say that the bang is due to break up of a structure.

3.4.6.61 The bang could have been due to either of the aforesaid two causes i.e. a bomb explosion or the sound emanating due to rapid decompression. The advantage of carrying out the said analysis is that a number of possible causes of the accident are eliminated. On the other hand, if the analysis is viewed in conjunction with other evidence on the record it is further possible to determine the exact nature or cause of the bang. In the present case the bang, as already noticed, could have been due to the sound originating from the detonation of a device or by reason of rapid decompression. Other evidence on the record, however, clearly indicates that the accident occurred due to a bomb having exploded in the forward cargo hold of Kanishka. The spectra analysis and the conclusions of Mr. S.N. Seshadri are corroborated by other evidence.

TESTS AND RESEARCH

3.5.1 During the course of investigation a number of groups were formed to study and analyse evidence and data which was available. Materials like CVR, ATC and DFDR tapes were also given to the various participants.

3.5.2 The groups as well as other experts studied and analysed the material with them and submitted their reports which have been referred to earlier.

3.5.3 The experts examining the CVR tapes did carry out a number of tests. Different graphs and traces were prepared and the sound was analysed by them. The result of their analysis has been referred to in Chapter 3.4 on Flight Recorders.

3.5.4. The metallurgical examination of some of the recovered pieces was carried out at BARC. The examination of some of the pieces showed different types of damages having been recorded on the targets such as petalling and curling round the holes, spikes etc. The said team carried out certain explosion experiments. Their report on the experiments so carried out has already been set-out in paragraph 3.2 above.

3.5.5 The Indian Air Force has set up an Institute of Aviation Medicine at Bangalore. The Court visited the said Institute on 9th December 1985. During that visit an experiment was conducted in the explosive decompression and high altitude chamber to demonstrate what actually happens during explosive decompression and subsequently on exposure to hypoxia.

3.5.6 Subjects were taken to 8,000 feet in the explosive decompression chamber with oxygen. They were exposed to an altitude of 25,000 feet within one second. During the course of this explosion a loud bang was heard and inside the chamber there was misting and drop in temperature. After this the chamber was allowed to run at 22,000 feet for roughly two minutes and an experiment to show the adverse affects of hypoxia on the subjects was done. In this experiment, subjects were asked to write a given sentence while their oxygen supply was cut off. It was observed that initially the subjects kept on writing the sentence correctly and then after about 120 seconds they started making errors while writing the sentence and finally they stopped writing. At this stage oxygen was re-started and within a few seconds, the subjects started writing their sentence once again. The experiment was completed at this stage and the altitude chamber was brought down to ground level.

3.5.7 The subjects were taken out and were asked questions as to what did they feel. They explained that at the time of explosive decompression, they heard a loud bang, felt cold and saw misting inside the chamber. They also found air escaping from their lungs. On further enquiry about the experiment pertaining to hypoxia, they said that they felt light headed and after that they did not know what happened till they once again noticed that they were writing on a piece of paper.

SECURITY

3.6.1 The evidence and the statements filed on record show that Canadian Security arrangements in place prior to 23rd June, 1985 met the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand baggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

3.6.2 Air India, as required by Canadian regulation, had a security programme. Because of the threat level assessed against the Airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and had received and arranged for extra security for the month of June, 1985. For Air India flight 181/182, Air India provided a security officer from its New York Office to oversee the security at Toronto and Montreal.

3.6.3 As it became apparent during the course of investigation that security would be an important aspect whilch would require the attention of the Court, Mr. Rodney Wallis, Director, Facilitation and Security, International Air Transport Association was good enough to appear in Court on 24th January, 1986. His testimony on certain aspects of security was recorded in camera by the Court on that date. The expert evidence has been taken into consideration while formulating some of the recommendations.

INTERNATIONAL COOPERATION

3.7.1 The manner in which persons and organisations from five different countries combined their resources and efforts in connection with this accident is an object lesson in international cooperation.

3.7.2 From the time the accident occurred, till the conclusion of the investigation proceedings by the Court in Delhi, there has been a consistent interplay amongst different persons and organisations. When all the persons got together, for the first time, at Cork the group was very heterogeneous. Each one had his own point of view, which did not necessarily coincide with that of another. At times, the atmosphere was charged with a bit of tension which continued even when the Court was constituted to investigate into the accident.

3.7.3 It was noticed that not only were the participants a bit apprehensive and suspicious but, during the course of investigation, there were also occasions when there appeared some acrimony between a few of them.

3.7.4 In such a sensitive situation, careful handling was called for. The participants' honesty of purpose could not be doubted. All that was wanted was that there should be an effort to try and understand the point of view of all the persons. This is precisely what the Court tried to do.

3.7.5 It is indeed fortunate that the efforts of the Court, in this regard, succeeded. After the Court had decided that it was not the purpose or the function of the investigation to affix responsibility for any lapse which may have been committed, one could see the general relieving of tension. With the passage of time there was a gradual building up of the confidence of the participants in the conduct of the investigation. The participants' interest for air safety transcended all barriers and any apprehension or suspicion, which was present in the minds of some, was soon dispelled. In its place there grew a deep sense of urgency, anxiety and cooperation in an effort to see that all the participants rendered utmost assistance for the satisfactory completion of the task in hand.

3.7.6 The main beneficiary of this international cooperation was not only the Court investigating the accident but it was the cause of air safety which benefited the most. Countries and Organisations went out of the way to help each other, financially and otherwise, even when they were not obliged to do so. Money and services were readily and voluntarily offered and usually the requirements of the Court were always fulfilled.

3.7.7 As the accident had occurred only about 100 miles off the coast of Ireland, the centre of activity, initially, was centred at Cork. The Government of Ireland, and the Irish people in particular, acted as though they regarded this as a national disaster. Not only did they render every assistance with regard to the search and rescue operation, hospital facilities, police etc. but the people acted as if one of their own kith and kin had died. In the situation which existed they were pillars of strength to the relatives of the deceased. Not only did complete strangers comfort such relatives but, more often than not, they even joined in their grief. The residents of Cork did everything possible to try and mitigate the sorrow of the victims' relatives. Everyone did their small bit, even the children of Cork queued up to place flowers at the coffins of the victims.

3.7.8 The Representatives of the Government of Canada also came to the scene, at the initial stages itself, and rendered full help and cooperation till the last. The major brunt of the mapping and the salvage operations was borne by Canada. Willingly and without any demur it incurred huge expenses, which must have been to the tune of a few million dollars, in carrying out these operations. It rendered full help and assitance to the Court whenever called upon to do so. For example, it offorded full facilities and help to the team which had been sent to Canada by the Court in August, 1985. It was only with the help of the Canadian Government, and the CASB and RCMP in particular, that the Court was able to obtain evidence and information relating to the accident. Without Canadian help the conduct of the investigation would have only been speculative in nature.

3.7.9 On their own, and without any request from the Court or from the Government of India, the Government of United States decided to lend a helping hand in the salvage operations. This was done
at a very critical juncture when financial help and expertise were required so as to salvage the important critical pieces of the

wreckage. It arranged for the services of a salvage expert and it also made necessary arrangements for the deployment of a second ship, duly fitted with necessary equipment to enable it to salvage some of the heavier pieces of the wreckage. The Court understands that the amount which was contributed in meeting the expenses by the United States was to the tune of U.S. $ 700,000.

3.7.10 The Government of United Kingdom also provided ship and helicopters in connection with the search and rescue operations. Even during the time when salvage operations were being carried out it was the British Helicopters which assisted in transporting personnel to and from the ship which were engaged in the salvage operations. The A.I.B. at Farnborough, on being asked by the Court to do so, carried out a very detailed analysis of the CVR and the ATC tapes.

3.7.11 Being the state of Registry of the aircraft and also the state holding the investigation, the major brunt of the work fell on the shoulders of officers of the Government of India and BARC. They acted as coordinators who had to oversee the work being carried out by persons belonging to diverse organisations and coming from different countries. Young engineers of Air India took turns in going aboard the ships and manning the Control Centre at Cork. They worked in conjunction with the engineers of Boeing and CASB and the crew members of the ships during the salvage operations. Without their enthusiastic participation the progress of the salvage operations would have been severely hampered.

3.7.12 The Scientists from BARC and National Aeronautical Laboratory, Bangalore were ever ready and willing to work together with the experts from abroad. Whenever called upon to do so, they rendered whatever assistance which was desired by the Court and the other participants.

3.7.13 It was seen that when the persons, coming from different countries and backgrounds, worked together with sincerety and honesty of purpose then they functioned smoothly and harmoniously, and usually arrived at an agreed solution or finding. These days it is indeed rare to see such a degree of international cooperation between different persons, organisations and countries.

ANALYSIS AND CONCLUSIONS

4.1 From the evidence which is available what has now to be determined is as to what caused the accident.

4.2 Finding the cause of the accident is usually a deduction from known set of facts. In the present case known facts are not very many, but there are a number of possible events which might have happened which could have led to the crash.

4.3 The first task is to try and marshal the facts which may have a bearing as to the cause of the accident.

4.4 It is undisputed, and there is ample evidence on the record to prove it, that Air India's Kanishka had a normal and uneventful flight out of Montreal. The aircraft had been in air for about five hours and was cruising smoothly at an altitude of 31,000 feet. The readout from the CVR shows that there was no emergency on board till the catastrophic event had occurred. This is corroborated by the printout available from the DFDR. The event occurred at approximately 0714 Z and that brought the aircraft down, and it probably hit the surface of the sea within a distance of 5 miles. The time within which the plane came down at such a steep angle could not have been more than very few minutes. There was a sudden snapping of the communication between the aircraft and the ground. The aircraft had also suddenly disappeared from the radar.

4.5 It is evident that an event had occurred at 31,000 feet which had brought down 'Kanishka'. What could have possibly happened to it? The aircraft was apparently incapacitated and this was due either to it having been hit from outside; or due to some structural failure; or due to the detonation of an explosive device within the aircraft.

4.6 Evidence indicates that after the event had occurred, though the pilots did not or were not in a position to communicate with the ground, they nevertheless appeared to have taken some action. According to Mr. Laflamme, witness No. 12, the examination of the wreckage showed that spoilers had been deployed and this must have been done
with a view to enter into emergency descent. He has further speculated that such an emergency descent would support or perhaps cause a rupture in the forward area or a partial damage to the hydraulic system or damage to the control system which created such a condition that the pilots were not able to control the flight. The wreckage fruther showed that the jack screw for the stabilizer trim was found in the nose-up position and it was hard to explain how this got there merely as a result of impact with the water. The trim being in that position could only have been due to the pilot selecting it or as a result of a situation created by an explosion. In that position, and at a high aircraft speed, there would have been an extremely high g-loading on the aircraft.

4.7 It can further be speculated that if an explosion takes place in the forward cargo compartment, the oxygen stream might have been damaged so that when the pilots donned their masks as part of the emergency drill for explosive decompression, they were not breathing enriched oxygen and the time of useful consciousness at about 31,000 feet would be significantly less than 30 seconds under high stress and if the pilots became unconscious as a result of this, then the aircraft would have got out of control which would explain the subsequent events.

4.8 None of the participants have produced any evidence which could lead one to the conclusion, that there was any external hit to the aircraft. In fact in the report dated 13th November, 1985, Mr. Paul Turner has stated as follows:

"The United States Norad/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.

4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.

4.11 The circumstantial and direct evidence which leads to the aforesaid conclusion is as follows :

A. Connection with an explosion at Narita Airport :

On 23rd June, 1985 there was an explosion at the Narita Airport. The explosion occurred when a bomb exploded in a suit case which was to be interlined to Air India's Flight No. 301 from Tokyo to Bangkok. The following events, which had occurred prior to this explosion, clearly establish the connection between the two incidents :

(i) On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight Indian accent. He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vacouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact

number was given and the call lasted about one-half hour.
(ii) On the same date at approxmimately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.
(iii) On 20 June, 1985 at about 1210 PDT (1910 GMT), a male appearing to be of Indian origin purchased the tickets with cash from a CP Air Ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to 'M. Singh'. The telephone contact number was also changed. The final itinerary was as follows :
(a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985
- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22nd June, 1985
- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22nd June, 1985
(b) L. Singh - CP 003 Vacouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June, 1985
- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 time in Tokyo, local 23 June, 1985
(iv) On 22 June, 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that the was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he

could not check his baggage past Toronto unless his flight was confirmed.
(v) On Saturday morning, 22 June, 1985, a CP Air passenger agent worked check-in position number 26 at the CP AIR ticket counter, Vancouver International Airport, and recalls dealing with a passenger of Indian origin booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto his baggage could not be interlined. The passenger insisted and, as the line-up were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that 'M. Singh' checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage.
(vi) The flight manifest for CP 003 shows that on the same day the person using the name of 'L. Singh' with an interline ticket to Bangkok also checked through the same counter, was assigned seat 38H, and checked one piece of baggage.
(vii) A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as 'M. Singh' and 'L. Singh' did not board these respective flights.
(viii) In a statement of William Long, annexed to the affidavit of I.G. Pole, Police Officer, City of Toronto, he has stated that on 22nd June, 1985 he was employed as a driver whose responsibility was to deliver interlined baggage between terminal 2 to Terminal 1 and vice versa at Toronto. He has further stated that he had picked up 4 bags from Terminal 1 which were destined for terminal 2 Air India. Three of these bags were from U.S. Air originating from New York city. Regarding the last bag he stated as follows :
"The fourth bag destined for Air India was, I distinctly remember looking at the baggage tag and it was pink with the CP logo in

blue and
letters saying CP on it there were also numbers but I can't remember the number, from CP Air and I remember it was from Vancouver. On the bottom of the tag it said vancouver using the initials YVR and the flight number which I can't remember. The bag was destined for India. When I arrived at the CP Air belt there were a number of bags from other airlines on the belt included in these were the three U.S. Air bags destined for Air India. As I was finishing loading the carts, a CP Air station attendant who had been unloading bags from containers, I noticed as I checked once more for anymore bags, drop another bag on the conveyer belt. This was the bag destined for Air India. It was dark brown Samsonite Hard sided Type 01A on the Baggage Identification Chart. After they were loaded onto the cart I took them over to Air Canada domestic belt at Gate 89-91". To further questions posed to him, Long stated that this bag from CP Air weighed approximately 70 lbs and there was something which rattled inside the bag. He could not say what it was but he said that "it sounded small". When specifically asked whether he thought there was something big inside the bag, he answered in the affirmative, and added that he did not know what was in it but it was heavy. There was discrepancy in the time when he is alleged to have picked up the bags which he had indicated in his schedule when compared with CP Air Vancouver flight which had arrived at 1622 hours. When this was pointed out to Long, he answered "I could have may be got the time wrong, it was during the busy period. It could have been an estimate time. But I do remember the bag came off CP air. It could have been 16:34 Hrs. I don't know."

(ix) The aircraft departed from Toronto for Mirable and London with the suitcase unaccompained by the passenger who had checked it in at Vancouver. Similarly, CP Air 003 departed Toronto for Tokyo with the baggage of one passenger 'L. Singh' to be interlined to Air India flight AI 301 to Bangkok even though 'L Singh' had not boarded that flight.

(x) The linking of the two occurrences namely the blast at Narita Airport and the Air India accident becomes startingly evident if we look at the following chronology of events:

CPA 003 (VANCOUVER-TOKYO) CPA 060 (VANCOUVER-TORONTO) Connection to Connecting to Air India 301 Air India 182 WESTBOUND EASTBOUND All Times GMT

Thurs 20 June, 1985 0057 A male called C.P. Air Reservations in Vancouver and after discussing a number of routings, booked a one-way ticket and CPA 060 to Toronto with connections to Air India 182 under the name of Jaswand SINGH. A return ticket was also booked on CPA 003 to Tokyo connecting with Air India 301 to Bangkok in the name of Mohinderbel SINGH.

1912 A male attended the CP Air Ticket Office in Vancouver. He paid $ 3005.00 in cash for the above tickets after changing the ticket of Mohinderbel SINGH to L. SINGH and changing
from a return to a one-way ticket. He changed the Jaswand SINGH ticket to M. SINGH.

Saturday 22 June A Mr. SINGH called Reservations and got 1330 confirmation on his one-way ticket to Toronto with luggage to be sent through to India. M. SINGH checked in with seat 10B confirmed to 1550 Toronto. Wanted suitcase interlined to AI 182. Agent relents. 1618 CPA 060 departed Vancouver 18 minutes late. M. SINGH not in assigned seat. L. SINGH checked in for CPA 003 and one suitcase interlined to Air India 301. Assigned seat 38H. CPA 060 arrived Toronto 2022 12 minutes late. Some

passengers and baggage interlined to AI 181.ÊÊÊÊÊÊ
CPA 003 departed 17 min. late for Tokyo. L. SINGH not in 2037 assigned seat. Sunday 23 June Air India 181 departed 0015 Toronto for Mirabel 1 hour 40 minutes late.
0100 Air India arrived Mirabel. 0218 Air India 182 departed Mirabel 1 hour 38 minutes late. CPA 003 arrived Narita Airport, Tokyo. Arrived 14 minutes early 0541
Baggage cart explodes in transit area. 2 killed, 4 injured, 0619 0714 Air India 182 disappeared from RadarÊÊÊÊÊÊ
Air India 301 departed Narita. 0805 0815 Air India 182 Scheduled arrival Heathrow (fuel stop).Ê

(xi) It would indeed to too much of a coincidence that two persons, whose tickets were bought at the same time and who had checked in under the names of 'L. Singh' and 'M. Singh' missed their respective flights, more so when 'M. Singh' had insisted at the check in counter at Vancouver that he should be interlined, even though his seat from Toronto on AI 181/182 was not confirmed, and his baggage (one suitcase) accepted and be routed through to Delhi. If there had been some reason for 'gate no-show' by both of them, one would ordinarily have expected both, or at least one of them, to have made efforts, at that time or thereafter, either to ask for refund of money or they should have contacted the airline staff at the Airport and asked that they should be put on another flight.

(xii) A large amount of money had been spent on the purchase of the two tickets and a question which comes to mind is as to why was this money spent if both the tickets were to be wasted and no one was to travel on them, after having checked in and obtained boarding cards. Furthermore, no effort has been made by any of these two persons to try and lodge a claim for the baggage which they had checked in.

(xiii) The aforesaid facts clearly indicate the connection between the travel plans of so called 'L. Singh' and 'M. Singh'. In fact the manner in which the reservations were changed to the names of 'M. Singh' and 'L. Singh' shows the anxiety of some one to hide behind the identity of persons who bore notorious names.

(xiv) The interlined baggage exploded at Narita Airport and there is strong probability that the suticase from Vancouver, which was interlined to AI 182, contained a device similar to the one which had exploded at Narita Airport on 23 June, 1985.

B. CVR and DFDR both stopped simultaneously:

There was simultaneous interruption of electrical power to the flight recorders. The electrical supply could have been interrupted either because of the cables being cut or because of total electric failure. Power supply wires to the CVR and the DFDR run under the passenger cabin ceiling on the left and the right hand side. The supply of electricity through these cables originates from the MEC compartment, which is in front of the forward cargo hold. If the CVR and the DFDR had stopped due to the breakage of electrical supply wires as a result of possible explosion in the aft cargo hold there would have had to be an instantaneous break of almost the entire section of fuselage, because both these recorders had stoped simultaneously. In such a catastrophic event it is not possible that the bottom skin panels of the aft cargo compartment would remain undistorted, or would have no rupture or holes in them. Furthermore, in such an event the tail portion of the aircraft would have been found in the beginning of the wreckage trail, but this was not so. On the other hand, and explosion in the forward cargo compartment would have resulted in damage to the electrical buses located in the MEC and that would, in turn, result in cutting off the electrical power supply causing simultaneous stoppage of the recorders.

C. The ATC Transponder Stopped Transmitting :

The transponder is located at the bottom of the one of the forward rakes immediately forward of the front cargo compartment. Signals from this also stopped being received by the secondary radar at Shannon. Keeping in view that the CVR and the DFDR had stopped simultaneously at about the same time, when the signals from ATC transponder had also ceased, it is reasonable to presume that there must have been a complete breackdown of electrical supply which had affected all the three units. The only event which could have caused such a damage to paralyse the entire MEC compartment could only have been an explosion in the forward cargo hold. It was not possible that any rapid decompression caused by a structural failure could have disrupted the entire electricl power supply from the MEC compartment. In known cases of aircraft being subjected to rapid decompression there has never been such an instantaneous and total stoppage of electrical power and in fact aircrafts have been known to have continued to fly and communicate with the ground even after decompression.

D. Non-supply of Oxygen :

Oxygen supply cylinders are located in the ceiling of the forward cargo compartment. Any rupture of the only pipeline which supplies oxygen to the passengers would result in there being no surge of oxygen flow, which alone drops the oxygen masks. The inspection of the wreckage shows that there is no indication of the oxygen masks ever having dropped. A rupture of this pipeline, simultaneously with power rupture, could only have been caused if there had been a detonation of the explosive device in the front cargo hold.

E. Damage in air :

The examination of the floating and the other wreckage shows that the right hand wing leading edge, the No. 3 engine fan cowl, right hand inboard mid flap leading edge and the leading edge of the right hand stabilizer were damaged in flight. This damage could have occurred only if objects had been ejected from the front portion of the aircraft when it was still in the air. The cargo door of the front cargo compartment was also found ruptured from above. This also indicates that the explosion perhaps occurred in the forward cargo compartment causing the objects to come out and thereby damaging the components on the right hand side.

F. Evidence of Overpressurization :

The examination of the structural panels and the other parts of the forward cargo compartment and the aft cargo compartment, recovered from the sea bed, indicates that overpressure condition had occurred in both the cargo compartments. The failure of the passenger cabin floor panels in upward direction also indicates that overpressure was created in both the compartments. It cannot be disputed that whenever an explosive detonates very high pressure shockwaves are formed which travel in all directions and high speed fragments of the container, or the loose material, also move away from the source of explosion. It is, therefore, clear that there was overpressurization in the cargo compartments which resulted in such rupture of the cabin floor panels.

G. Holes in the front cargo hold panels

While the skin panels of the aft cargo compartment are fairly straight and undamaged, the panels of the front cargo compartment are ruptured and have a large number of holes. This shows that there was occurrence of an event in the front cargo compartment and not in the aft cargo compartment.

H. Buckling of Seats :

The seats towards the rear of the aircraft had only the aft legs buckled, whereas the seats towards the front had both the front and the aft legs buckled. This indicated that the whole floor was subjected to a vertical force and was more severe towards the front. Moreover, the upper deck storage cabin was found among floating wreckage. The bottom of this cabin was pushed up in the shape of a dome with no evidence of impact damage. This deformation was indicative of having been caused, possibly, as a result of a shockwave.

I. Metallurgical Examination Results :

A metallurgical examination, especially of Targets 362 and 399, clearly confirms that there was an explosion in the forward cargo compartment. Microscopy around some of the holes discloses that they have such characteristics like twinning which can be present only if the holes had been puntured due to the detonation of an explosive device.

J. CVR Tape Analysis :

The report of CVR tape analysis by Mr. S.N. Seshadri also corroborates the aforesaid evidence i.e. that there was a bomb in the forward cargo hold of the aircraft.

RECOMMENDATIONS

5.1 ICAO, IATA and the States should :-

(a) undertake an ongoing review of established aviation security standards to prevent the placement of explosive substances on board commercial aircraft;

(b) establish a programme of monitoring the implimentation of security measures in airports around the world, in cooperation with the Governments concerned. For each airport studied, it should report its findings and recomend any improvements that may be required;

(c) consider establishing a group of civil aviation experts to investigate serious breaches of security. The purpose of these investigations would be to determine the facts of an incident so that necessary measures could be developed and implemented world wide to prevent similar breaches in the future.

Note : As it may take some time for ICAO and IATA to implement these recommendations, at least those countries which have international air traffic should take up effective measures without delay.

5.2 ICAO should :-

(a) develop a model clause on security that could be used in the bilateral air agreements that govern the exchange of air traffic rights between countries;

(b) consider establishing standards for the training of security personnel.

5.3 IATA should develop practical procedures for reconciliation of interlined passengers and their baggage at intermediate airports.

5.4 Interlining of checked-in baggage should not be done if a passenger does not have a confirmed reservation on the onward carrier flight.

5.5 The baggage of interlined passengers should be matched with passengers by the onward carriers before loading the baggage on the aircraft.

5.6 Whenever a Government becomes aware of particular high risk security threat it should notify not only the airline at risk, but also all connecting airlines in order that extra precaution can be taken at potential points of introduction of interline baggage into the system.

5.7 When an Airline is aware of a high security threat it should communicate the same to the host state as well as, if possible and prudent, to the other airlines operating there.

5.8 Passenger count should be done at boarding gate and in case of 'no gate show' of a passenger, his baggage must be off-loaded.

5.9 All checked-in baggage, whether it has been screened by X-ray machine or not, should be personally matched and identified with the passengers boarding an aircraft. Any baggage which is not so identified should be off-loaded. This is advisable as examination of the baggage with the help of an X-ray machine has its own limitations and is not fool proof. Some explosives hidden in Radios, Cameras etc. may not be readily detected by such a machine. In fact an explosive not placed in a metallic container will not be detectable by an X-ray machine. Similarly, a plastic explosive can be given an innocuous shape or form so as to avoid detection by an X-Ray. Reliance on an X-Ray machine alone may in fact provide a false sense of security.

5.10 Effectiveness of the instrument known as PD-4 is highly questionable. It is not advisable to rely on it.

5.11 All unaccompanied baggage should be placed on the aircraft after their contents have been physically checked. In the alternative, it should be loaded only after it has been placed in a decompression chamber and the host state is satisfied that the baggage is clean and the shipper has been identified.

5.12 Airlines should have effective backup security equipment or procedures available in case of machanical break down of security equipment.

5.13 All hand baggage, including that of the crew, should be opened and the contents physically checked even if the said baggage has been x-rayed. This will no doubt be a bit time consuming and laborius but if security is to be meaningful, then slight inconvenience has to be endured in order to ensure a safer flight.

5.14 The manufacturers of aircraft should take effective steps for protecting sensitive parts of the aircraft from explosive damage.

5.15 Studies should be undertaken to determine the feasibility of physically separating the avionics bay and emergency oxygen systems from the cargo area in aircraft so that these sensitive and essential areas of the aircraft cannot be damaged or destroyed by a relatively small explosive deivce concealed in luggage.

5.16 The seats should have safety belts which can act as restraint for the upper part of the body e.g. like a shoulder harness with inertial restraint.

5.17 The seats in the aircraft should be so designed so as to incorporate shock absorbing systems within the seat and they should be manufactured by using material which does not break easily.

5.18 In addition to the cockpit voice recorder, there should be in the cockpit a video/scanning camera which would record the movements and the audio sounds in the cockpit. This will not only assist in ascertaining as to how the pilots act during as emergency but, in the case of hijacking, would also assist in the identification of the hijackers.

5.19 The CVR should record all the conservation and sounds in the cockpit for the entire duration of the flight, and not merely for the last 30 minutes.

5.20 The CVR and the DFDR should be powered from two alternative sources of energy.

5.21 The oxygen for the flight crew should be supplied from two different sources i.e. in the event of an emergency the pilot and the co-pilot must don the oxygen mask and the oxygen must be supplied from different source.

5.22 Suitable provisions should be incorporated in Annex 13 which would give power to an Investigator to record evidence outside the country of investigation and also to summon witness from abroad. It should also be mandatory on the contracting States to give information sought for by an Investigator.

(B. N. KIRPAL)

February 26, 1986 COURT

We agree with the conclusions and recommendations stated above.

ASSESSORS

(V. Ramachandran) (J.S. Gharia)

(J.S. Dhillon) (J.K. Mehra)

(B.K. Bhasin)

ACKNOWLEDGEMENTS

When I was appointed as the Court to investigate into the accident, the magnitude of the task involved was known. With the help, assistance and cooperation of a team of dedicated workers, the work was, however, completed in not too long time.

The assistance received from those who helped me cannot be too highly praised.
From amongst my Assessors, Captian B.K. Bhasin was the only one who was permanently stationed in Delhi. We met for the first time on 15th July, 1985 and little did I realise then that, by the time our work would be over, how much I would be depending upon him. Not only was his advice on the technical aspects of flying and air safety invaluable but, whenever any difficulty or a problem arose, I invariably turned to him for assistance and advice which I readily got. I found him having a very practical and positive approach to all the problems but, at the same time, he very rightly was not prepared to compromise on any principal issues.
The only interest Dr. V. Ramachandran appeared to have was to do his work to perfection. No praise can be too high for the manner in which this Metallurgist from landlocked Bangalore volunteered and boarded the salvage ships which were carrying out operations in the cold and choppy waters of Atlantic Ocean. He sarificed all comforts and went to sea with a view to be present on board the ships at the time when salvaged pieces of wreckage were brought on board. His deep knowledge of metallurgy greatly assisted the examination of the salvaged pieces of wreckage. In this connection the entire metallurgical examination was planned and organised by him.
Whenever any information was required concerning explosives, Mr. J.S. Gharia was ever eager and in a position to provide the information.
Mr. J.K. Mehra looked into the engineering aspect of the accident and he spent a lot of time in going through various Air-India Maintenance Manuals. He always made discussions very lively and interesting.
Captain J.S. Dhillon came out of his retirement and provided useful information to the Court on some aspects of flying.

This work would never have been satisfactorily completed without the help and assistance received by the Court from late Mr. S.N. Seshadri of Bhabha Atomic Research Centre. From the time when the CVR was first played by him at BARC on 16 July, 1985 till the very end, he most willingly and pleasantly undertook any assignment which was given to him by the Court. It was a great national loss when he suddenly passed away on 2nd February, 1986, only a few days after he had deomonstrated his brilliance when his testimony, regarding the analysis of the CVR tape, was recorded by me in the Court.

I am also grateful to the other Scientists and staff of B.A.R.C. who rendered considerable assistance to the Court. The facilities made available by Dr. P.K. Iyengar, Director, B.A.R.C. with regard to the finalisation and completion of the report cannot be easily forgotten. In the absence of late Mr. S.N. Seshadri, with whom I had developled a personal rapport, Dr. Ashok Mohan and Mr. V.K. Chadda met with all our requirements in the finalisation and preparation of the Report. Dr. Asundi of BARC and the other Metallurgists of that Organisation and of the National Aeronautical Laboratory also spent a considerable amount of their time and energy in successfully carrying out metallurgical tests and examination of the salvaged pieces.

During the investigation I had to visit Ireland on two occasions. I immediately realised the extent of help, assistance and guidance which was being rendered to all of us by Mr. Kiran Doshi, the Indian Ambassador to Ireland. There was no problem to which he did not have a solution. On my visit to Dublin not only did I enjoy the hospitality of Kiran and his wife Razia but it also gave an opportunity to personally meet Mr. Mitchel, the Minister of Communications, and senior officials of his Ministry, and to express my gratitude to them for all the help and assistance which the Government and people of Ireland had, most willingly, rendered.

At Tokyo the Indian Ambassador and members of his staff looked after all our needs and arranged meetings with the Japanese officials whom we wanted to meet.
As representatives of the Court in Cork, Mr. P.R. Chandrasekhar and Mr. C.D. Kolhe did a commendable job. They kept me informed of the progress which was taking place at Cork and, whenever required to do so, they took vital decisions while coordinating the mapping and salvage operations.
Mr. H.S. Khola, Director of Air Safety, New Delhi willingly carried out all the directions of the Court. Special mention must also be made of Mr. Satendra Singh, Regional Controller of Air Safety, Bombay, who worked day and night when the flight recorders were first opened and the copies of the tapes made and the data analysed.
I have also to express my gratitude to the Counsel who assisted the Court in the Investigation. Without their help and cooperation, it would not have been possible to complete the work in 7-1/2 months.
On my trip to Bombay, the Staff and Management of Centaur Hotel made my stay very comfortable. It was like a home away from home. The work done during the salvage operarations by four young engineers of Air-India was highly commendable and valuable. All of them namely, Mr. Balasubramanium, Mr. L.S. Carvalho, Mr. G.D. Nayar and Mr. A.K. Sheode, worked round the clock even during adverse climatic conditions.
The Registrar of the Delhi High Court, Ms. Usha Mehra spared no efforts in rendering every assistance whenever the same was required. She ably marshalled all the resources available in the High Court in order to ensure the smooth and efficient functioning of my office. My own personal staff in particular, headed by Mr. V.P. Ahuja, Court Master and Mr. Balram Chopra, Private Secretary, as usual, rose to the occasion. While Mr. Ahuja kept complete control of hundreds of documents and affidavits

which had been filed, Mr. Chopra besides bearing the brunt of the typing work, very ably supervised the work of other Stenographers.

It was most fortunate that I was able to persuade Mr. S.N. Sharma to accept the trying job of being the Secretary to the Court. His vast experience in such Investigations, he had been a Secretary in three such Investigations earlier, made my task much lighter. Moreover, as an Aircraft Engineer, he was always ready to explain technical intricacies involved in the case. Without his help I could not have completed my work within the stipulated time.

(B. N. KIRPAL)

26th February, 1986 COURT

POSITIVELY IDENTIFIED DEBRIS AIR INDIA 747 VT-EFO KANISHKA AIRCRAFT

SECTION TARGET LAT LONG DESCEIPTION 41 DOOR 192 51 03.28 12 47.74 FIRST CLASS AND COCKPIT AREA (+ UPPER DECK DOOR) 41 131 51 03.21 12 47.93 LEFT HAND UPPER DECK SLIDE MECHANISM 41 134 51 03.28 12 47.81 NOSE LANDING GEAR 41 265 51 02.37 12 44.51 LANDING GEAR DOOR (NOSE GEAR) 41 244 51 03.56 12 48.19 UPPER DECK WINDOW TRIM (REVEAL) 41 63 51 02.51 12 47.37 2 FIRST CLASS SEATS 41 77 51 02.59 12 47.83 2 FIRST CLASS SEATS 42 DOOR 193 51 03.30 12 47.85 PIECE OF FUSELAGE, WING PLUS LANDING GEAR (#2 LEFT DOOR) 42 138 51 03.37 12 47.77 SMALL PIECE OF WRECKAGE (BS 800) 42 200 51 03.347 12 47.831 Dual Heat Exchanger 42 DOOR 204 51 03.33 12 47.87 FORWARD CARGO DOOR + FLOOR 42 255 51 03.72 12 48.01 GALLEY COMPLEX (UPPER DECK) 42 232 51 03.49 12 47.92 'P93' RACK MARKED 'DANGER HIGH VOLTAGE' (BS 670) 42 327 51 01.62 12 43.03 NACA SCOOP

42 DOOR 358 51 03.39 12 47.86 MASS OF DEBRIS (#2 RIGHT DOOR) 42 361 51 03.384 12 47.848 BOX MARKED "FAN BLADES" 42 362 51 03.372 12 47.840 MASS OF DEBRIS FUSELAGE SKIN 42 383 51 03.32 12 47.81 MASS OF DEBRIS WITH UPPER DECK FLOOR 44 DOOR 137 51 03.30 12 47.80 CENTER FUSELAGE SECTION WITH #3 LEFT DOOR 6 WINDOWS AFT OF DOOR AND 13 WINDOWS FORWARD. LEFT UPPER WING SKIN AND ONE MAIL LANDING GEAR ATTACHED. 44 103 51 02.86 12 46.37 LANDING GEAR DOOR 44 105 51 02.81 12 46.04 LEFT WHEEL WELL LANDING GEAR DOOR 44 186 51 03.32 12 47.825 KEEL BEAM 44 195 51 03.32 12 47.78 WING STRUCTURE 44 224 51 03.46 12 48.49 TWO WHEELS FROM MAIN LANDING GEAR 44 239 51 03.62 12 47.38 MAIN BRAKE UNIT WITHOUT AXEL, PLUS EQUALIZING ROD 44 240 51 03.62 12 47.44 MAIN TIRE AND RIM 44 241 51 03.62 12 47.40 MAIN TIRE AND RIM PLUS AXEL 44 242 51 03.61 12 47.40 MAIN BRAKE UNIT 44 267 51 03.35 12 44.45 PART OF LANDING GEAR DOOR 44 275 51 02.13 12 44.10 BODY LANDING GEAR DOOR 44 279 51 02.30 12 44.64 MAIN LANDING GEAR DOOR 44 280 51 02.26 12 44.61 SECTION OF MAIN LANDING GEAR DOOR 44 343 51 03.285 12 47.809 MAIN LANDING GEAR DOOR 59 51 02.57 12 45.73 SECTION OF LANDING GEAR 44 218 51 03.41 12 47.86 STEP WELL AREA (STA 1250-1480)ÊÊ
46 6 51 02.79 12 49.44 SMALL MOTOR 10" x 8" (FAN) 46 7 51 02.90 12 49.92 LOWER SKIN OF CARGO AREA 4' x8' (BS 1480)) 46 #11 51 02.04 12 45.44 PIECE OF OUTER SKIN BODY STATION #1760 PART NO. 65B04325-403 46 25 51 02.21 12 46.27 BODY FRAME (BS 1660-1680) 46 26 51 02.20 12 46.72 CABIN SECTION WITH 4 WINDOWS (ABOVE 'T' IN REG No.) 46 28 51 02.31 12 47.02 SKIN PANEL 1460-1800 46 33 51 02.49 12 48.28 AFT FUSELAGE SKIN PANEL

'YOUR PALACE IN THE SKY' (AFT OF #5 DOOR) 46 34 51 02.49 12 48.29 RIGHT HAND FUSELAGE SKIN PANEL AT DOOR #5 46 DOOR 40 51 02.47 12 47.41 CARGO DOORS C2, C3 46 47 51 02.39 12 46.61 REAR CARGO FLOOR 46 50 51 02.38 12 46.60 CARGO FLOOR (STA 1500) 46 DOOR 74 51 02.49 12 47.71 FIVE FRAMES AND DOOR-PORT SIDE AFT (#5 LEFT DOOR) 46 78 51 02.52 12 47.95 FRAME SECTION (SHEAR WEB STA 2000-2020) 46 87 51 02.58 12 48.43 BUILT UP STRUCTURE (STA 2412) 46 DOOR 97 51 02.52 12 47.38 FUSELAGE SKIN SECTION WINDOW BELT AREA WITH DOOR FOLDED UNDER FRAME 46 DOOR 101 51 02.84 12 47.14 5 WINDOWS AND DOOR (#4 RIGHT DOOR) 46 292 51 01.81 12 44.24 FRAME (STA 2240) 46 321 51 02.39 12 46.61 '4R' DOOR ENTRANCE WITH NO DOOR AND 10 WINDOWS (BS 1700)   320 51 01.84 12 44.59 FUSELAGE BOTTOM SKIN NEAR OUTFLOW VALUE 46 336 51 01.34 12 42.03 BULK CARGO COMPARTMENT FLOOR AND STRUCTURE 46 369 51 02.17 12 46.20 FUSELAGE PANEL SECTION, 4 WINDOWS 48 31 51 02.37 12 48.43 HORIZONTAL STAB 48 37 51 02.47 12 47.99 VERTICAL TAIL FIN (+ PRESSURE BULKHEAD SECTION) 48 35 51 02.50 12 48.08 AFT PRESSURE BULKHEAD (25%) 48 22 51 02.19 12 45.68 ELECTRICAL PANEL (RUDDER RATIO JUNCTION BOX) 48 27 51 02.20 12 46.83 APU HOUSING 48 66 51 02.59 12 47.54 BODY FRAME (BS 25XX) 48 67 51 02.55 12 47.50 FUSELAGE SKIN (3 FRAMES FORWARD OF APU BS 2638) 48 68 51 02.57 12 47.55 FUSELAGE SECTION (BS 2598) 48 73 51 02.51 12 47.70 PART OF PRESSURE BULKHEAD 48 75 51 02.47 12 47.63 FRAME FOR OVERHEAD LUGGAGE COMPARTMENT (ROW 46 F-G) 48 88 51 02.90 12 48.84 CONTROL LINKAGE FROM TAIL OF AIRCRAFT (ELEVATOR CONTROL QUADRANT) 48 99 51 02.71 12

47.92 FUSELAGE SKIN SECTION (BS 2598) 48 296 51 02.03 12 43.17 PART OF PRESSURE BULKHEAD 48 314 51 01.84 12 44.19 APU AIR DUCT 48 371 51 02.51 12 48.28 AFT FUSELAGE SKIN 10'x15' (HORIZ. STAB CUTOUT)ÊÊ SECTION TARGET LAT LONG ENGINESÊÊ 7.13 108 51 02.97 12 47.12 AIRCRAFT ENGINE (WITH STRUT) 149 51 03.26 12 47.38 ENGINE AND STRUT 154 51 03.32 12 47.75 ENGINE SECTION (5th ENGINE) 171 51 03.16 12 47.16 TURBINE SECTION OF ENGINE (POSSIBLY COMPLETE ENGINE) 235 51 03.63 12 47.07 AIRCRAFT ENGINE ENGINE PARTS 106 51 02.98 12 46.41 ENGINE COWLING (INLET) MARKED 'A124' (5th ENGINE) 109 51 02.97 12 47.11 STARTER FOR AIRCRAFT ENGINE 111 51 03.02 12 47.20 ENGINE COWL 116 51 02.99 12 47.80 ENGINE DEVICE 124 51 02.85 12 48.47 FIFTH ENG CENTER DOME 150 51 03.25 12 47.36 PART OF ENGINE 151 51 03.29 12 47.42 SMALL PART OF ENGINE 152 51 03.31 12 47.44 LOWER PORTION OF ENGINE 153 51 03.31 12 47.44 LOWER ENGINE COWLING 155 51 03.32 12 47.44 FAN INNER EXIT AREA 156 51 03.32 12 47.43 PART OF ENGINE 158 51 03.23 12 47.35 PART OF ENGINE COWLING 159 51 03.25 12 47.29 ENGINE COWLING 161 51 03.26 12 47.29 PORTION OF ENGINE COWL 165 51 03.20 12 47.21 THRUST REVERSER SLEEVE 166 51 03.20 12 47.21 UNIDENTIFIED ENGINE PARTS 167 51 03.21 12 47.24 UNIDENTIFIED ENGINE PARTS 168 51 03.20 12 47.22 UNIDENTIFIED ENGINE PART 169 51 03.18 12 47.20 UNIDENTIFIED ENGINE PARTS 170 51 03.19 12 47.19 PART OF DIAPHRAM (OIL COOLER) 172 51 03.25 12 47.21 ENGINE EXHAUST CONE 173 51 03.27 12 47.38 ENGINE EXHAUST CONE AND EXHAUST 237 51 03.690 12 47.10 ENGINE PARTS CASE 238 51 03.72 12 47.10 ENGINE INLET COWL 206 51 03.34 12 47.50 SECTION OF

ENGINE EXHAUST STAGE #7 207 51 03.35 12 47.49
ENGINE HOT SECTION AREA 208 51 03.37 12 47.51
ENGINE TAIL CONE 214 51 03.19 12 47.36 CASCADE
VANEÊÊ
STRUTS 7.12 4 51 02.87 12 49.05 #3 ENGINE
NACELLE STRUT 157 51 03.23 12 47.36 STRUT (SIMILAR
TO 149) 110 51 03.15 12 47.16 NACELLE STRUT
WING PARTS 17 120 51 03.01 12 47.98
OUTBOARD AILERON (50%) 16 135 51 03.28 12 47.81
TRAILING EDGE FLAP AND DRAG JACK 16 136 51 03.31
12 47.81 TRAILING EDGE FLAP JACK SKREW 12 140 51
03.35 12 47.83 LEADING EDGE SECTION OF WING 14 145
51 03.34 12 47.85 WING LEADING EDGE VARIABLE
CAMBER FLAP 16 177 51 03.34 12 47.91 TRAILING EDGE
FLAP 12 181 51 03.38 12 47.87 LOWER CARGO
COMPARTMENT AND WING LOWER SKIN 16 183 51 03.38
12 47.87 SECTION OF FLAP SKIN 16 188 51 03.33 12 47.81
TRAILING EDGE FLAP WITH JACK SKREW 16 189 51
03.32 12 47.80 TRAILING EDGE FLAP WITH SKREW JACK
16 191 51 03.32 12 47.78 FLAP ACTUATOR AND FLAP
TRACK 16 194 51 03.32 12 47.77 TRAILING EDGE OF
FORE FLAP 16 253 51 03.32 12 47.86 PIECE OF TRAILING
EDGE FLAP 16 254 51 03.40 12 47.86 PIECE OF TRAILING
EDGE FLAP 16 264 51 02.47 12 44.74 TRAILING EDGE
FLAP FAIRING 16 277 51 02.18 12 44.40 WING FLAP 16
344 51 03.294 12 47.802 TRAILING EDGE FLAP AND FLAP
TRACK 16 384 51 03.33 12 47.80 T/E FLAP TAPER AND
DRIVE SHAFT 16 398 51 03.325 12 47.85 PIECE OF TE MID
FLAP 15 190 51 03.32 12 47.79 SPOILER ACTUATOR
14 187 51 03.34 12 47.81 LEADING EDGE FLAP
SECTION 14 387 51 03.33 12 47.853 PIECE OF L/E FLAP
MECHANISMÊÊ
12 54 51 02.38 12 45.86 LE FROM WING 12 202 51 03.33 12

47.86 WING LOWER SKIN 12 221 51 03.39 12 47.89 UPPER EDGE LEFT WING 12 225 51 03.38 12 48.78 SMALL PIECE OF WING LEADING EDGE PANEL 12 222 51 03.38 12 47.94 WING FILLER & WING PARTS 12 243 51 03.59 12 47.85 PIECE OF LEADING EDGE FLAP 12 252 51 03.38 12 47.84 LOWER WING SECTION 12 262 51 03.85 12 46.92 MID LOWER WING SKIN, ONE AFT FLAP TRACK WITH JACK SKREW 12 266 51 02.36 12 44.46 LANDING GEAR DOOR 12 297 51 01.91 12 43.18 PART OF WING TIP 12 345 51 03.28 12 47.842 'REAR WING SPAR' 12 365 51 03.338 12 47.842 REAR SPAR RIB WITH SPOILER ACTUATOR 12 379 51 03.315 12 47.785 WING REAR SPAR AND SPOILER STA 1150 12 381 51 03.40 12 47.88 LE OF WING SECTION 12 182 51 03.38 12 47.87 POSSIBLE REAR SPAR, (WING STA 802 I.D. ON PART)   17 274 51 02.19 12 43.57 LEFT INBOARD AILERONÊ
PAGE   i

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From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Date: February 22, 2001 6:52:18 PM PST
To: John Barry Smith <barry@corazon.com>
Subject: **Re: Reports**

Thank you Barry.

Is there anyway that you can save these documents as word documents and then attach them to the emails?

if not i will print them as is.

I will most definetly forward these to Mr. Malik so
that he can read them.

thanks again

sundeep
--- John Barry Smith <barry@corazon.com> wrote:
Hi Sundeep! Yes, of course I can and will. I will
attach one report
to three emails. They are big.

A benefit of reading on the computer is text can be
searched and
located much faster than in hard copy. Both are
important.

They are very important and must be reviewed in
detail. The pattern
of wiring/cargo door cause can be discerned in each.

There are four actually but one is on a web site. It
is over 8 megs
of PDF. It is the NTSB AAR 00/03 for TWA 800.
http://www.ntsb.gov/publictn/A_Acc1.htm is the URL
to go to to
download Title: Aviation Accident Report: In-flight
Breakup Over the
Atlantic Ocean Trans World Airlines (TWA) Flight 800
Boeing 747-141,
N93119 near East Moriches, New York July 17, 1996
NTSB Report Number: AAR-00-03, adopted on 08/23/2000
[Abstract | PDF document]
NTIS Report Number: PB2000-910403

The TWA 800 report is 350 pages.

The AI 182 report I shall attach in another email.
It is about 250 pages.

The UAL 811 report I shall attach in next email. It
is NTSB AAR 92/02
and must almost be memorized, it is the model for
the other three.

The PA 103 report I shall insert and attach in
another email.

They are very long and if you don't get them from me
in the right
manner, tell me and we shall try again.

Get lots of printing paper and be patient, it takes
a long time to
print out, I've done it myself several times.

I must impress upon you, Aniljit, Mr. Malik, and Mr.
Smart the
importance of becoming very knowledgeable about the
details in these
four accident reports. Always remember, AI 182 was a
plane crash, not
a bank robbery. Mr. Malik in prison will find the
reading of these
documents very enlightening. They will give him
hope.

The pattern in all four is wiring/cargo door rupture
event and not
bomb although for all four, bomb was the initial
explanation.

Cheers,
Barry

Hi Barry!

My name is Sundeep Kaur, I am helping Aniljit Singh
and Mr. Malik with legal research, etc.

YOu sent three reports to Aniljit Singh and he has
asked me to print them up, I was wondering if you
could send those reports to me as attachments so
that
i can do that. It is easier for us to review hard
copies of reports than on the computer. This would
be
much appreciated.

Thanks in advance.

Sundeep Kaur

=====
WAHEGURU JI KA KHALSA,
WAHEGURU JI KI FATEH!!!

SUNDEEP KAUR

From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Date: February 22, 2001 7:07:21 PM PST
To: John Barry Smith <barry@corazon.com>
Subject: **Re: UAL 811 report**

Barry,

you do not need to email these documents again. I am going to print them directly from your webpage.

thank you

Sundeep Kaur

Do You Yahoo!?
Yahoo! Auctions - Buy the things you want at great prices! http://auctions.yahoo.com/

From: Aniljit Singh <aniljitsingh@hotmail.com>
Date: February 23, 2001 10:14:17 AM PST
To: John Barry Smith <barry@corazon.com>
Subject: **Re: 747 retired Sikh pilot**

on 22/2/01 12:59 PM, John Barry Smith at barry@corazon.com wrote:

Also I learned yesterday that the crown may refuse the funding for Keith
Hamilton, the joint defence lawyer and that we may have to go at it by
ourselves.

Aniljit Singh

Dear Aniljit,

Oh, very disappointing if confirmed. His presence would cut a lot of
red tape in gaining access to the evidence in the hangars.

It's not fair that the Crown literally spends years and millions of dollars to prosecute a flimsy case against someone who will be bankrupted even if cleared.

However, there is a strong case for a successful suit against the Crown for not following up my contacts with them years ago. The RCMP
and TSB both are aware of the wiring/cargo door explanation and if
they had done their duty for public safety, they would not have arrested the accused; therefore there is a false arrest suit, and a wrongful harassment grievance in there somewhere. Malicious prosecution? I think so.

The quickest way to confirm the wiring/cargo door as cause for AI 182
and get charges dismissed is to positively match UAL 811 to AI 182.
This can be done by examining the videotapes. Then to match AI 182 to
PA 103 and that can be done by examining the wreckage in the hangar
in Farnborough. Then to match AI 182 to TWA 800 which can be done by
examining the evidence of the wreckage. Then all three can be matched
to the model, UAL 811.

Rather than refute the lies and misleading statements by

conspiracy
minded witnesses, let the Crown try to refute the wiring/cargo door
explanation for AI 182. It can't be done. I've tried for six years. The wiring/cargo door explanation always is confirmed from whatever
angle I approach it.

It's impossible to rebut fantasy thinking of conspiracy people, it's all hearsay. Let the Crown refute the science of reality with wreckage, tapes, sounds, metal, and latches; they will not be able to. Your case is won.

You should be able to obtain some financial and legal assistance on
such a major case. The Libyans had funding from the country. Canada
should provide something.

If Mr. Hamilton is not to be a member, who will I meet in Vancouver?

The time is now and the people to be persuaded are the lead attorneys
for both accused, Mr. Peck and Mr. Smart I believe, and the accused
themselves need to read the four accident reports. It will them hope.

The sooner I meet with the lead attorneys the better.

Cheers,
Barry

I am the contact person till such time that we find a more qualified
resource. I meet with Mr. Malik and Mr. Smart on almost a daily basis and I
will be discussing you with Mr. Smart or his partner Mr. Williams this
morning.

I admire your confidence and hope I can supplement it with the information
that you have requested.

Aniljit Singh

From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Date: February 23, 2001 10:47:52 AM PST
To: John Barry Smith <barry@corazon.com>
Subject: **Re: UAL 811 report**

Barry,

I just wanted to let you know I was successfully able
to print off the reports. THank you for your
cooperation and help.

Sundeep
--- John Barry Smith <barry@corazon.com> wrote:
Barry,

you do not need to email these documents again. I

am
going to print them directly from your webpage.

thank you

Sundeep Kaur

Sundeep, good thinking, thanks,

Cheers,
Barry

From: Aniljit Singh <aniljitsingh@hotmail.com>
Date: February 24, 2001 8:31:07 AM PST
To: John Barry Smith <barry@corazon.com>
Subject: **Re: Examination of the Narita incident**

on 23/2/01 6:54 PM, John Barry Smith at barry@corazon.com wrote:

Dear Aniljit, I just sent the below to Santokh. Note terrorist attack in 1988 and tower destruction of 1978. The bombing of June 1985 could have been the same people.

Barry

Santokh, Narita was no sleepy airport. There was planning to expand airport before 1986 when construction started. It is very possible that the violent group went to violence again in 1985 to protest expansion. Need more data. But....there was a motive for a 'bombing' at Narita that was independent of AI 182. And there was a terrorist attack in 1988. See, the whole Narita thing against AI 182 stinks. And destroy the Narita connection to AI 182 and the whole case falls apart.

Cheers,
Barry

1971, Sep. Second compulsory execution of the land expropriation by proxy
Three policemen killed in conflict during expropriation.

1977, May. Removal of the obstructing steel tower. The death of one the
supporters of the opposition group during the protest rally.

1978, Mar. The extremists attack on the control tower and subsequent
destruction of most of the equipment resulting in
the opening of the airport being postponed.

1978, May. Opening of Narita Airport (on 20 May)

1986, Nov. Start of land development work on second phase site.

1988, Sep.   Chairman of the Chiba Pref. Land Expropriation Committee
seriously injured in an attack of terrorism. All members
of the committee,thereby, resigned.

The solution to this problem was the second-phase zone, as originally planned. The construction work was begun in 1986.

Narita Airport (NRT) is the largest airport in Japan, used by fifty airline companies from thirty-eight countries. Proof that it's the major sky-gateway of Japan. From early morning until midnight the 4,000 meter runway is busy. A daily average of 335 planes arrive and depart carrying passengers and cargo.

Narita Airport is the sky-gate of Japan. Since its opening in 1978, its reputation has spread worldwide. 50 airline companies from 38 countries connect Narita Airport to 98 cities, handling on average 65,000 passengers and 4,200 tons of cargo daily, making it the fifth largest transporter of people in the world and the number one concerning its cargo transport. Because of increased demand for Terminal building 2 was opened in December 1992.

Overviews of the Narita Airport Disputes

1966, Jul.   The Cabinet decision of the construction of
Narita Airport

1966, Jul. Organization of the Opposition group against the airport (on 10 July)

1966, Jul. Establishment of the Airport Authority (on 30 July)

1969, Apr. Start of construction work of A runway and other facilities

1969, Dec. Authorization of the construction of Narita Airport according
to the Land Expropriation Law

1971, Feb. First compulsory execution of the land expropriation by proxy
1971, Sep. Second compulsory execution of the land expropriation by proxy
Three policemen killed in conflict during expropriation.

1977, May. Removal of the obstructing steel tower. The death of one the
supporters of the opposition group during the protest rally.

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destruction of most of the equipment resulting in
the opening of the airport being postponed.

1978, May. Opening of Narita Airport (on 20 May)

1986, Nov. Start of land development work on second phase site.

1988, Sep. Chairman of the Chiba Pref. Land Expropriation Committee seriously injured in an attack of terrorism. All members of the committee,thereby, resigned.

1990, Jan. Talk was held with Eto, the current Minister of Transport and the opposition group.

1990, Nov. Organization of the Regional Promotion and Liaison Conference

1991, Feb. Regional Promotion and Liaison Conference proposed the open symposium.

1991, Nov. Start of Narita Airport Issues Symposium

1992, Dec. Opening of Passenger Terminal 2

1993, May Final session of the Symposium

- To withdraw the authorization of the construction of Narita airport
- lanning of B,C runways should begin all over again.
- Organization of a new conference for talking regarding the airport issues All members agreed to the above

decisions.

1993, Sep. Start of Narita Airport Issues Round Table Conference

1994, Apr. Opening of a Community Consultation Center of the Airport Authority

1994, Oct. Final session of the Round Table Conference
- Break the conflicting relations
- Establishment of a new committee for Symbiosis between the Local Community and Narita Airport
- Establishment of a new committee for creating an Experimental Park Village regarding Global issues

Construction of parallel runway and cross runway should be constructed apart from each other

Improvement of the noise countermeasures

Regional promotion
All members agreed to the above decisions.

1994, Nov. The Airport Authority establishment of new organizations,
Symbiosis Office(Planning office for building partnerships with the local community) and Environment Management

Office, to implement the agreement at the Round Table Conference.

1995, Jan. Establishment of the Committee for Symbiosis between the Local Community and Narita Airport Ogawa group, one of the opposite groups, declared termination of opposition movements.

1995, Mar. Opening of Airport Information Center

1995, Dec. Issue of "Umenoki Common owned Land" solved, now in service as an apron.

1996, May Agreement of one of the farmers of the Ogawa group to trade with the Airport Authority for his land.

1996, May The holding of the 6th ACI(Airports Council International) Pacific Region Assembly and Conference at Narita with the theme "Airports and the Community Building Partnerships"

1996,July Relocation of the Airport Authority head office to Narita Airport.

+ Opposition Movement Gathers Strength

Chiba Prefecture took a resistant attitude to this decision, stating that there had not been sufficient communication in advance before the selection of Tomisato. It requested postponement of a decision on the airport's location at a Cabinet session. Local residents had shown signs of growing opposition to the new airport since the time when the selection of candidate sites was narrowed to either Tomisato or Kasumigaura, but after the unofficial decision for Tomisato, the opposition movement in the Tomisato area grew increasingly strong. Thereafter, in response to a request from the Ministry of Transport, Chiba Prefecture sought to improve the situation with thorough measures for local residents by the national government. However, government arrangements for those measures dragged on over some time, while local opposition continued to intensify. Ultimately it was decided that the government would postpone action on the Tomisato site for the time being.

+ Polarization of Conditional Acceptance vs. Opposition, - Formation of Airport Opposition Alliance -

The Chiba Prefecture Assembly had passed a resolution to promote construction of the airport as early as July 4, 1966. However, in the same month, the Narita City Assembly and Shibayama Town Assembly both passed resolutions opposing the airport, causing a complex situation. Still, enthusiastic efforts at persuasion by Chiba Prefecture and parties related to the airport bore fruit, and the Narita City Assembly overturned its resolution opposing the airport on August 2. As a result, there was a shift in controversy over the airport toward a focus on the conditions of its establishment. On August 25, the Community Association on Measures Relating to Narita Airport was formed. On December 27, Shibayama Town Assembly also overturned its resolution opposing the airport. Meanwhile, residents taking the stance of opposition to establishment of the airport formed the Sanrizuka Airport Opposition Alliance and the Shibayama District Sanrizuka Airport Opposition Alliance. On July 10, these groups were combined as the Sanrizuka-Shibayama Airport Opposition Alliance.

+ Tension Mounts on Night Before Opening

The year had finally arrived for the long-delayed opening of the new airport. Enormous losses had resulted from the delay in the airport's opening, not only to the Airport Authority but also to airport-related enterprises. This delay was also a critical problem for the persons who had provided land and now would make their living in a new way related to the airport. The opening date of the new airport was awaited impatiently by the government and Airport Authority, as well as by the city of Narita and other local governments, airline companies, related enterprises, and persons who had provided land. In November 1977, inspection of the airport's facilities was completed, and it remained only for governmental agencies and airline companies to relocate to Narita. It was decided that the airport would open on March 30, 1978. The Airport Authority notified the Minister of Transport of the opening date for the new airport on November 26, and the Minister of Transport announced this date on November 28. On

December 3, the Ministry of Transport issued a notice to airmen, or NOTAM, to the International Civil Aviation Organization (ICAO) and 50 related nations concerning the opening of the new airport, and announced the planned opening to the world. As the opening date drew near, preparatory work in the airport approached fever pitch. The atmosphere was charged with anticipation as boarding information announced by a computer-synthesized voice began to be broadcast for testing purposes. Meanwhile, tension was growing day by day around the airport. Opposition groups had mobilized protesters from around the country to carry on continuous protests. To prevent entry by the most violent faction, nine gates around the airport were kept under tight security, and the airport was enclosed by a chain-link fence three meters in height. Over 10,000 riot police were stationed all around the airport.

+ Control Tower Sabotaged on March 26

In spite of all this, a nightmarish incident took place. On the afternoon of March 26, some members of the most violent faction gained access to the control tower. They entered the sixteenth-floor control room and the fourteenth-floor micro-communications room, destroying control equipment and other property. This crippled communications for the transmission of air traffic control instructions, flight plans, and so on. It was not possible to conduct thorough repairs by the opening date, March

30. On March 28, the New Tokyo International Airport ministerial council officially decided to postpone the opening of the airport. The Ministry of Transport immediately dispatched a NOTAM concerning the delayed opening of the new airport to air travel related institutions all over the world.

+ Airport Opened Under Guard on May 20

The work of restoring the destroyed facilities was executed at a rapid pace, until it was judged that safety was assured. On April 4, the New Tokyo International Airport ministerial council again sent a NOTAM around the world stating that the new opening date would be May 20. The airline companies, which had already completed their preparations, began relocating to Narita on May 10, and this was completed on May 26. During this relocation, a total of 1,790 vehicles were use, and strict guard was maintained. The relocation was completed smoothly and without confusion. Finally, at midnight on May 20, Narita Airport was opened under tight security. The opening ceremony was held at 10:30 a.m. at the departure lobby in the north wing of the passenger terminal. It was attended by 58 persons, including the Minister of Transport and the president of the Airport Authority. Although simple, the ceremony was conducted with solemnity and included a prayer for safety. In a congratulatory speech, Minister of Transport Mr. Tominaga expressed his expectations for the future of Narita Airport with the proverb, "A child whose birth is difficult will grow smoothly to adulthood."

+ Second Passenger Terminal Opened on December 4, 1992

Following the airport's opening, it was operated with the facilities corresponding to the first-phase plan, which included Runway A, the first passenger terminal, and cargo handling facilities. This amounted to about half, or 550 hectares, of the total planned area. Compared to other major international airports, this was definitely not a large size. The airport was reaching its limits of handling capacity with regard to passenger demand, which was growing year by year. The solution to this problem was the second-phase zone, as originally planned. The construction work was begun in 1986. The second terminal was the first of the second-phase facilities to be completed, and opened on December 6, 1992. The new terminal housed 32 of the airline companies serving the airport. Since two terminals are now used in the operation of Narita Airport, customs and immigration procedures and boarding now occur smoothly even at peak times. The second passenger terminal is spacious, with 280,000 square meters of floor space, or about 1.6 times that of the first passenger terminal. In addition, the paths of passenger flow are divided clearly in a structure that allows for easy use, with the first and second floors used for arrivals and the third floor for departures. New services and facilities befitting a modern airport are found throughout the building, including a business travel center, refreshment room, game room, and audio-visual room. The world's first automatic shuttle system without a human operator provides access between the main building and the satellites.

Thank you for the e-mail. I am being flooded with information and am trying very hard to keep up. I have printed all the information you sent me and have copied one set for Narinderpal Singh who spoke to you earlier. He will be contacting you after he returns this weekend.

From: John Barry Smith <barry@corazon.com>
Date: February 24, 2001 10:02:50 AM PST
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net
Subject: **AI 182**

Dear Mr. Jeffrey Campbell,
Mr. Aniljit Singh Uppal,
Ms. Sundeep Kaur Dhaliwal,
Captain Santokh Singh,
Ms. Shyrone Kaur Singh,

From: John Barry Smith <barry@corazon.com>
Date: February 24, 2001 3:13:23 PM PST
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net

aft door
narita
ticketing
fifth pod
200 series
descending

800
streak
radar blip
door sill

103
shotgun
green diamond

811
fire on three
smaller hole
nose on

From: John Barry Smith <barry@corazon.com>
Date: February 27, 2001 7:26:22 AM PST
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: Another one bites the dust

Dear Crew,

The DC 10 evolved into the MD 11, a tri jet wide body. The DC

10 had three wiring/cargo door/explosive decompression events, the last out of Paris in 1974 which killed hundreds. The DC 10 never recovered from that bad reputation. McDonnell Douglas was bought by Boeing and now MD is gone. Boeing is losing market share yearly to Airbus.

The Comet never regained its place in commercial airline history after the window/metal fatiuge/explosive decompression events.

These fuselage structural failures due to design errors are fatal to the plane, the crew, the airline, and the manufacturer.

De Havilland, McDonnell, TWA, Pan AM, TWA, Air India, Comet, DC 10, and Boeing 747 have all been tainted by explosive decompression events.

There are other factors of course, but the public does not like to fly in planes that come apart in the air for mostly unexplained and unsatisfactory reasons.

Cheers,
Barry

LONG BEACH, Calif. - Almost to the day Donald Douglas flew his first plane 80 years ago, the last aircraft bearing the McDonnell Douglas name rolled out onto a Long Beach tarmac, ending another chapter of aviation history.

At an elaborate ceremony yesterday at the plant's main hangar, about 1,000 people - including former McDonnell Douglas executives, engineers and factory workers - watched as an MD-11 was delivered to Lufthansa. The airplane was the last of the widebody tri-jet aircraft built in Long Beach, ending a 30-year production run.

"It's the end of a historic era," said John Brizendine, former McDonnell Douglas president who retired in 1982 after 34 years at the company, which was acquired by Boeing in 1997. For Southern California, the delivery of the 200th MD-11 represents another retrenchment of its commercial-aircraft industry that once had massive factories stretching from Burbank to Long Beach to San Diego.

Commercial-aircraft manufacturing has basically dwindled to a single Boeing facility in Long Beach, where about 5,000 workers make the 106-passenger 717 jet that was derived from the original MD-95. In its heyday, the Long Beach complex had more than 160,000 workers, producing three to four different types of airplanes. McDonnell Douglas was created from a merger in 1967 of Donald Douglas' Douglas Aircraft and McDonnell Aircraft.

From: John Barry Smith <barry@corazon.com>
Date: February 28, 2001 11:05:46 AM PST
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **Lights, camera, action!**

Dear Crew,

Let me address the attorneys:

Dear gentlemen of the law: As you make your plea to the Crown for understanding and action, I make a plea to you:

Take action. Evaluate the proposition that your clients are innocent and evidence exists that will exonerate them. To do that you must talk to me; you must email me, you must call me, you must contact Santokh and Shyrone and Sundeep, ask the questions that only can can think of to rule in or rule out the wiring/cargo door/explosive decompression explanation for AI 182 and which a Boeing 747 pilot, a ticketing agent, and a fellow attorney can answer.

From your point of view, I believe you see the first priority is the release of your clients and I agree. How to to do that? Go for bail again with this new evidence. You may believe that a proper case for decompression needs to be developed and that takes time and your clients are in no danger from angry mobs or crashing airplanes. So you wait. You peruse. You contemplate. You weigh your options. You check expenses versus likelihood of success. You use your experience to imagine what will happen when you go to court and present to judge or jury the idea that AI 182 was not a bomb. And then your imagination sees the incredulity on people's face which then break out in laughter followed by ridicule from your fellow attorneys. Derision and scoffing in the press ensues and your future client list dries up. You will be forever known as the weirdo law firm that tried something so bizarre that you were laughed out of court literally and scorned thereafter.

Maybe. And then your clients go to jail forever. Your families starve. All is lost.

Well, I have faced that imagination for real for the last twelve years. I have been investigated, verbally attacked and ridiculed by authorities and media. It has affected my personal life with my wife and family and friends. So?

I have done more than anyone else on this planet to discredit the wiring/cargo door/explosive decompression explanation and I'm telling you straight out, it can't be done. I have made life and death decisions in flying based upon less certainty the AI 182 was not brought down by a bomb, and that goes for PA 103, and TWA 800. Yes, PA 103 not a bomb is a real laugher too. Ha, ha, ha.

I've been in a real sudden night fiery fatal jet airplane crash and I don't laugh at any possible cause of a sudden night fiery fatal jet airplane crashes, like AI 182 or PA 103 or TWA 800 or UAL 811.

So, I'm making my plea to you to not only consider the lives of your clients and their families but the lives and families of hundreds of thousands of other persons too, the current passengers and crews of airliners with this known faulty wiring problem which leads to the rupture/opening of the forward cargo door of early model Boeing 747s in flight causing explosive decompression.

This Poly X wiring problem is real and acknowledged by the authorities but they consider the problem to be mild and controllable, not leading to catastrophic failure of the airframe. AI 182 had Poly X wiring, as do all early model Boeing 747s.

The urgency is to protect others' lives, not only your clients. And for that I appeal to the Sikh aspect of this case. Sikhism, the little

I know about it, has concern for all persons, regardless of religious affiliation. Please have concern for the innocents flying right now above us in early model Boeing 747s with bad wiring. There are thousands. They are in danger.

How to approach the problem? How to persuade the aviation authorities a hazard exists which needs immediate attention with the side benefit of proving your clients innocent?

Well, after you have discussed with me all the aspects and become firmly convinced that AI 182 was explosive decompression at the forward cargo door and the cause was most likely bad wiring and most probably not a bomb, there are several ways.

1. Call another bail hearing and present the evidence to a judge. He will probably plead ignorance about technical aviation matters and deny request.

2. Bring in right now TSB and RCMP officials. Let me meet them; I can present the wiring/cargo door/explosive decompression evidence which carries weight since it came from the TSB and RCMP themselves and irrefutable since it has support from PA 103, TWA 800 and UAL 811 events. Hindsight is ever wiser. They will have to act. Their testimony in front of the bail judge will carry weight.

3. Contact your press reporters such as Bob Matas of the Globe and Mail and present to them the concept that you have stumbled upon an alternate explanation for AI 182 but the research and confirmation is beyond your means and could they help? Present the wiring/cargo door/explosive decompression explanation and ask that they contact their experts for evaluation referring them

to www.corazon.com Once the idea is out in the open, the aviation media can turn their attention to it, attack it, try to rebut it, and will fail, if they stick to the evidence and stay away from the nutty conspiracy nonsense. Of course they will relive the Narita event and the ticketing procedures, that is good, now is the time to show how flimsy that circumstantial and hearsay evidence is and how strong the wiring/cargo door/explosive decompression explanation is.

Instead of you rebutting conspiracy craziness, which is almost impossible, have the world's aviation press try to discredit the mechanical explanation with precedent of UAL 811 for AI 182. They will not be able to do it because it is the correct explanation with real evidence for support.

Once the idea of explosive decompression not caused by a bomb for AI 182 is in the minds of the aviation authorities and press, then the evidence to persuade a jury can be obtained, such as access to Farnborough hangar in England for PA 103 wreckage, and the hangar in which TWA 800 wreckage resides, exactly for this purpose, for further examination. The videotapes of AI 182 and other photographs now held by the RCMP can be examined. The Narita trial transcripts can be obtained. Depositions can be obtained on several officials who were involved with AI 182 and PA 103, UAL 811, and TWA 800. Forensic evidence on the victims can be evaluated. There is much more but you have the power to get it under discovery rules of law.

I opt for number two. Let me meet with you and aviation safety officials in a room with my computers, text, documents, photographs, and charts and let me persuade them that clear and present dangers exists right now for thousands of citizens for which they have been entrusted with the public safety. This possibility mandates immediate action, such as ruling in or ruling out the wiring/cargo door/explosive decompression explanation for AI 182 and that requires their cooperation with you and me. We are all on the same side in proving a hazard to innocents exists, if it does.

The aviation officials may not care about your clients but they will care about the thousands of other citizens at risk, as I do, as the Sikhs do, and I trust you do.

Regardless of strategy, please act. Rule it in or rule it out, but please do not ignore the wiring/cargo door/explosive decompression explanation for AI 182.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Quote from TWA 800 Public Docket 516A, Exhibit 9A Systems Group Chairman's Factual report of Investigation, Page 47, "A Boeing telefax of June 25, 1997, stated that: The Poly-X wire was used as general purpose wire on the RA164 (TWA 800) aircraft. Wire insulation known as Poly-X had three in-service problems:
-Abrasion of the insulation in bundles installed in high vibration areas.

(This problem was corrected by Boeing Service Bulletin No. 747-71-7105, Dated July 19, 1974)
-Random flaking of the topcoat.
-Insulation radial cracks in tight bend radii.
Radial cracking phenomenon of the Poly-X wire was mainly associated with mechanical stress. Bend radius is the largest contributor to mechanical stress in installed wire or cable. Presence of moisture in conjunction with mechanical stress is also a contributor."

The Systems Exhibit 9A continues on same page 47, "Evidence of arcing or short circuiting was found in the fuselage of N93119, (TWA 800) in addition to what was found in the wiring from the raceway below the left cabin floor and near the forward wing spar.

The Systems Exhibit 9A continues, page 116:
"Some wires found in the section of W480 from forward of station 570 and identified as BMS13-42A had numerous cracks in the insulation. Most of the cracks in this bundle were found to expose the core conductor when examined by microscope. Only within five feet of the aft end of the W480 bundle from station 570-900 were insulation cracks found."

(Please note that BMS13-42A is Poly-X wiring. Cargo door location is FS 560-670 and cracked wires discovered are within that zone. Frayed wires in that area have shorted before and caused the forward cargo door to open in flight, NTSB AAR 92/02 UAL 811. Water has been seen pouring out of a forward cargo bay of a Boeing airliner. Water and leaking electricity make a powerful conductor. Both are known to exist in Boeing airliners.)

From: John Barry Smith <barry@corazon.com>
Date: February 28, 2001 1:49:33 PM PST
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **You guys all right?**

Hey, Earthquake!

You guys up there in Vancouver all right? Need bottled water to fight of Cholera? How about some sniffing dogs?

Really, I hope everyone and your families made it through all right. Here in California we take quakes very seriously.

Good Luck,

Barry

From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Date: February 28, 2001 2:53:20 PM PST
To: John Barry Smith <barry@corazon.com>
Subject: **Re: You guys all right?**

Hey Barry!

We are all fine thank you...no dogs or water
needed...the crown might need it though...just b/c
they are in those high downtown buildings..

cheers..

sundeep kaur
--- John Barry Smith <barry@corazon.com> wrote:
Hey, Earthquake!

You guys up there in Vancouver all right? Need
bottled water to fight
of Cholera? How about some sniffing dogs?

Really, I hope everyone and your families made it
through all right.
Here in California we take quakes very seriously.

Good Luck,

Barry

From: "aniljit singh uppal" <aniljitsingh@hotmail.com>
Date: February 28, 2001 4:51:21 PM PST
To: barry@corazon.com

Subject: **Re: You guys all right?**

From: John Barry Smith <barry@corazon.com>
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: You guys all right?
Date: Wed, 28 Feb 2001 13:49:33 -0800

Hey, Earthquake!

You guys up there in Vancouver all right? Need bottled water to fight
of Cholera? How about some sniffing dogs?

Really, I hope everyone and your families made it through all right.
Here in California we take quakes very seriously.

Thank you for asking. We are all fine.

Aniljit Singh
Good Luck,

Barry

---

www.hotmail.com.

From: John Barry Smith <barry@corazon.com>
Date: March 3, 2001 9:11:14 AM PST
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my, dsreyat@hotmail.com
Subject: **For Mr. Malik**

Dear Mr. Bill Smart, 3 Mar 01

The following is a personal note for Mr. Malik. I believe a personal contact from me is important for him to know I am a real person with real experience and knowledge. My research and analysis proves him innocent and will give him hope. He can confirm my analysis himself by reading the officials reports and visiting my web site for further information.

I do hope you can get internet access privileges granted to him. It's only fair since he is not on bail and unable to assist in his own defence.

Good luck with the funding for assisting experts in law and aviation, as well as gaining access to the evidence used against him.

I am available anytime to discuss the wiring/cargo door/ explosive decompression explanation for AI 182 and others at your convenience. The sooner the better. I look forward to meeting with you and your staff.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Dear Mr. Malik,

You have been described as a "Millionaire Sikh businessman' and yet I am now told 'I am a friend of Mr. Malik's who has served at the Board of the Khalsa Schools in Vancouver and Surrey founded by Mr. Malik.". I will thus address you, sir, as an educator; and that means you respect reason, logic, and a well constructed argument with a deserved point.

My point is you are innocent of the crime for which you are confined and that thousands of others are currently at risk because of mechanical flaws in commercial aircraft.

I know you did not plant a bomb on Air India Flight 182. You may believe a bomb caused the crash of AI 182 but that you did not put it there and someone else did.

I know you did not put a bomb on AI 182 because I know nobody put a bomb on the plane. There was no bomb. There was no crime. There are no criminals. You are innocent.

There was an event on AI 182 which mimics a bomb; it's call explosive decompression. It's happened before in a similar type aircraft as AI 182 and left similar evidence. That accident is called UAL 811. AI 182 and UAL 811 are mechanical accidents and not evil plots although both were initially thought by authorities to be plots by bombers.

I know this through twelve years of research into the specific causes of explosive decompressions in early model Boeing 747s which leave a sudden loud sound on the cockpit voice recorder quickly followed by an abrupt power cut to the flight data recorder; events of which there are certainly four, AI 182, PA 103, UAL 811, and TWA 800. I know there was no bomb on AI 182 because of my forty years of aviation experience to include my years as aircrewman, mechanic, navigator, bombardier, and pilot. I know this belief of no bomb for AI 182 and which few others believe because of my objectivity of having no official conflict of interest connection to manufacturer, airline, law enforcement, legal, media, or grieving family members. My motive, as best as I can explain it to myself and my family and friends, is that a pilot literally saved my life years ago in a sudden night fiery fatal jet airplane crash. He lost his life very possibly because he took the two seconds to tell me to eject which I did. He died because his parachute did have the two seconds to blossom and he hit the ground very hard.I did have the two seconds for my chute to blossom which is the time I was in the air before landing and fracturing my back but otherwise all right. I am repaying a moral debt.

The political aspects of these four aircraft crashes are complex. They are very interesting, as all conspiracy spy fiction is. I urge you sir, to forego explaining what is happening to you with conspiracy nonsense. Try not to explain anything about AI 182 through plots of either the Indian government, rogue Sikhs, or collusion between government agencies in the UK or USA. Everyone is acting in their own perceived best interest and that interest is dictating that the persons and agencies involved are blameless and the cause lies elsewhere, specifically in your cell. Yes, you are a martyr; yes you are innocent, yes, it is unfair, yes, it is an injustice, yes, you can never be adequately compensated for the time spent away from your family and friends and profession, yes, the prosecutors and RCMP are cheating to try to get a conviction, yes, the public turns against you because they are told you did a heinous crime, and yes, your life is ruined.

Well, not yet ruined; changed yes, but until convicted, not ruined.

The answers to AI 182 are the answers found in any plane crash. The machine flies according to the rules of science and it crashes according to the same. Do you respect science? Do you know why a balloon pops? Do you know why your hand moves backward when you stick it out of a moving car window and turn it against the wind? Do you know why lightning strikes?

If you answer 'yes' to those questions you can understand what happened to AI 182, PA 103, UAL 811. and TWA 800 and thus why you are innocent and also why the authorities think bombs or fuel tanks caused the accidents.

If you understand the value of education then you must educate yourself and that means research. Research means reading through and though the aircraft accident reports, AAR, of AI 182, PA 103, UAL 811, and TWA 800. They contain hundreds and hundreds of pages of facts, data, evidence, and interpretation. Concentrate on the facts, data, and evidence, and always take into account the bias of the interpretations of the authorities who are prosecuting a cause more than an objective investigation. The raw data in the evidence is what counts and it consistently supports the wiring/cargo door/explosive decompression explanation for all four accidents. You can confirm that conclusion yourself. You can try to refute it as I have done for a dozen years.

As you read the reports, please make notes of questions that come into your mind. Then try to answer the questions yourself by rereading the texts. When you find that the answers to very important and relevant questions are not answered in the texts, then ask me and I will try; however, many important, relevant questions that should have been asked and answered in an objective AAR are missing. There are glaring omissions. I know the questions that need answering which are only possible by you, as the defendant who has certain rights unavailable to the manufacturer, the media, the airline, or me. That right is called the right to examine the evidence used against you. The process is called discovery. You have the right, and I encourage, even insist, Mr. Malik, you exert that right to demand several things:

1. Access to the videotapes of AI 182 and all photographs, and all wreckage databases, now held by TSB and RCMP.
2. Access to the wreckage of PA 103 in the hangar in Farnborough UK.
3. Access to the wreckage of TWA 800.
4. Access to all records of UAL 811 held by NTSB.
5. Obtaining the forensic autopsy reports for AI 182.
6. Obtaining the records of the Narita bombing trial and all data about CP Flight 003.
7. Interview notes with ticket taker for AI 182.
8. Maintenance logs of the aircraft for a period before the accident AI 182.
9. Maintenance report on the aft cargo door removal and

reinstallation. AI 182
10. CVR evaluation report. AI 182
11. FDR evaluation report. AI 182

I believe you have a legitimate requests from the Crown in your category as suspect but not yet convicted:
1. A legal expert to assist you.
2. An aviation technical expert to assist you.
3. Access to the internet.

To achieve the latter, agree that all your web sites will be logged and reviewed; agree that all your emails be logged and screened. Internet access for you is essential and can be done. A phone line is needed for just a few minutes a day for upload and download and then later you can review the information received and prepare your outgoing mail.

You are innocent until proven guilty. You must assist in your own defense and to do that you need interactive outside information via phone, letter and the internet.

I know full well the consequences of the wiring/cargo door/ explosive decompression explanation for the three crashes which now are blamed on terrorists and a spontaneous center fuel tank explosion with an unknown ignition source. USA, UK, Canada, Libya, Malta, Germany, New Zealand, Australia, and India are all involved as well as manufacturers, airlines, and victims worldwide. Political boundaries will shift and billions of dollars will change hands. So be it.

Prison experience, I imagine, can be excruciating. My only taste was a week of pretend Prisoner of War camp that the US Navy operated in the mountains of Maine. All aircrews who were to fly over North Vietnam in combat were sent there. The physical tortures were real such as naked punishment in snow and being slapped around but the most severe tortures were the mental. We were sleep and food deprived for days. We were shut up in small boxes in a small room in a small camp harassed by callous guards with barbed wired everywhere. We were humiliated and coerced in attempts to make us sign confessions or to make otherwise damaging admissions in return for some small favor. Any racist tendencies were exploited. We were encouraged to betray our shipmates. My pilot and I successfully finished the course and were released/graduated. The sights and sounds and smells and tastes of that short period of my life remain with me to this day even thirty four years later. I draw upon that stressful time in the past for handling stressful times in the present to keep body and soul together.

I will be meeting your brother in law, Narinder, on Tuesday, 6 March, at 11AM in my home. I have faith in his understanding because he is an engineer and will respect facts, data, and evidence.

I am always available by letter, email, or phone to you, Mr. Malik, good luck.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: March 4, 2001 12:47:09 PM PST
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **More cargo doors open in flight than bombs go off**

Various cargo door/depressurization accidents:

T96-01-51 BOEING

TRANSMITTED AS FOLLOWS IS TELEGRAPHIC
AIRWORTHINESS
DIRECTIVE T96-01-51 FOR IMMEDIATE TRANSMITTAL
TO ALL OWNERS
AND OPERATORS OF BOEING MODEL 747-100 SERIES
AIRPLANES
MODIFIED IN ACCORDANCE WITH SUPPLEMENTAL
TYPE CERTIFICATES
(STC) SA2322SO AND A MODEL 747-200 SERIES
AIRPLANE MODIFIED
IN ACCORDANCE WITH STC SA4227NM-D.
THE FAA HAS RECENTLY RECEIVED A REPORT THAT
THE
FLIGHTCREW ON A BOEING MODEL 747-100 SERIES

AIRPLANE NOTED
AN ABNORMAL CABIN ALTITUDE RATE OF CLIMB. ALTHOUGH THE
PRESSURIZATION VENT DOOR LIGHT WAS NOT ILLUMINATED (WHICH
INDICATED TO THE FLIGHTCREW THAT THE DOOR WAS CLOSED AND
LOCKED), THE FLIGHTCREW WAS UNABLE TO PRESSURIZE THE
AIRPLANE. THE FLIGHTCREW ALSO NOTED THAT THE MAIN DECK SIDE
CARGO "DOOR UNLOCKED" LIGHT ILLUMINATED SHORTLY AFTER
TAKEOFF. INVESTIGATION REVEALED THAT 11 OF THE 12 LATCHES
ON THE MAIN DECK SIDE CARGO DOOR WERE UNLATCHED AND
UNLOCKED. HOWEVER, THE PRESSURIZATION VENT DOOR WAS CLOSED
AND LOCKED, WHICH WOULD INDICATE A MALFUNCTION OF THE SAFETY
INTERLOCK SYSTEM.
A PROPERLY FUNCTIONING SAFETY INTERLOCK SYSTEM ELECTRO-
MECHANICALLY PREVENTS THE PRESSURIZATION VENT DOOR FROM
CLOSING UNTIL ALL OF THE LATCHES ARE IN THE FULLY LATCHED
AND LOCKED POSITION. IF THE PRESSURIZATION VENT DOOR IS NOT
CLOSED THE AIRPLANE CANNOT BE PRESSURIZED.
ALTHOUGH THE ORIGINAL CAUSE OF THE FAILURE TO PROPERLY

LATCH THE DOOR MAY BE ATTRIBUTABLE TO HUMAN ERROR, THE
PURPOSE OF THE INTERLOCK SYSTEM IS TO ENSURE THAT SUCH
ERRORS ARE DETECTED SO THAT THE AIRPLANE CANNOT BE
PRESSURIZED UNLESS THE MAIN DECK SIDE CARGO DOOR IS PROPERLY
LATCHED AND LOCKED. MALFUNCTION OF THE SAFETY INTERLOCK
SYSTEM OF THE MAIN DECK SIDE CARGO DOOR, IF NOT CORRECTED,
COULD RESULT IN AN IN-FLIGHT OPENING OF THE MAIN DECK SIDE
CARGO DOOR, AND SUBSEQUENT RAPID DECOMPRESSION OF THE
AIRPLANE.
THE AIRPLANE IN THE REPORTED INCIDENT WAS MODIFIED IN
ACCORDANCE WITH SUPPLEMENTAL TYPE CERTIFICATE (STC)
SA2322SO. THE MODIFICATION ENTAILED INSTALLATION OF A MAIN
DECK SIDE CARGO DOOR AS PART OF A CONVERSION THAT
RECONFIGURED THE AIRPLANE FROM A PASSENGER CONFIGURATION TO
A SPECIAL FREIGHTER CONFIGURATION.
SINCE STC SA2322SO FOR MODEL 747-100 SERIES AIRPLANES IS
SIMILAR IN DESIGN TO STC SA4227NM-D FOR A MODEL 747-200
SERIES AIRPLANE, THE FAA HAS DETERMINED THAT

THE UNSAFE
CONDITION MAY ALSO EXIST ON A MODEL 747-200
SERIES AIRPLANE
THAT HAS BEEN MODIFIED IN ACCORDANCE WITH STC
SA4227NM-D.
THIS STC CONVERTED A MODEL 747-200 SERIES
AIRPLANE FROM A
PASSENGER CONFIGURATION TO A SPECIAL
FREIGHTER
CONFIGURATION.
SINCE AN UNSAFE CONDITION HAS BEEN IDENTIFIED
THAT IS
LIKELY TO EXIST OR DEVELOP ON OTHER AIRPLANES
OF THIS SAME
TYPE DESIGN, THIS TELEGRAPHIC AIRWORTHINESS
DIRECTIVE IS
ISSUED TO REQUIRE REPETITIVE INSPECTIONS OF THE
LATCH SAFETY
PINS OF THE MAIN DECK SIDE CARGO DOOR.
THIS TELEGRAPHIC AD ALSO REQUIRES
DEACTIVATION OF THE
"LATCHES UNLOCKED" LIGHT AT THE DOOR
OPERATING PANEL AND THE
"DOOR UNLOCKED" LIGHT AT THE FLIGHT ENGINEER
PANEL, AND
FABRICATION AND INSTALLATION OF A PLACARD TO
INDICATE THAT
THE "DOOR UNLOCK" LIGHT AT THE FLIGHT ENGINEER
(F/E) PANEL
HAS BEEN DEACTIVATED, IN ACCORDANCE WITH A
METHOD APPROVED
BY THE FAA.
THIS TELEGRAPHIC AD PROVIDES FOR TERMINATION

OF THE
REQUIREMENT TO REPETITIVELY INSPECT THE PINS AND REMOVAL OF
THE PLACARD FOLLOWING ACCOMPLISHMENT OF A MODIFICATION THAT
POSITIVELY ADDRESSES THE UNSAFE CONDITION AND THAT HAS BEEN
APPROVED BY THE FAA.
THIS IS CONSIDERED TO BE INTERIM ACTION UNTIL FINAL
ACTION IS IDENTIFIED, AT WHICH TIME THE FAA MAY CONSIDER
FURTHER RULEMAKING.
THIS RULE IS ISSUED UNDER 49 U.S.C. SECTION 44701
(FORMERLY SECTION 601 OF THE FEDERAL AVIATION ACT OF 1958)
PURSUANT TO THE AUTHORITY DELEGATED TO ME BY THE
ADMINISTRATOR, AND IS EFFECTIVE IMMEDIATELY UPON RECEIPT OF
THIS TELEGRAM.

T96-01-51 BOEING: TELEGRAPHIC AD ISSUED ON JANUARY 3,
1996. DOCKET NO. 96-NM-01-AD.
APPLICABILITY: MODEL 747-100 SERIES AIRPLANES HAVING
SERIAL NUMBERS 19637, 19638, 19642, 19647, 19648, 19657,
19725, 20320, AND 20347, THAT HAVE BEEN MODIFIED IN
ACCORDANCE WITH SUPPLEMENTAL TYPE CERTIFICATE (STC)
SA2322SO, AND MODEL 747-200 SERIES AIRPLANE

HAVING SERIAL
NUMBER 20010 THAT HAS BEEN MODIFIED IN ACCORDANCE WITH STC
SA4227NM-D, CERTIFICATED IN ANY CATEGORY.
NOTE 1: THIS AD APPLIES TO EACH AIRPLANE IDENTIFIED IN
THE PRECEDING APPLICABILITY PROVISION, REGARDLESS OF WHETHER
IT HAS BEEN MODIFIED, ALTERED, OR REPAIRED IN THE AREA
SUBJECT TO THE REQUIREMENTS OF THIS AD. FOR AIRPLANES THAT
HAVE BEEN MODIFIED, ALTERED, OR REPAIRED SO THAT THE
PERFORMANCE OF THE REQUIREMENTS OF THIS AD IS AFFECTED, THE
OWNER/OPERATOR MUST USE THE AUTHORITY PROVIDED IN PARAGRAPH
(D) OF THIS AD TO REQUEST APPROVAL FROM THE FAA. THIS
APPROVAL MAY ADDRESS EITHER NO ACTION, IF THE CURRENT
CONFIGURATION ELIMINATES THE UNSAFE CONDITION; OR DIFFERENT
ACTIONS NECESSARY TO ADDRESS THE UNSAFE CONDITION DESCRIBED
IN THIS AD. SUCH A REQUEST SHOULD INCLUDE AN ASSESSMENT OF
THE EFFECT OF THE CHANGED CONFIGURATION ON THE UNSAFE
CONDITION ADDRESSED BY THIS AD. IN NO CASE DOES THE
PRESENCE OF ANY MODIFICATION, ALTERATION, OR

REPAIR REMOVE
ANY AIRPLANE FROM THE APPLICABILITY OF THIS AD.
COMPLIANCE: REQUIRED AS INDICATED, UNLESS ACCOMPLISHED
PREVIOUSLY.
TO PREVENT MALFUNCTION OF THE SAFETY INTERLOCK SYSTEM OF
THE MAIN DECK CARGO DOOR AND SUBSEQUENT RAPID DECOMPRESSION
OF THE AIRPLANE DUE TO IN-FLIGHT OPENING OF THE MAIN DECK
SIDE CARGO DOOR, ACCOMPLISH THE FOLLOWING:
(A) NOTWITHSTANDING THE REQUIREMENTS OF PARAGRAPH E. OF
AD 90-09-06, AMENDMENT 39-6581, WITHIN 3 DAYS AFTER RECEIPT
OF THIS TELEGRAPHIC AD, DEACTIVATE THE "LATCHES UNLOCKED"
LIGHT AT THE DOOR OPERATING PANEL AND THE "DOOR UNLOCKED"
LIGHT AT THE F/E PANEL, AND FABRICATE AND INSTALL PLACARDS;
IN ACCORDANCE WITH A METHOD APPROVED BY THE MANAGER, ATLANTA
AIRCRAFT CERTIFICATION OFFICE (ACO), FAA, SMALL AIRPLANE
DIRECTORATE.
(B) WITHIN 3 DAYS AFTER RECEIPT OF THIS TELEGRAPHIC AD,
ACCOMPLISH THE REQUIREMENTS OF PARAGRAPHS (A)(1), (A)(2),
(A)(3), (A)(4), (A)(5), AND (A)(6) OF THIS AD. REPEAT THESE

PROCEDURES THEREAFTER PRIOR TO EACH FLIGHT. THESE
PROCEDURES MUST BE PERFORMED BY PROPERLY TRAINED AND
QUALIFIED MAINTENANCE PERSONNEL.

(1) CLOSE THE MAIN DECK SIDE CARGO DOOR IN ACCORDANCE WITH NORMAL OPERATIONS PROCEDURES.

(2) UNSCREW, LIFT, AND SECURE THE DOOR LOWER ACCESS
PANELS IN THE "UP" POSITION.

(3) PERFORM A VISUAL INSPECTION OF ALL 12 LATCH AND
LOCK ARMS TO ENSURE THAT THEY ARE OVERCENTER IN THE "LOCKED"
POSITION AND THAT ALL ALIGNMENT MARKS LINE-UP CORRECTLY.

(4) PERFORM A DETAILED VISUAL INSPECTION TO ENSURE
THAT THE TEN PHOTO SCANNER ALIGNMENT HOLES IN LATCHES 2
THROUGH 11 HAVE NO OBSTRUCTIONS.

(I) COUNTING FORWARD TO AFT, INSTALL PINS IN PHOTO SCANNER ALIGNMENT HOLES IN LATCH ASSEMBLIES 2 THROUGH
11. THE SAFETY PINS MUST ENGAGE LOCK ARM AND LATCH ARM
LEVER AND GO COMPLETELY THROUGH LATCH ASSEMBLY.

(II) ALL LATCH SAFETY PINS MUST BE FASTENED TOGETHER WITH A SAFETY CABLE, AND THE SAFETY CABLE MUST BE
ATTACHED TO THE MAIN DECK DOOR SILL

PROTECTOR.
(III) LOWER AND SECURE THE LOWER ACCESS PANELS IN PLACE.
(IV) OPEN CIRCUIT BREAKER HC5, LOCATED ON
P-10, MAIN POWER CENTER-LEFT.
(5) TO CLOSE THE PRESSURE VENT DOOR ON THE MAIN DECK
SIDE CARGO DOOR, ACCOMPLISH PARAGRAPHS (A)(5)(I),
(A)(5)(II), (A)(5)(III), AND (A)(5)(IV) OF THIS AD.
(I) REMOVE PRESSURE VENT DOOR COVER,
(II) MANUALLY RETRACT THE TWO SOLENOID VALVES
TO ALLOW PRESSURE VENT DOOR CLOSURE,
(III) CLOSE PRESSURE VENT DOOR, AND
(IV) REPLACE VENT DOOR COVER.
(6) ALL SAFETY PINS MUST BE REMOVED BEFORE OPENING
OR OPERATING CARGO DOOR, AND
(C) ACCOMPLISHMENT OF A MODIFICATION IN ACCORDANCE WITH
A METHOD APPROVED BY THE MANAGER, ATLANTA, ACO CONSTITUTES
TERMINATING ACTION FOR THE REQUIREMENTS OF THIS AD.
(D) AN ALTERNATIVE METHOD OF COMPLIANCE OR ADJUSTMENT OF
THE COMPLIANCE TIME THAT PROVIDES AN ACCEPTABLE LEVEL OF
SAFETY MAY BE USED IF APPROVED BY THE MANAGER, ATLANTA ACO.
OPERATORS SHALL SUBMIT THEIR REQUESTS THROUGH AN APPROPRIATE
FAA PRINCIPAL MAINTENANCE INSPECTOR, WHO MAY

ADD COMMENTS
AND THEN SEND IT TO THE MANAGER, ATLANTA ACO.
NOTE 2: INFORMATION CONCERNING THE EXISTENCE OF
APPROVED ALTERNATIVE METHODS OF COMPLIANCE WITH THIS AD, IF
ANY, MAY BE OBTAINED FROM THE ATLANTA ACO.
(E) SPECIAL FLIGHT PERMITS MAY BE ISSUED IN ACCORDANCE
WITH SECTIONS 21.197 AND 21.199 OF THE FEDERAL AVIATION
REGULATIONS (14 CFR 21.197 AND 21.199) TO OPERATE THE
AIRPLANE TO A LOCATION WHERE THE REQUIREMENTS OF THIS AD CAN
BE ACCOMPLISHED.
(F) INFORMATION PERTINENT TO THIS RULEMAKING ACTION MAY
BE EXAMINED AT THE FAA, TRANSPORT AIRPLANE DIRECTORATE, 1601
LIND AVENUE, SW., RENTON, WASHINGTON; OR AT THE FAA, SMALL
AIRPLANE DIRECTORATE, ATLANTA AIRCRAFT CERTIFICATION OFFICE,
CAMPUS BUILDING, 1701 COLUMBIA AVENUE, SUITE 2-160, COLLEGE
PARK, GEORGIA 30337-2748.
(G) TELEGRAPHIC AD T96-01-51, ISSUED ON JANUARY 3, 1996,
BECOMES EFFECTIVE UPON RECEIPT.
FOR FURTHER INFORMATION CONTACT: RANDY AVERA, AEROSPACE
ENGINEER, SYSTEMS AND EQUIPMENT BRANCH,

ACE-130A, FAA, SMALL
AIRPLANE DIRECTORATE, ATLANTA AIRCRAFT
CERTIFICATION OFFICE,
CAMPUS BUILDING, 1701 COLUMBIA AVENUE, SUITE
2-160, COLLEGE
PARK, GEORGIA 30337-2748; TELEPHONE (404) 305-7381;
FAX
(404) 305-7348.

NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-80-20
Last Updated: 09-21-94
[O] On march 8, 1980, a swearingen sa-226 at, n720r, with a crew of two and sixpassengers, experienced a rapid decompression at 16,000 feet
when most of the aft cargo compartment door separated in flight. About 3/4 of the door along with interior furnishings, including an
unoccupied passenger seat, separated from the aircraft. Two passengers were injured slightly during the decompression and the empennage
was damaged slightly when some of the material from the cargo door or the cabin struck the upper fuselage and thevertical stabilizer. Some
of the material from the cabin lodged around thecontrol surfaces in the empennage. A safe landing was made in albany, new york. Although
ground search continues for the separated items, only baggage

has thus far been recovered.
Recommendations:
A-80-20. Issue a telegraphic ad requiring an immediate inspection of the door latching mechanism of the aft cargo doors on all swearingen
SA-226 aircraft to assure proper adjustment and structural integrity.
Responses:
FAA LTR DTD: 05/13/80
Emergency telegraphic airworthiness directive (ad), no. T80sw14, applicable to operators of swearingen model sa226tc airplanes, was issued
march 15, 1980. The ad required an immediate inspection of the door latching mechanism of the aft cargo door to assure proper adjustment,
operation, and structural integrity, and prohibited flight operation with pressurized cabin. Later on 3/15, ad t80sw 14 was amended by adding a
clarifying paragraph requiring compliance prior to further flight. On 3/19, telegraphic ad t80sw 15 was issued, superseding ad t80sw 14, as
amended. This ad t80sw 15 includes the provisions of ad t80sw 14 and provides for inspection at 250-hour intervals to assure proper adjustment,
operation, an structural integrity of the door system. Enclosed are copies of all referenced ads. We are in receipt of the ntsb letter dated may 5
and note that recommenda- tions a-80-20 and 21 are now classified in a closed--acceptable action status.
NTSB LTR DTD: 05/05/80
The safety board has examined emergency telegraphic airworthiness directive (ad), no. 580sw14, dated march 15, 1980, as amended, and

emergency telegraphic ad t80sw15, dated march 19, 1980. We are satisfied that compliance with these ad's will fulfill safety recommendations
a-80-20 and 21, which are now classified in a closed-- acceptable action status.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-80-21
Last Updated: 09-21-94
[O] On march 8, 1980, a swearingen sa-226 at, n720r, with a crew of two and sixpassengers, experienced a rapid decompression at 16,000 feet
when most of the aft cargo compartment door separated in flight. About 3/4 of the door along with interior furnishings, including an
unoccupied passenger seat, separated from the aircraft. Two passengers were injured slightly during the decompression and the empennage
was damaged slightly when some of the material from the cargo door or the cabin struck the upper fuselage and thevertical stabilizer. Some
of the material from the cabin lodged around thecontrol surfaces in the empennage. A safe landing was made in albany, new york. Although
ground search continues for the separated items, only baggage has thus far been recovered.
Recommendations:
A-80-21. Issue an ad restricting the cabin pressure differential in swearingen SA-226 aircraft until the cause of the aft cargo door failure can be
determined and an appropriate corrective action carried out.
Responses:
NTSB LTR DT: 05/05/80

The safety board has examined emergency telegraphic airworthiness directive (ad), no. T80sw14, dated march 15, 1980, as amended, and
emergency telegraphic ad, t80sw15, dated march 19, 1980. We are satisfied that compliance with these ad's will fulfill safety recommendations
a-80-20 and 21, which are now classified in a closed-- acceptable action status.
FAA LTR DTD: 05/13/80
Emergency telegraphic airworthiness directive (ad), no. T80sw14, applicable to operators of swearingen model sa226tc and sa226at airplanes,
was issued on march 15, 1980. The ad required an immediate inspection of the door latching mechanism of the aft cargo door to assure
proper adjustment, operation, and structural integrity, and prohibited flight operation with a pressurized cabin. Later on march 15, ad t80sw 14
was amended by adding a clarifying para- graph requiring compliance prior to further flight. On march 19, telegraphic ad t80sw 15 was issued,
superseding ad t80sw 14 as amended. This ad t80sw 15 includes the provisions of ad t80sw 14 and provides for inspection at 250-hour intervals
to assure proper adjustment, operation, and structural integrity of the door system. Enclosed are copies of all referenced ads. We are in
receipt of the ntsb letter dated mary 5 and note that recommendations a-80-20 and 21 are now classified in a closed-- acceptable action status.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-80-76

Last Updated: 09-21-94
[O] On march 8, 1980, a swearingen sa-226 at, n720r, with a crew of two and sixpassengers, experienced a rapid decompression at 16,000 feet
when most of the aft cargo compartment door separated in flight. About 3/4 of the door along with interior furnishings, including an
unoccupied passenger seat, separated from the aircraft. Two passengers were injured slightly during the decompression and the empennage
was damaged slightly when some of the material from the cargo door or the cabin struck the upper fuselage and thevertical stabilizer. Some
of the material from the cabin lodged around thecontrol surfaces in the empennage. A safe landing was made in albany, new york. Although
ground search continues for the separated items, only baggage has thus far been recovered.
Recommendations:
A-80-76. Issue a telert maintenance bulletin to alert operators of swearingen models sa226-at and sa226-tc aircraft of the dangers of machining
or filing any component of the latch or receptacle to ease the engagement.
Responses:
FAA LTR DTD: 10/30/80
The faa concurs with a-80-76 and 77. Our southwest region has issued a telert maintenance bulletin advising all regions to notify operators who
re operating swearingen models sa-226at and sa226tc aircraft of the dangers of machining or filing any component of the latching mechanisms
to ease engagement. Further, we have included in this bulletin

instructions to advise operators of unsafe conditions which can result from
forcing the latching mechanism during operations when the latches are mis- aligned or not properly adjusted. In addition, a general aviation
airworthiness alert has been prepared for in ac 43-16 which willreflect the information contained in both recommenda-tions. A copy of both
these documents is enclosed. The faa considers action on a-80-76 and 77 completed.
NTSB LTR DTD: 12/03/80
The safety board is pleased to note that on october 2, 1980, the faa issued a telert maintenance bulletin a-80-76, and that a general aviation
airworthiness alert has been prepared for insertion in ac 43-16 to fulfill a-80-77. Both these recommendation are now classified in a
closed--acceptable action status.
NTSB Accident/Incident Brief
Data_Source: NTSB Aviation Accident/Incident Data
Rprt_Nbr: DCA89MA035
Event_Lcl_Date: 03/18/1989
Time (Lcl): 216 CST
Loc_State_Code: TX
Loc_City_Name: SAGINAW
Loc_Arpt_Name: CARSWELL AFB
Loc_Arpt_Id_Code: FWH
Event_Acdnt_Incdnt_Code: ACCIDENT
Inj_Hi_Deg_Code: FATAL
Rprt_Status_Code: FINAL
Event_Mid_Air_Code: No
--- Aircraft Information ---
Opn_Cat_Code: SCH121

Acft_Type_Code: AIRPLANE
Acft_Dmg_Code: DESTROYED
Flt_Phase_Code: 580 MANEUVERING
Acft_Manf_Name: MCDONNELL-DOUGLAS
Acft_Series_Name: DC-9-33F
Aic_Make_Id: DOUG
Aic_Ac_Id: DC-9-33F
Acft_Hm_Built_Flag: No
Oprtr_Biz_Name:
Oprtr_Name:
Oprtr_Desigtr_Code:
Owner_Name: EVERGREEN INTL AIRLINES
--- Narrative ---
AS THE ACFT ROTATED FOR TKOF, THE CARGO DOOR (CD) OPENED. THE CREW CONTD
TKOF & TURNED TO A DWNWND LEG TO LND ON RWY 17. THEY ANSWERED TWR INSTRNS
TO RPRT "BASE." THIS WAS THE LAST TMTN THEY RCVD, THO THEY TRIED SVRL
TIMES TO CTC TWR OR APCH CTL. AS THE ACFT TURNED ON BASE LEG (WITH A TAIL
WND AT TFC PATTERN ALT), RADAR DATA INDCD ACFT WOULD CROSS THE RWY
CENTERLINE. RADAR CTC WAS THEN LOST; THE ACFT CRASHED IN A STEEP DSCNT.
THERE WAS EVIDENCE THAT BFR FLT, THE 1ST OFFICER MISINTERPRETED THE
EXTERNAL LOCKPIN MANUAL CTL HANDLE PSN TO MEAN THE CD WAS LOCKED (AS A
RESULT OF INCORRECT MARKINGS). ALSO, THERE WAS A MALFUNCTION OF A CD OPEN
WARNING LGT SW, PREVENTING OPN OF THE WARNING LGT. ADDITIONALLY, SVRL SVC

BULLETINS (SB'S) CONCERNING THE CD HAD NOT
BEEN COMPLIED WITH. THESE SB'S
WOULD HAVE PROVIDED AN EXTRA SAFETY FEATURE
OF THE CD WARNING LGT SYS, A
DOOR VENTING SYS & A LOCKPIN VIEWING WINDOW
FOR THE DOOR. THERE WAS NO
EMERG PROC OR SPECIFIC GUIDANCE TO AID DC-9
CREWS FOR THIS SITUATION,
THOUGH SVRL CD OPENINGS HAD OCCURRED. (SEE:
NTSB/AAR-90/02)
--- Sequence of Events ---
Occurrence #: 1 130 AIRFRAME/COMPONENT/SYSTEM
FAILURE/MALFUNCTION
Phase of Operation: 501 STANDING - PRE-FLIGHT
----- Findings -----
Subj - Mod - Pers C/F
1b. 24119(S) - 3124(M) - 4121(P) Factor
MAINTENANCE, SERVICE BULLETINS - NOT FOLLOWED
- COMPANY/OPERATOR MANAGEMENT
1ind. 90000(S) - 6110(P) Factor
INADEQUATE SURVEILLANCE OF OPERATION - FAA
(ORGANIZATION)
2a. 10505(S) - 1213(M)
DOOR, CARGO/BAGGAGE - NOT SECURED
3a. 12015(S) - 1134(M)
ELECTRICAL SYSTEM, ELECTRIC SWITCH - FAILURE,
PARTIAL
4a. 13107(S) - 1150(M)
WARNING SYSTEM (OTHER) - INOPERATIVE
6b. 24032(S) - 3115(M) - 4121(P) Factor
PROCEDURES/DIRECTIVES - INADEQUATE - COMPANY/
OPERATOR MANAGEMENT
6ind. 91200(S) - 6110(P) Factor

INSUFFICIENT STANDARDS/REQUIREMENTS, AIRCRAFT - FAA (ORGANIZATION)
Occurrence #: 2 430 MISCELLANEOUS/OTHER
Phase of Operation: 522 TAKEOFF - INITIAL CLIMB
----- Findings -----
Subj - Mod - Pers C/F
1a. 10505(S) - 1202(M) Factor
DOOR, CARGO/BAGGAGE - DISENGAGED
Occurrence #: 3 250 LOSS OF CONTROL - IN FLIGHT
Phase of Operation: 563 APPROACH - VFR PATTERN - BASE LEG/BASE TO FINAL
----- Findings -----
Subj - Mod - Pers C/F
1b. 25000(S) - 3001(M) - 4001(P) Cause
REASON FOR OCCURRENCE UNDETERMINED - -
4a. 21103(S) - 2104(M) Factor
AIRCRAFT MANUALS, PROCEDURE INFORMATION - INADEQUATE
4b. 24032(S) - 3115(M) - 4123(P) Factor
PROCEDURES/DIRECTIVES - INADEQUATE - MANUFACTURER
Occurrence #: 4 230 IN FLIGHT COLLISION WITH TERRAIN/WATER
Phase of Operation: 553 DESCENT - UNCONTROLLED
----- Findings -----
Subj - Mod - Pers C/F
--- Probable Cause ---
THE LOSS OF CONTROL OF THE AIRPLANE FOR UNDETERMINED REASONS FOLLOWING THE INFLIGHT OPENING OF THE IMPROPERLY LATCHED CARGO DOOR. CONTRIBUTING TO
THE ACCIDENT WERE: INADEQUATE PROCEDURES USED BY EVERGREEN AIRLINES AND

APPROVED BY THE FAA FOR PREFLIGHT VERIFICATION OF CARGO DOOR SECURITY,
EVERGREEN'S FAILURE TO MARK PROPERLY THE AIRPLANE'S EXTERNAL CARGO DOOR
LOCKPIN MANUAL CONTROL HANDLE, AND THE FAILURE OF MCDONNELL DOUGLAS TO
PROVIDE FLIGHTCREW GUIDANCE AND EMERGENCY PROCEDURES FOR AN INFLIGHT
OPENING OF THE CARGO DOOR. ALSO CONTRIBUTING TO THE ACCIDENT WAS THE
FAILURE OF THE FAA TO MANDATE MODIFICATION TO THE DOOR-OPEN WARNINGSYSTEM
FOR DC-9 CARGO-CONFIGURED AIRPLANES, GIVEN THE PREVIOUS KNOWN OCCURRENCES
OF INFLIGHT DOOR OPENINGS.
Acft_Nbr_Seat_Qty: 3
Opn_Biz_Code: Code Not Found
Opn_Biz_Otr_Desc:
Fltcndct_Code: 14 CFR 121
Fltcndct_Otr_Desc:
Opn_Sked_Code: SCHEDULED
Opn_Dom_Intnl_Code: DOMESTIC
Opn_Psgr_Cargo_Code: CARGO
Regist_Nbr: 931F
Owner_Cert_Held_Flag: Code Not Found
Oprtr_Cert_Acr_Type_Code: FLAG CARRIER/DOMESTIC (121)
Oprtr_Cert_Otr_Acft_Flag: Code Not Found
Oprtr_Cert_Rotor_Ag_Code: Code Not Found
Acft_Fire_Code: ON GROUND
Injuries
Fatal Serious Minor None
Crew 2 0 0 0

Pass 0 0 0 0
Other 0 0 0 0
Invlvd 2 0 0 0
Lndgr_Type_Fix_Code: TRICYCLE-RETRACTABLE
Acft_Crtfyd_Max_Wt_Lb_Qty: 114000
Eng_Manf_Name: P&W
Eng_Model_Name: JT8D-9A
Acft_Nbr_Eng_Qty: 2
Eng_Typ_Code: TURBO FAN
Eng_Rated_Pwr_Hpwr_Qty: 0
Eng_Rated_Pwr_Thrust_Lb_Qty: 14500
Elt_Instld_Flag: No
Elt_Oprtd_Flag: Code Not Found
Stall_Warn_Instl_Flag: Yes
--- Environment/Operations Information ---
Wx_Brfg_Srce_Code:
Wx_Brfg_Mthd_Code:
Wx_Brfg_Cmplt_Code: WEATHER NOT PERTINENT
Wx_Flt_Cond_Code: VISUAL METEOROLOGICAL CONDITIONS (VMC)
Wx_Wind_From_Vrbl_Flag: Code Not Found
Wx_Wind_Degm_Qty: 320
Wx_Wind_Type_Code: Code Not Found
Wx_Wind_Spd_Kt_Qty: 6
Wx_Vis_Sm_Qty: 10
Wx_Vis_Rvr_Ft_Qty: 0
Wx_Vis_Rvv_Sm_Qty: 0
Wx_Cloud_Code: THIN BROKEN
Wx_Cloud_Hgt_Agl_Ft_Qty: 25000
Wx_Cig_Code: NONE
Wx_Cig_Hgt_Agl_Ft_Qty: 0
Wx_Vis_Rstr_Fix_Code: NONE
Wx_Precip_Type_Fix_Code: NONE

Wx_Cond_Lgt_Code: NIGHT (DARK)
Dep_Point_Flag: Yes
Dep_Point_Arpt_Id_Code: FWH
Dep_Point_City_Name:
Dep_Point_State_Code:
Destn_Same_Lcl_Code: Code Not Found
Destn_Arpt_Id_Code: TIK
Destn_City_Name: OKLAHOMA CITY
Destn_State_Code: OK
Fltplan_Filed_Code: INSTRUMENT FLIGHT RULES (IFR)
Clnc_Atc_Type_Code: IFR
Apch_Vfr_Fix_Code: TRAFFIC PATTERN
Loc_Event_Code: OFF AIRPORT/AIRSTRIP
Rwy_Used_Id_Sffx_Code:
Rwy_Used_Id_Code: 17
Rwy_Len_Ft_Qty: 12000
Rwy_Wid_Ft_Qty: 300
Rwy_Sfc_Type_Fix_Code: CONCRETE
Rwy_Status_Type_Fix_Code: DRY
--- Personnel Information ---
Plt_Cert_Type_Code: COMMERCIAL, AIRLINE TRANSPORT
Pltrtng_Plane_Code: SINGLE ENGINE LAND, MULTIENGINE LAND
Pltrtng_Non_Plane_Code: NONE
Pltrtng_Inst_Code: AIRPLANE
Plt_Bfr_Flag: Yes
Plt_Last_Bfr_Mo_Qty: 2
Plt_Bfr_Acft_Make_Name: SIMULATOR
Plt_Bfr_Acft_Model_Name: DC9 SI
Plt_Med_Cert_Code: CLASS 1
Plt_Med_Cert_Vldty_Code: VALID MEDICAL-NO WAIVERS/ LIMITATIONS
Flight Time (Hours)

Total : 7238 Last 24 Hrs : 4
Make/Model: 1938 Last 30 Days: 0
Instrument: 0 Last 90 Days: 0
Multi-Eng : 0 Rotorcraft : 0
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-90-86
Last Updated: 09-21-94
[O] On March 18, 1989, an Evergreen International Airlines McDonnell Douglas DC-9-33F, registered in the United States as N931F, crashed
during the turn to final approach as the pilot was attempting to return to Carswell Air Force Base (AFB), Fort Worth, Texas after a cargo door
opened. This cargo flight was on an instrument flight rule (IFR) flight plan and was being operated in accordance with Title 14 Code of Federal
Regulations (CFR) Part 121. Night visual meteorological conditions existed at the time of the accident. The captain and first officer, the only
persons onboard, were killed.
Recommendations:
A-90-86. Require that McDonnell Douglas amend its DC-9 Flight Crew Operating Manual "Cargo Door Opens After Takeoff" procedure to
include the fact that the possibility exists that variations in indicated airspeed and altitude can exist during flight with an open cargo door.
Responses:
FAA LTR DTD: 8/28/90
The FAA agrees with the intent of these safety recommendations, but cannot "require" that changes or revisions be made to the Flight Crew

Operations Manual. Since the operations manual is not an FAA-approved document, the FAA has no direct control over the content of the
information contained in these manuals. The FAA will consider the issuance of an airworthiness directive (AD) to require a revision to the
Airplane Flight Manual to include the information requested in Safety Recommendation A-90-86. If an AD is issued, the FAA will request that
the manufacturer amend the Flight Crew Operations Manual to reflect the changes made to the Airplane Flight Manual.
I will provide the Board with a copy of any document that may be issued.
NTSB LTR DTD: 11/5/90
The Safety Board notes that the FAA agrees with the intent of these safety recommendations and is considering the issuance of an
airworthiness directive (AD) to require a revision to the airplane flight manual. If the AD is issued, the FAA will request that the manufacturer
amend the flight crew operational manual to reflect the changes made to the airplane flight manual. Pending the FAA's further report, these
safety recommendations are classified as "Open--Acceptable Response."
FAA LTR DTD: 2/15/91
The McDonnell Douglas Aircraft Corporation revised its DC-9 Flight Crew Operating Manual to incorporate a revision to the emergency
procedure when the main cargo door opens after takeoff. I have enclosed a copy of the manual revision for the Board's information.
I consider the FAA's action to be completed on this safety

recommendation.
NTSB LTR DTD: 5/7/91
The Safety Board notes that McDonnell Douglas has revised the DC-9 Flight Crew Operating Manual to meet the intent of Safety Recommendation A-90-86. Based on the above information, Safety Recommendation A-90-86 is reclassified as "Closed--Acceptable Action."
<WEBMASTER>
NTSB Accident/Incident Brief
Data_Source: NTSB Aviation Accident/Incident Data
Rprt_Nbr: FTW89MA047
Event_Lcl_Date: 02/09/1989
Time (Lcl): 100 MST
Loc_State_Code: UT
Loc_City_Name: SALT LAKE CITY
Loc_Arpt_Name:
Loc_Arpt_Id_Code:
Event_Acdnt_Incdnt_Code: ACCIDENT
Inj_Hi_Deg_Code: FATAL
Rprt_Status_Code: FINAL
Event_Mid_Air_Code: No
Opn_Cat_Code: SCH121
Acft_Type_Code: AIRPLANE
Acft_Dmg_Code: NONE
Flt_Phase_Code: 530 CLIMB
Acft_Manf_Name: MCDONNELL DOUGLAS
Acft_Series_Name: DC-9-32F
Aic_Make_Id: DOUG
Aic_Ac_Id: DC-9-32F
Acft_Hm_Built_Flag: No
Oprtr_Biz_Name:
Oprtr_Name:
Oprtr_Desigtr_Code: EIAA

Owner_Name: EVERGREEN INTL AIRLINES
--- Narrative ---
AS 1ST OFFICER (FO) WAS FLYING ACFT, DRG CLB AFTER TKOF, CABIN WOULDN'T
PRESSURIZE. HE BGN LVL OFF AT 16,000', BUT CAPT ORDERED HIM TO CONT CLBG
TO ASSIGNED FLT LVL (FL 330), WHILE HE (THE CAPT) WENT AFT TO FND PRBLM.
FO DISLIKED THE ORDER, BUT COMPLIED RATHER THAN CONFRONT CAPT. CAPT LEFT
COCKPIT WITH PORTABLE "ON DEMAND" OXYGEN (O2) SYS, WHICH HAD 15 MIN SUPPLY
OF O2. WHEN CAPT DIDN'T RTRN, FO TRIED SIGNALING HIM. THO RELUCTANT TO
COUNTERMAND CAPT'S ORDER, FO MADE SERIES OF DSCNTS TO 13,000'. AFTER ABT
30 MIN, HE LEFT COCKPIT & FND CAPT UNCONSCIOUS & UNRESPONSIVE IN FWD CARGO
AREA WITH O2 MASK ON HIS FACE. CAPT'S FOOT WAS ENTANGLED IN CARGO NET
WHICH CVRD A PALLET. FO TRIED TO REVIVE CAPT, TO NO AVAIL, THEN DECLARED
EMERG & LNDD AT LUBBOCK. CAPT WAS RUSHED TO HOSPITAL, BUT WAS DEAD ON
ARRIVAL. EXAM REVEALED AFT PRESSURE BULK- HEAD WAS NOT INSTALLED. IT HAD
BEEN REMOVED FOR MAINT BFR FLT. PORTABLE O2 SYS WAS STILL FULL, INDCG CAPT
HAD LITTLE OR NO USE OF O2; IT WAS TESTED & FUNCTIONED NMLY. GROUP OF 8
FORENSIC PATHOLOGISTS CONCLUDED CAPT DIED FM HYPOXIC HYPOXIA.
--- Sequence of Events ---

Occurrence #: 1 430 MISCELLANEOUS/OTHER
Phase of Operation: 530 CLIMB
----- Findings -----
Subj - Mod - Pers C/F
1a. 10510(S) - 1205(M) Factor
DOOR, INSPECTION - NOT INSTALLED
1b. 24102(S) - 3115(M) - 4107(P) Factor
MAINTENANCE, INSPECTION OF AIRCRAFT - INADEQUATE - COMPANY MAINTENANCE PERSONNEL
2a. 10003(S) - 1163(M) Factor
FUSELAGE, CABIN - NO PRESSURE
3b. 24010(S) - 3109(M) - 4000(P) Cause
IN-FLIGHT PLANNING/DECISION - IMPROPER - PILOT IN COMMAND
4b. 24527(S) - 3102(M) - 4001(P) Factor
CLIMB - CONTINUED -
6b. 24624(S) - 3136(M) - 4000(P) Factor
CREW/GROUP COORDINATION - POOR - PILOT IN COMMAND
7b. 23308(S) - 3110(M) - 4000(P) Cause
OXYGEN SYSTEM - IMPROPER USE OF - PILOT IN COMMAND
7dir. 33211(S) - 5000(P) Cause
INCAPACITATION (ANOXIA/HYPOXIA) - PILOT IN COMMAND
--- Probable Cause ---
IMPROPER IN-FLIGHT PLANNING/DECISION BY THE CAPTAIN (PILOT-IN-COMMAND)
AND HIS IMPROPER USE OF THE PORTABLE OXYGEN SYSTEM, WHICH RESULTED IN HIS
INCAPACITATION DUE TO HYPOXIA. FACTORS RELATED TO THE ACCIDENT WERE:
INADEQUATE MAINTENANCE/INSPECTION OF THE

AIRCRAFT BY COMPANY MAINTENANCE
BY FAILING TO REINSTALL THE AFT PRESSURE
BULKHEAD HATCH (INSPECTION DOOR)
AND POOR CREW COORDINATION.
--- Detail ---
Acft_Nbr_Seat_Qty: 2
Opn_Biz_Code: Code Not Found
Opn_Biz_Otr_Desc:
Fltcndct_Code: 14 CFR 121
Fltcndct_Otr_Desc:
Opn_Sked_Code: SCHEDULED
Opn_Dom_Intnl_Code: DOMESTIC
Opn_Psgr_Cargo_Code: CARGO
Regist_Nbr: 935F
Owner_Cert_Held_Flag: Code Not Found
Oprtr_Cert_Acr_Type_Code: SUPPLEMENTAL
Oprtr_Cert_Otr_Acft_Flag: Code Not Found
Oprtr_Cert_Rotor_Ag_Code: Code Not Found
Acft_Fire_Code: NONE
Injuries
Fatal Serious Minor None
Crew 1 0 0 1
Pass 0 0 0 0
Other 0 0 0 0
Invlvd 1 0 0 1
Lndgr_Type_Fix_Code: TRICYCLE-RETRACTABLE
Acft_Crtfyd_Max_Wt_Lb_Qty: 108000
Eng_Manf_Name: P&W
Eng_Model_Name: JT8D-9A
Acft_Nbr_Eng_Qty: 2
Eng_Typ_Code: TURBO FAN
Eng_Rated_Pwr_Hpwr_Qty: 0
Eng_Rated_Pwr_Thrust_Lb_Qty: 14000

Elt_Instld_Flag: No
Elt_Oprtd_Flag: Code Not Found
Stall_Warn_Instl_Flag: Yes
--- Environment/Operations Information ---
Wx_Brfg_Srce_Code: MILITARY
Wx_Brfg_Mthd_Code: IN PERSON
Wx_Brfg_Cmplt_Code: WEATHER NOT PERTINENT
Wx_Flt_Cond_Code: VISUAL METEOROLOGICAL CONDITIONS (VMC)
Wx_Wind_From_Vrbl_Flag: Code Not Found
Wx_Wind_Degm_Qty: 120
Wx_Wind_Type_Code: Code Not Found
Wx_Wind_Spd_Kt_Qty: 8
Wx_Vis_Sm_Qty: 15
Wx_Vis_Rvr_Ft_Qty: 0
Wx_Vis_Rvv_Sm_Qty: 0
Wx_Cloud_Code: CLEAR
Wx_Cloud_Hgt_Agl_Ft_Qty: 0
Wx_Cig_Code: NONE
Wx_Cig_Hgt_Agl_Ft_Qty: 0
Wx_Vis_Rstr_Fix_Code: NONE
Wx_Precip_Type_Fix_Code: NONE
Wx_Cond_Lgt_Code: NIGHT (DARK)
Dep_Point_Flag: Code Not Found
Dep_Point_Arpt_Id_Code: KHIF
Dep_Point_City_Name: OGDEN
Dep_Point_State_Code: UT
Destn_Same_Lcl_Code: Code Not Found
Destn_Arpt_Id_Code: KSKF
Destn_City_Name: SAN ANTONIO
Destn_State_Code: TX
Fltplan_Filed_Code: INSTRUMENT FLIGHT RULES (IFR)
Clnc_Atc_Type_Code: IFR

Apch_Vfr_Fix_Code: PRECAUTIONARY LANDING
Loc_Event_Code: OFF AIRPORT/AIRSTRIP
Rwy_Used_Id_Sffx_Code:
Rwy_Used_Id_Code: 0
Rwy_Len_Ft_Qty: 0
Rwy_Wid_Ft_Qty: 0
Rwy_Sfc_Type_Fix_Code:
Rwy_Status_Type_Fix_Code:
--- Personnel Information ---
Plt_Cert_Type_Code: AIRLINE TRANSPORT, FLIGHT INSTRUCTOR
Pltrtng_Plane_Code: SINGLE ENGINE LAND, MULTIENGINE LAND
Pltrtng_Non_Plane_Code: NONE
Pltrtng_Inst_Code: AIRPLANE
Plt_Bfr_Flag: Yes
Plt_Last_Bfr_Mo_Qty: 4
Plt_Bfr_Acft_Make_Name: DOUGLAS
Plt_Bfr_Acft_Model_Name: DC-9
Plt_Med_Cert_Code: CLASS 1
Plt_Med_Cert_Vldty_Code: VALID MEDICAL-NO WAIVERS/ LIMITATIONS
Flight Time (Hours)
Total : 11000 Last 24 Hrs : 5
Make/Model: 232 Last 30 Days: 62
Instrument: 0 Last 90 Days: 152
Multi-Eng : 10000 Rotorcraft : 0
<WEBMASTER>
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-80-77
Last Updated: 09-21-94
[O] On march 8, 1980, a swearingen sa-226 at, n720r, with a

crew of two and sixpassengers, experienced a rapid decompression at 16,000 feet
when most of the aft cargo compartment door separated in flight. About 3/4 of the door along with interior furnishings, including an
unoccupied passenger seat, separated from the aircraft. Two passengers were injured slightly during the decompression and the empennage
was damaged slightly when some of the material from the cargo door or the cabin struck the upper fuselage and thevertical stabilizer. Some
of the material from the cabin lodged around thecontrol surfaces in the empennage. A safe landing was made in albany, new york. Although
ground search continues for the separated items, only baggage has thus far been recovered.

Recommendations:

A-80-77. Issue an addition to the general aviation airworthiness alerts, Advisory Circular 43-16, to alert operators of sa226 aircraft to the unsafe
condition which can result from forcing the latching mechanism while the latches are not properly engaged.

Responses:

FAA LTR DTD: 10/30/80

The faa concurs with a-80-76 and 77. Our southwest region has issued a telert maintenance bulletin advising all regions to notify operators who
are operating swearingen models sa-226at and sa226tc aircraft of the dangers of machining or filling any component of the latching
mechanisms to ease engagement. Further, we have included in this bulletin instructions to advise operators of the unsafe

conditions which
can result from forcing the latching mechanism during operations, when the latches are misaligned or not properly adjusted. In addition, a
general aviation airworthiness alert has been prepared for insertion in ac 43-16 which will reflect the information contained in both
recommendations. A copy of both these documents is enclosed. The faa considers action on a-80-76 and 77 completed.
NTSB LTR DTD: 12/03/80
The safety boards is pleased to note that on october 2, 1980, the faa issued a telert maintenance bulletin fulfilling a -80-76, and that a general
aviation airworthiness alert has been prepared for insertion in ac 43-16 to fulfill a-80-77. Both these recommendations are now classified in a
closed--acceptable action status.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-74-27
Last Updated: 09-21-94
[O] The ntsb is investigating an accident involving an american airlines mcdonnell douglas dc-10-10, n103aa, which occurred shortly after
takeoff from detroit metropolitan-wayne county airport on june 12, 1972. The aft left-hand cargo door opened while the aircraft was at
approximately 12,000 feet. The cabin floor over this cargo compartment then failed as a result of depressurization loading, and the floor
dropped partially into the cargo compartment. This displacement of the floor caused serious disruption of the control cables which are routed

through the floor beams to the empennage control systems and the engine controls. With the exception of the right rudder pedal cable, all of
the cables on the left side of the fuselage broke. The cable guides tore from their attachments to the floor beams, and the cables were
deflected downward by the floor structure.
Recommendations:
A-74-27. Require that the provisions of the McDonnell-Douglas Service Bulletin 52-49 entitled doors-cargo-install revised 'closed loop' cargo
door locking mechanism be made mandatory by the immediate issuance of an airworthiness directive.
Responses:
FAA LTR DTD: 04/04/74
On march 22, 1974, the faa issued their second ad which included the requirement for compliance with the mcdonnell douglas service bulletin
(sb) 52-49 by july 1, 1974. Prior to the issuance of the ad, sb 52-49 would not have been completed on all aircraft for another 20-24 months.

NTSB LTR DTD: 04/26/74
Closed--acceptable action.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-72-97
Last Updated: 09-21-94
[O] The ntsb is investigating an accident involving an american airlines mcdonnell douglas dc-10-10, n103aa, which occurred shortly after
takeoff from detroit metropolitan-wayne county airport on june 12, 1972. The aft left-hand cargo door opened while the aircraft

was at
approximately 12,000 feet. The cabin floor over this cargo compartment then failed as a result of depressurization loading, and the floor
dropped partially into the cargo compartment. This displacement of the floor caused serious disruption of the control cables which are routed
through the floor beams to the empennage control systems and the engine controls. With the exception of the right rudder pedal cable, all of
the cables on the left side of the fuselage broke. The cable guides tore from their attachments to the floor beams, and the cables were
deflected downward by the floor structure.
Recommendations:
A-72-97. Require a modification to the DC-10 cargo door locking system to make it physically impossible to position the external locking
handle and vent doorto their normal door locked positions unless the locking pins are fully engaged.
Responses:
FAA LTR DTD: 07/07/72
Additional modifications to the cargo door locking and pressurization systems are being considered as part of a continued investi-gation
effort. While a preliminary investigation indicates that it may not be feasible to provide complete venting between cabin and cargo compartments, your recommendations will be considered with respect to further action taken.
NTSB LTR DTD: 12/11/74
The safety board is aware of your continued efforts toward modifying the dc-10 cargo compartment doors to insure the integrity of fuselage

pressure containment. However, the safety board believes that critical control systems must be protected against a loss of cargo compartment
pressurization, which may occur for any reason. Therefore, we are specifically interested in corrective actions to strengthen the passenger
compartment floor, to vent or partially vent the aft cargo compartment, and to isolate or otherwise protect critical systems which pass through
the passenger compartment floor structure. The safety board would appreciate a status report on actions taken or contemplated by the faa to
implement safety recommendation a-72-98.
NTSB LTR DTD: 06/01/75
Closed--acceptable action.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-72-98
Last Updated: 09-21-94
[O] The ntsb is investigating an accident involving an american airlines mcdonnell douglas dc-10-10, n103aa, which occurred shortly after
takeoff from detroit metropolitan-wayne county airport on june 12, 1972. The aft left-hand cargo door opened while the aircraft was at
approximately 12,000 feet. The cabin floor over this cargo compartment then failed as a result of depressurization loading, and the floor
dropped partially into the cargo compartment. This displacement of the floor caused serious disruption of the control cables which are routed
through the floor beams to the empennage control systems and the engine controls. With the exception of the right rudder pedal

cable, all of
the cables on the left side of the fuselage broke. The cable guides tore from their attachments to the floor beams, and the cables were
deflected downward by the floor structure.
Recommendations:
A-72-98. Require the installation of relief vents between the cabin and aft cargo compartment to minimize the pressure loading
depressurization of the cargo compartment.
Responses:
FAA LTR DTD: 07/07/72
Additional modifications to the cargo door locking and pressurization system are being considered as part of a continued investi- gation
effort. While a preliminary investigation indicates that it may not be feasible to provide complete venting between cabin and cargo compart-
ments, your recommendations will be considered with respect to further action taken.
NTSB LTR DTD: 02/23/73
With respect to recommendation a-72-98, you observed that a preliminary investigation indicated that it may not be feasible to provide
complete venting between cabin and cargo compartments. When your investigation is complete, the board would appreciate knowing if the
installation of vents similar to those on other dc-10 cargo compartments is feasible in the aft cargo compartment. If complete venting is not
possible, partial venting would be beneficial. Such venting could prevent the collapse of the aft cabin floor, or it couldreduce the amount of

floor deflection, and attendant control cable damage in a dc-10.
FAA LTR DTD: 03/15/73
We have requested that the manufacturer reassess the dc-10 with regard to the effects on safety of probable large openings in the pressurized
fuselage. The manufacturer is to consider rerouting of vital systems, reinforcement of the floor as well as incorporation of additional venting
between compartments. These alternatives will include considera- tion of various degrees of venting as recommended in your letter.
FAA LTR DTD: 01/17/75
Major discussions were held with mcdonnell-douglas on march 15, april 30, june 6 and 7, september 25, october 2, 3, and 4, 1974, and most
recently on january 7. We have also reviewed the l-1011 and b727 designs with lockheed and boeing representatives on april 30 and may 1,
1974. These many discussions covered specific design improvements including external door designs, floor structure and strengthening,
intercompartment venting and isolation of critical systems, and other features. We can advise you shortly of the results of our investigation
and the corrective measures to be required. This should be prior to january 31.
NTSB LTR DTD: 06/01/75

Closed--acceptable action.
NTSB Accident/Incident Brief
Data_Source: NTSB Aviation Accident/Incident Data
Rprt_Nbr: NYC92IA030
Event_Lcl_Date: 11/13/1991

Time (Lcl): 445 EST
Loc_State_Code: OH
Loc_City_Name: TOLEDO
Loc_Arpt_Name:
Loc_Arpt_Id_Code:
Event_Acdnt_Incdnt_Code: INCIDENT
Inj_Hi_Deg_Code: NONE
Rprt_Status_Code: FINAL
Event_Mid_Air_Code: No
--- Aircraft Information ---
Opn_Cat_Code: NSC121
Acft_Type_Code: AIRPLANE
Acft_Dmg_Code: MINOR
Flt_Phase_Code: 530 CLIMB
Acft_Manf_Name: DOUGLAS
Acft_Series_Name: DC-8-63
Aic_Make_Id: DOUG
Aic_Ac_Id: DC-8-63
Acft_Hm_Built_Flag: No
Oprtr_Biz_Name:
Oprtr_Name: FLAGSHIP EXPRESS
Oprtr_Desigtr_Code: RAXA
Owner_Name: AERO LEASE FINANCIAL GROUP INC
--- Narrative ---
THE MAIN CARGO DOOR OPENED IN FLIGHT AND THE AIRPLANE RETURNED FOR A
NORMAL LANDING. OF THE TWO CIRCUIT BREAKERS REQUIRED TO BE PULLED PRIOR
TO TAKEOFF, ONE WAS FOUND STILLENGAGED. A CONFORMITY INSPECTION ON THE
CARGO DOOR INSTALLATION REVEALED SEVERAL AREAS OF NONCONFORMITY INCLUDING
DOOR LOCKS OF LESS THAN REQUIRED STRENGTH,

LACK OF PAINT ON DOOR LOCKS
WHICH IS USED FOR VISUAL IDENTIFICATION, AND
DAMAGED WIRES IN A BUNDLE.
THE WIRES WERE PART OF THE DOOR CLOSING, DOOR
LOCKED INDICATING SYSTEM.
THE INVESTIGATION REVEALED IT WAS POSSIBLE FOR
THE DOOR TO BE NOT
COMPLETELY CLOSED AND HAVE THE DOOR WARNING
LIGHT GO OUT, INDICATING IT
WAS FULLY LOCKED.
--- Sequence of Events ---
Occurrence #: 1 140 DECOMPRESSION
Phase of Operation: 531 CLIMB - TO CRUISE
----- Findings -----
Subj - Mod - Pers C/F
1a. 10505(S) - 1147(M) Factor
DOOR, CARGO/BAGGAGE - IMPROPER
1b. 24111(S) - 3109(M) - 4108(P) Factor
MAINTENANCE, INSTALLATION - IMPROPER - OTHER
MAINTENANCE PERSONNEL
2a. 12013(S) - 1113(M) Factor
ELECTRICAL SYSTEM, ELECTRIC WIRING - CHAFED
2b. 24002(S) - 3109(M) - 4102(P) Cause
AIRCRAFT PREFLIGHT - IMPROPER - FLIGHT ENGINEER
--- Probable Cause ---
THE FAILURE OF THE FLIGHT ENGINEER TO CONDUCT
A PROPER PREFLIGHT
INSPECTION AND ENSURE THE MAIN CARGO DOOR
WAS FULLY CLOSED AND LOCKED.
FACTORS RELATED TO THE ACCIDENT WERE
THEDAMAGED WIRES IN THE BUNDLE, AND
THE IMPROPER MAIN CARGO DOOR INSTALLATION.
--- Detail ---

Acft_Nbr_Seat_Qty: 0
Opn_Biz_Code: Code Not Found
Opn_Biz_Otr_Desc:
Fltcndct_Code: 14 CFR 121
Fltcndct_Otr_Desc:
Opn_Sked_Code: NON-SCHEDULED
Opn_Dom_Intnl_Code: DOMESTIC
Opn_Psgr_Cargo_Code: CARGO
Regist_Nbr: 794AL
Owner_Cert_Held_Flag: Code Not Found
Oprtr_Cert_Acr_Type_Code: SUPPLEMENTAL
Oprtr_Cert_Otr_Acft_Flag: Code Not Found
Oprtr_Cert_Rotor_Ag_Code: Code Not Found
Acft_Fire_Code: NONE
Injuries
Fatal Serious Minor None
Crew 0 0 0 3
Pass 0 0 0 0
Other 0 0 0 0
Invlvd 0 0 0 3
Lndgr_Type_Fix_Code: TRICYCLE-RETRACTABLE
Acft_Crtfyd_Max_Wt_Lb_Qty: 355000
Eng_Manf_Name: PRATT & WHITN
Eng_Model_Name: JT3D-7
Acft_Nbr_Eng_Qty: 4
Eng_Typ_Code: TURBO FAN
Eng_Rated_Pwr_Hpwr_Qty: 0
Eng_Rated_Pwr_Thrust_Lb_Qty: 19000
Elt_Instld_Flag: Code Not Found
Elt_Oprtd_Flag: Code Not Found
Stall_Warn_Instl_Flag: Yes
--- Environment/Operations Information ---
Wx_Brfg_Srce_Code: COMPANY

Wx_Brfg_Mthd_Code:
Wx_Brfg_Cmplt_Code: WEATHER NOT PERTINENT
Wx_Flt_Cond_Code: VISUAL METEOROLOGICAL CONDITIONS (VMC)
Wx_Wind_From_Vrbl_Flag: Code Not Found
Wx_Wind_Degm_Qty: 0
Wx_Wind_Type_Code: Code Not Found
Wx_Wind_Spd_Kt_Qty: 0
Wx_Vis_Sm_Qty: 0
Wx_Vis_Rvr_Ft_Qty: 0
Wx_Vis_Rvv_Sm_Qty: 0
Wx_Cloud_Code: Code Not Found
Wx_Cloud_Hgt_Agl_Ft_Qty: 0
Wx_Cig_Code: Code Not Found
Wx_Cig_Hgt_Agl_Ft_Qty: 0
Wx_Vis_Rstr_Fix_Code:
Wx_Precip_Type_Fix_Code: NONE
Wx_Cond_Lgt_Code: NIGHT (DARK)
Dep_Point_Flag: Yes
Dep_Point_Arpt_Id_Code:
Dep_Point_City_Name:
Dep_Point_State_Code:
Destn_Same_Lcl_Code: Code Not Found
Destn_Arpt_Id_Code: LAX
Destn_City_Name: LOS ANGELES
Destn_State_Code: CA
Fltplan_Filed_Code: INSTRUMENT FLIGHT RULES (IFR)
Clnc_Atc_Type_Code: IFR
Apch_Vfr_Fix_Code: PRECAUTIONARY LANDING
Loc_Event_Code: OFF AIRPORT/AIRSTRIP
Rwy_Used_Id_Sffx_Code:
Rwy_Used_Id_Code: 0
Rwy_Len_Ft_Qty: 0

Rwy_Wid_Ft_Qty: 0
Rwy_Sfc_Type_Fix_Code: Code Not Found
Rwy_Status_Type_Fix_Code:
--- Personnel Information ---
Plt_Cert_Type_Code: COMMERCIAL, AIRLINE TRANSPORT
Pltrtng_Plane_Code: SINGLE ENGINE LAND, MULTIENGINE LAND
Pltrtng_Non_Plane_Code: NONE
Pltrtng_Inst_Code: AIRPLANE
Plt_Bfr_Flag: Yes
Plt_Last_Bfr_Mo_Qty:
Plt_Bfr_Acft_Make_Name: DOUGLAS
Plt_Bfr_Acft_Model_Name: DC-8
Plt_Med_Cert_Code: CLASS 1
Plt_Med_Cert_Vldty_Code: VALID MEDICAL-NO WAIVERS/ LIMITATIONS
Flight Time (Hours)
Total : 8000 Last 24 Hrs : 0
Make/Model: 6300 Last 30 Days: 0
Instrument: 0 Last 90 Days: 0
Multi-Eng : 0 Rotorcraft : 0
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-72-78
Last Updated: 09-21-94
[O] A fatal aircraft accident, which the ntsb is currently investigating, and a recent aircraft incident have indicated to the board that a safety
problem exists on twin-engined general aviation aircraft which have baggage compartments located in the nose section.
Recommendations:
A-72-78. Provide for double failure protection by means of a secondary locking device or cargo restraint system on those

cargo doors where
inadvertent opening in flight would seriously jeopardize the safety of flight of the aircraft or the safety of its occupants on all so affected
aircraft.
Responses:
FAA LTR DTD: 07/13/72
With respect to the beechcraft 99 inadvertent door opening incident, proposed rulemaking action is being considered to require a thirdcargo
door latch device which is in addition to the two existing latches now in use. The new double failure protection device is provided in accordance
with beech service instruction 051-113 sent to all owners and operators on 20 june 1972. With the proposed modification to the beech 99, and
with proper maintenance, the cargo compartments of both the beech 65 and the beech 99 should adequately restrain cargo and fulfill the
requirements of the regulation. Therefore, we do not concur that rulemaking under part 135 be recommended.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-89-94
Last Updated: 11-06-96
[O] On February 24, 1989, United Airlines, Inc., (UAL), Flight 811, a Boeing 747-122, N4713U, with 3 flight crewmembers, 15 cabin crewmembers,
and 337 passengers on board, experienced an explosive decompression as a result of the in-flight loss of the right forward lower lobe cargo
compartment door and a part of the right cabin fuselage.
Recommendations:

A-89-94. Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for
conceivable human errors in addition to electrical and mechanical malfunctions.
Responses:
FAA LTR DTD: 11/3/89
The FAA will determine its course of action to address this safety recommendation as soon as its review in response to Safety Recommendation A-89-93 is completed.
As stated in our response to Safety Recommendation A-89-93, 14 CFR 25.783 and AC 25.783-1 consider human factors in the routine operation
of closing and locking doors to ensure that the latch and lock systems are fail-safe. To emphasize the importance of human factors, the FAA
has developed a training program for FAA certification personnel to enhance their knowledge of human factors in aircraft design. This
training program will be offered to approximately 100 certification personnel during the next year. I believe that this training program will
result in more effective review of designs for human factor considerations as required by present regulations.
I will keep the Board apprised of the FAA's progress on this safety recommendation.
NTSB LTR DTD: 4/16/90
The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all
jet-powered transport category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight.

The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against
criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted
in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock
systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification
personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100
certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as
"Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using
non-plug doors and that the FAA should not be limiting this review to only those transports which are jet-powered.
FAA LTR DTD: 6/29/93
The FAA is considering the issuance of an NPRM to address this safety recommendation. The FAA has asked the Aviation Rulemaking
Advisory Committee to participate in the drafting of this document.
I will provide the Board with a copy of any document that may be issued.
FAA LTR DTD: 9/5/96
The Federal Aviation Administration (FAA) asked the aircraft

industry to form an industry task group to review cargo door designs on the
fleet of transport airplanes and to provide the FAA with recommendations regarding any deficiencies found as a result of the review.
Subsequently, the FAA issued airworthiness directives (AD's) in accordance with the recommendations received from the task group to
prevent nonplug cargo doors from opening in flight. Copies of the AD's were provided to the Board in response to Safety Recommendation
A-89-93. The FAA is satisfied that the task group reviewed these designs in an effective and comprehensive manner and that the resultant
AD's ensure that human factors considerations in both 14 CFR 25.783 (as amended by Amendment 25-72) and Advisory Circular 25.783-1 are
adequate for the current fleet of transport category airplanes.

The FAA also developed a training course for aircraft certification engineers to address the fail-safe design requirements and the human
factors aspects of proper door locking and latching mechanisms. All certification engineers assigned to work on door issues have received the
training.
I believe that the FAA has taken appropriate action to address this safety recommendation, and I consider the FAA's action to be completed.
NTSB LTR DTD: 10/29/96
The Safety Board notes that the FAA urged the aircraft industry to form a task group to review cargo door designs and to provide the FAA

with recommendations regarding any deficiencies noted during the review. Subsequently, the FAA issued airworthiness directives in response
to the recommendations developed by the task group to prevent non-plug cargo doors from opening in flight. The FAA also developed a
training course for all aircraft certification engineers to address the fail-safe design requirements and the human factors aspects of proper
door locking and latching mechanisms. All certification engineers assigned to work on door issues have received the training.

In view of the actions taken by the FAA, the Safety Board classifies Safety Recommendation A-89-94 "Closed Acceptable Action."

NTSB Safety Recommendation Brief

Data_Source: U.S. NTSB Safety Recommendations

Rprt_Nbr: A-92-21

Last Updated: 09-21-94

[O] On February 24, 1989, United Airlines flight 811, a Boeing 747-122 (B-747), N4713U, was operating as a regularly scheduled flight from Los
Angeles, California, to Sydney, Australia, with intermediate stops in Honolulu, Hawaii, and Auckland, New Zealand. There were 3 flight
crewmembers, 15 flight attendants, and 337 passengers aboard the airplane.

The flightcrew's first indication of a problem was while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed of 300
knots. They heard a sound, described as a "thump," which shook the airplane. This sound was followed immediately by a "tremendous

explosion." The airplane had experienced an explosive decompression. Power was lost from the Nos. 3 and 4 engines because of damage from
foreign object ingestion.
The airplane made a successful emergency landing in Honolulu, and the occupants evacuated the airplane. An examination of the evidence
at the time revealed that the forward lower lobe cargo door had separated in flight, causing extensive damage to the fuselage and cabin
structure adjacent to the door. As a result, nine of the passengers were ejected from the airplane and lost at sea.
Recommendations:
A-92-21. Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all
electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the
door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits.
Responses:
FAA LTR DTD: 6/22/92
The FAA has initiated a review of all outward opening nonplug cargo doors on transport-category airplanes. One aspect of this review is to
verify that all electrical power to the doors (except for any indicating circuit power necessary to provide positive indication that the door is
properly latched and locked) is removed in flight. The FAA has completed its review of the Boeing Models 747, 757, 767, 737, and 727 and

concluded that the power is removed from the doors in flight. Consequently, the FAA does not plan to initiate mandatory action on these
moels.
I will keep the Board apprised of the FAA's progress on its review of other transport category airplanes.
NTSB LTR DTD: 8/31/92
Safety Recommendation A-92-21 states that the FAA should require that the electrical actuating systems for nonplug cargo doors on
transport category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating
circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of
uncommanded actuator movements caused by wiring short circuits. The Safety Board notes that the FAA has completed its review of one
aspect of this recommendation and has concluded that electrical power is removed from the circuit on the doors in flight on Boeing Models
747, 757 767, 737, and 727. However, the intent of this safety recommendation is to insure that no electrical power is available to actuating
systems for nonplug cargo doors on transport-category aircraft after closure of the doors.
The Safety Board stated in the accident report involving United Airlines flight 811 that the door opening was attributed to a faulty switch or
wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door

closure and before takeoff. The Safety Board believes that by requiring that all electrical power be removed from door actuating circuits after
closure, the possibility of uncommanded actuator movements caused by wiring short circuits that might occur between the time that the door
is closed and the time that the airplane takes off is eliminated. Pending further information, the Safety Board classifies Safety Recommendation A-92-21 as "Open--Await Response."
FAA LTR DTD: 4/20/93
The FAA has completed its review of this safety recommendation and agrees with the intent. The FAA has evaluated the door designs of all
large transport category airplanes for isolation of power to the doors during flight. All of the nonplug doors on these category airplanes have
been modified as necessary to achieve this objective. Nonplug doors already have a separate power switch at the door operator's station that
removes power from the door. Some switches operate directly while others, such as the power switches on the Boeing Models 737, 747, and 767,
are operated by the lock handle. The Boeing Models 727 and 757 have separate disarm switches. On the lighter transport category airplanes,
the outward opening doors without powered latches and locks do not have the potential safety problems associated with inadvertent operation
due to electrical shorts.
Additional automatic protection against electrical shorts is provided on the Boeing Model 747 airplanes. The ground handling bus is the sole
source of electrical power for all of the airplanes' nonplug doors.

During departure from the gate once ground power has been disconnected from the airplane and an engine generator has been placed on line, power is removed from the ground handling bus. Additional protection against an inadvertent power source is provided by the operation of a relay which opens when the main landing gear leaves the ground and the air-ground squat switch opens.

The current policy as stated in Advisory Circular 25.783-1 requires an additional warning for doors that could create a hazard in the event they open during takeoff. These doors require a red light to announce an unsafe door condition and some configurations may require an aural warning during the initial takeoff run.

The FAA's review of the nonplug door configurations currently installed on the large transport category airplanes showed that electrical power is removed from all of these doors before the airplane leaves the gate. On some of these airplanes, all of the electrical power to the door operating controls is removed as soon as an engine is started and its associated generator placed on-line. In addition, the warning systems on the doors of these airplanes meet the policies contained in Advisory Circular 25.783-1. Any inadvertent change of the positioning of the door lock mechanisms would be annunciated to the flightcrew. Based on these data, the FAA believes that the present door configuration provides adequate protection against the possibility of an inadvertent power application caused by an electrical short.

I consider the FAA's action to be completed on this safety recommendation.
NTSB LTR DTD: 8/10/93
The Safety Board notes that during the past year the FAA has worked with and encouraged the airline industry in the development of new
methods for removal of electrical power from nonplug cargo door actuating systems on transport-category aircraft. Furthermore, the FAA has
reviewed the nonplug cargo door configurations currently installed on large transport-category airplanes and found that electrical power is
removed from all of these doors before the airplane leaves the gate.
Additionally, on some of these airplanes, all electrical power to the door operating controls is removed as soon as an engine is started and its
associated generator is placed on-line. Any inadvertent change in the position of the door lock mechanisms that occurred before the removal
of electrical power would be annunciated to the flightcrew. The review verified that the warning systems on the doors of these airplanes meet
the policies contained in Advisory Circular 25.783-1.
The Safety Board accepts the FAA position that removal of electrical power from door circuits before taxi in conjunction with redundant and
reliable lock position warning systems as described in the AC meet the intent of Safety Recommendation A-92-21. Thus, Safety
Recommendation A-92-21 is classified "Closed--Acceptable Alternate Action."
NTSB Safety Recommendation Brief

Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-89-92
Last Updated: 09-21-94
[O] On February 24, 1989, United Airlines, Inc., (UAL), Flight 811, a Boeing 747-122, N4713U, with 3 flight crewmembers, 15 cabin crewmembers,
and 337 passengers on board, experienced an explosive decompression as a result of the in-flight loss of the right forward lower lobe cargo
compartment door and a part of the right cabin fuselage.
Recommendations:
A-89-92. Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have
torque-limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical
operation of the latch cams.
Responses:
FAA LTR DTD: 11/3/89
The FAA evaluated this safety recommendation and has determined that Boeing 747 cargo doors with lock sectors, modified in compliance
with Airworthiness Directive (AD) 88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams because the
latch cam actuators incorporate at least one torque-limiting device. Based on this information, the FAA does not plan to issue an AD as
requested by this safety recommendation.
NTSB LTR DTD: 4/16/90
The FAA responded to Safety Recommendations A-89-92 through -94 on November 3, 1989. During its evaluation of

Safety Recommendation
A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with Airworthiness Directive (AD)
88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams because the latch cam actuators incorporate at
least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this, Safety
Recommendation A-89-92 has been classified as "Closed--Reconsidered."

NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-89-93
Last Updated: 09-21-94
[O] On February 24, 1989, United Airlines, Inc., (UAL), Flight 811, a Boeing 747-122, N4713U, with 3 flight crewmembers, 15 cabin crewmembers,
and 337 passengers on board, experienced an explosive decompression as a result of the in-flight loss of the right forward lower lobe cargo
compartment door and a part of the right cabin fuselage.
Recommendations:
A-89-93. Issue an Airworthiness Directive for non-plug cargo doors on all transport category airplanes requiring the installation of positive
indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently.
Responses:
FAA LTR DTD: 11/3/89
The FAA is reviewing all outward opening (nonplug) doors on all jet-powered transport category airplanes to determine what, if

any,
modifications are needed to ensure that these doors will not open in flight. The door latch indicating system is only part of this review. Door
designs are being evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in
Advisory Circular (AC) 25.783-1, Fuselage Doors, Hatches, and Exits. These standards were adopted in 1980 and account for human factors
involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe.
I will keep the Board apprised of the FAA's progress on this safety recommendation.
NTSB LTR DTD: 4/16/90
The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all
jet-powered transport category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight.
The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against
criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted
in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock
systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification

personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100
certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as
"Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using
non-plug doors and that the FAA should not be limiting this review to only those transports which are jet-powered.
FAA LTR DTD: 6/29/93
The FAA has issued five final rules and one notice of proposed rulemaking (NPRM) which address this safety recommendation. On
November 28, 1989, the FAA issued a final rule applicable to certain McDonnell Douglas DC-9 series airplanes, and on February 27, 1990, the
FAA issued a final rule applicable to certain DC-8 series airplanes. These two rules require installation of a main cargo door hydraulic
isolation valve; installation of an additional (and modification of an existing) door-open indicating system; installation of a main cargo door
lock pin viewing window; installation of a main cargo door vent system; installation of a "vent door-open" indicating system; installation of a
main cargo door hinge pin retainer; and modification to the main cargo door latch operating mechanism.
Effective May 29, 1990, the FAA issued Airworthiness Directive 90-09-06 applicable to certain B-747 series airplanes to prevent the inadvertent
opening of lower lobe forward and aft cargo doors and main side

cargo doors. The terminating action includes inspections, repairs, tests,
and placard installations.
On August 14, 1990, the FAA issued a final rule applicable to certain DC-10 series airplanes to require the installation of a main deck cargo
door "vent door-open" indicating system and installation of cargo door hinge pin retainers. On September 25, 1992, the FAA issued a final
rule applicable to certain B-737 series airplanes to require modification of the main deck cargo door lock, viewing windows, and warning
indication system.
I have enclosed copies of these final rules for the Board's information.
On March 10, 1993, the FAA issued an NPRM applicable to certain Lockheed Model L-1011 series airplanes. This NPRM proposes to require
inspection of the cargo door components for cracks and corrosion and require modification, rework, or replacement of discrepant parts.
I have also enclosed a copy of the NPRM for the Board's information. I will provide the Board with a copy of the final document as soon as it is
issued.
FAA LTR DTD: 7/20/94
In response to this safety recommendation, the Federal Aviation Administration (FAA) reviewed all outward opening (nonplug) doors on all
jet-powered transport category airplanes for both design deficiencies and for service-related safety problems. The nonplug door review
included an examination of the door latch indicating system, as

well as all other design criteria specified in 14 CFR 25.783 and the policy
material published in Advisory Circular 25.783-1, Fuselage, Doors, Hatches, and Exits. As a result of this review, the FAA issued five final rules
that addressed different aspects of nonplug doors on transport category aircraft. The final rules, which were provided to the Board on June 29,
1993, addressed McDonnell Douglas DC-9, DC-10, and certain DC-8 series airplanes, and Boeing 747 and 737 series airplanes. On December
6, 1993, the FAA issued Airworthiness Directive (AD) 93-24-12 applicable to the L-1011-385 series airplane. The issuance of AD 93-24-12
completes the FAA's action to prevent nonplug cargo doors from opening in flight. I have enclosed a copy of AD 93-24-12 for the Board's
information.
The FAA's review of this issue included only jet-powered transport category airplanes. The service history of nonjet-powered transport
category airplanes does not indicate safety issues that needed to be addressed through the door review effort.
The actions taken by the FAA address the full intent of this safety recommendation. Consequently, I consider the FAA's action to be
completed, and I plan no further action on this issue.
NTSB LTR DTD: 8/30/94
The Safety Board notes that the FAA has completed a review of all non-plug doors on jet-powered transport-category airplanes. The review
resulted in the issuance of five rules that addressed changes to the McDonnell Douglas DC-9, DC-10, and DC-8; Boeing 737 and

747; and
Lockheed L-1011-385 series airplanes.
The Safety Board agrees that these actions address the intent of Safety Recommendation A-89-93 and classifies this recommendation "Closed
Acceptable Action."
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-91-84
Last Updated: 03-13-95
[O] On June 13, 1991, United Airlines (UAL) maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B,
N152UA, at John F. Kennedy Airport (JFK), Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between
Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.
Recommendations:
A-91-84. Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and
issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the
provisions recommended in A-91-83.
Responses:
FAA LTR DTD: 11/01/91
The FAA agrees with the intent of these safety recommendations and is considering the issuance of a notice of proposed rulemaking to
address these issues. I will provide the Board with a copy of any document that may be issued.

NTSB LTR DTD: 11/27/91
These recommendations were issued as a result of the Board's investigation of an incident in which the rear cargo door on a Boeing 747-222B
initially would not open electrically and then opened electrically without activation of the door open switches. Your letter indicates that the
Federal Aviation Administration agrees with the intent of these recommendations and is considering the issuance of a notice of proposed
rulemaking to address these issues. The Board urges the FAA to move expeditiously on the recommendations. Pending receipt of additional
information concerning the action to be taken by the Federal Aviation Administration, the Safety Board is classifying Safety Recommendations A-91-83 and -84 as "Open--Acceptable Action."

FAA LTR DTD: 4/5/93
The Federal Aviation Administration (FAA) agrees with the intent of these recommendations. On February 18, 1992, the FAA issued a notice of
proposed rulemaking (NPRM) applicable to certain Boeing Model 747 series airplanes. This NPRM proposed to require inspection of the
flexible conduit, wiring, and support brackets between the fuselage and the forward and aft cargo doors. Since the issuance of this NPRM, the
FAA has further reviewed the circumstances surrounding this door opening incident and has confirmed that an inadvertent in-flight opening
of the cargo door cannot be caused solely by wire chafing. The FAA has determined that in addition to chafing at least four

independent
failures must also occur in order to drive the door latches to the open position. In light of these findings, the FAA determined that the
requirements proposed by the NPRM were unnecessary. On December 21, 1992, the FAA withdrew the NPRM. I have enclosed a copy of the
notice of withdrawal for the Board's information.
Airworthiness Directive (AD) 90-09-06 (Docket No. 89-NM-148-AD) mandates the installation of a door warning switch located on the lock
sector, as well as a reinforcement of the lock sector to ensure that the latches remain locked against backdriving of the latches by the latch
power drive unit. Failure of lock sectors that are reinforced in accordance with AD 90-09-06 has been shown to be unlikely and, even in the
event of such a failure, an indication by means of the door warning switch will warn the flightcrew of the problem. The modifications, tests, and
inspections required in AD 90-09-06 provide an acceptable level of safety to preclude inadvertent actuation of the cargo door power drive unit
and possible injury to maintenance or cargo handling personnel. I have enclosed a copy of the AD for the Board's information. The FAA
believes that the current requirements of AD 90-09-06 address the full intent of these safety recommendations to preclude an uncommanded
opening of the forward and aft cargo doors.
I consider the FAA's action to be completed, and I plan no further action on Safety Recommendations A-91-83 and -84.
NTSB LTR DTD: 11/8/93

The National Transportation Safety Board has reviewed the Federal Aviation Administration (FAA) response of April 5, 1993, to Safety Recommendations A-91-83 and -84. These recommendations asked that the FAA issue an airworthiness directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between-the-fuselage and aft cargo door to require an expedited inspection of:
(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test method or visual examination); (2) the conduit support bracket and attached standoff pin-on the upper arm of the forward lift actuator mechanism; (3) the flexible conduit for the presence of cracking in the convoluted innercore.
The Board further recommended that wires with damaged insulation be repaired before further service. Damage to the flexible conduit, conduit support bracket, and standoff pin should result in an immediate replacement of the conduit as well as. the damaged parts. The inspection should be repeated at an appropriate cyclic interval.
The Safety Board then asked, in Safety Recommendation A-91-84, that the FAA evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an airworthiness directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in Safety Recommendation A-91-83.

The FAA's April 5, 1993, response listed a number of findings of an FAA review of the circumstances surrounding the subject door opening.
Among the findings, the FAA confirmed that an inadvertent inflight opening of the cargo door cannot be caused solely by wire chafing.
Further, the FAA determined that at least four independent failures must occur to drive the door latches to the open position. The FAA also
stated that failure of lock sectors that are reinforced in accordance with AD 90-09-06 has been shown to be unlikely and, even in the event of
such a failure, the door warning switch would warn the flightcrew, of the problem.
Based on these findings, the FAA has decided that the requirements of AD 90-09-06 address the full intent of these recommendations-to
preclude an uncommanded opening of the forward and aft cargo doors.
FAA staff has also expressed concern that the recommended inspections could result in damage to the wire bundle insulation during the
intrusive inspection. Therefore, based on the level of redundancy that now exists to prevent inadvertent door opening in flight, the Safety
Board has classified Safety Recommendations A-91-83 and -84 as "Closed-Reconsidered. The Board will closely monitor incidents related to
the uncommanded opening of cargo doors on 747 airplanes to further document this position.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-91-83

Last Updated: 03-13-95
[O] On June 13, 1991, United Airlines (UAL) maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B,
N152UA, at John F. Kennedy Airport (JFK), Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between
Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.
Recommendations:
A-91-83. Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between
the fuselage and aft cargo door to require an expedited inspection of:
(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test
method or visual examination);
(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;
(3) the flexible conduit for the presence of cracking in the convoluted innercore.
Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and
standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an
appropriate cyclic interval.
Responses:
FAA LTR DTD: 11/1/91
The FAA agrees with the intent of these safety recommendations

and is considering the issuance of a notice of proposed rulemaking to
address these issues. I will provide the Board with a copy of any document that may be issued.

NTB LTR DTD: 11/27/91
These recommendations were issued as a result of the Board's investigation of an incident in which the rear cargo door on a Boeing 747-222B
initially would not open electrically and then opened electrically without activation of the door open switches. Your letter indicates that the
Federal Aviation Administration agrees with the intent of these recommendations and is considering the issuance of a notice of proposed
rulemaking to address these issues. The Board urges the FAA to move expeditiously on the recommendations. Pending receipt of additional
information concerning the action to be taken by the Federal Aviation Administration, the Safety Board is classifying Safety Recommendations A-91-83 and -84 as "Open--Acceptable Action."
FAA LTR DTD: 4/5/93
The Federal Aviation Administration (FAA) agrees with the intent of these recommendations. On February 18, 1992, the FAA issued a notice of
proposed rulemaking (NPRM) applicable to certain Boeing Model 747 series airplanes. This NPRM proposed to require inspection of the
flexible conduit, wiring, and support brackets between the fuselage and the forward and aft cargo doors. Since the issuance of this NPRM, the
FAA has further reviewed the circumstances surrounding this

door opening incident and has confirmed that an inadvertent in-flight opening
of the cargo door cannot be caused solely by wire chafing. The FAA has determined that in addition to chafing at least four independent
failures must also occur in order to drive the door latches to the open position. In light of these findings, the FAA determined that the
requirements proposed by the NPRM were unnecessary. On December 21, 1992, the FAA withdrew the NPRM. I have enclosed a copy of the
notice of withdrawal for the Board's information.
Airworthiness Directive (AD) 90-09-06 (Docket No. 89-NM-148-AD) mandates the installation of a door warning switch located on the lock
sector, as well as a reinforcement of the lock sector to ensure that the latches remain locked against backdriving of the latches by the latch
power drive unit. Failure of lock sectors that are reinforced in accordance with AD 90-09-06 has been shown to be unlikely and, even in the
event of such a failure, an indication by means of the door warning switch will warn the flightcrew of the problem. The modifications, tests, and
inspections required in AD 90-09-06 provide an acceptable level of safety to preclude inadvertent actuation of the cargo door power drive unit
and possible injury to maintenance or cargo handling personnel. I have enclosed a copy of the AD for the Board's information. The FAA
believes that the current requirements of AD 90-09-06 address the full intent of these safety recommendations to preclude an uncommanded

opening of the forward and aft cargo doors.
I consider the FAA's action to be completed, and I plan no further action on Safety Recommendations A-91-83 and -84.
NTSB LTR DTD: 11/8/93
The National Transportation Safety Board has reviewed the Federal Aviation Administration (FAA) response of April 5, 1993, to Safety
Recommendations A-91-83 and -84. These recommendations asked that the FAA issue an airworthiness directive applicable to all Boeing 747
airplanes with a flexible conduit protecting the wiring bundle between-the-fuselage and aft cargo door to require an expedited inspection of:
(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test
method or visual examination); (2) the conduit support bracket and attached standoff pin-on the upper arm of the forward lift actuator
mechanism; (3) the flexible conduit for the presence of cracking in the convoluted innercore.

The Board further recommended that wires with damaged insulation be repaired before further service. Damage to the flexible conduit,
conduit support bracket, and standoff pin should result in an immediate replacement of the conduit as well as. the damaged parts. The
inspection should be repeated at an appropriate cyclic interval.

The Safety Board then asked, in Safety Recommendation A-91-84, that the FAA evaluate the design, installation, and operation of the forward

cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an airworthiness directive for inspection and repair
of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in Safety Recommendation
A-91-83.

The FAA's April 5, 1993, response listed a number of findings of an FAA review of the circumstances surrounding the subject door opening.
Among the findings, the FAA confirmed that an inadvertent inflight opening of the cargo door cannot be caused solely by wire chafing.
Further, the FAA determined that at least four independent failures must occur to drive the door latches to the open position. The FAA also
stated that failure of lock sectors that are reinforced in accordance with AD 90-09-06 has been shown to be unlikely and, even in the event of
such a failure, the door warning switch would warn the flightcrew, of the problem.

Based on these findings, the FAA has decided that the requirements of AD 90-09-06 address the full intent of these recommendations-to
preclude an uncommanded opening of the forward and aft cargo doors.

FAA staff has also expressed concern that the recommended inspections could result in damage to the wire bundle insulation during the
intrusive inspection. Therefore, based on the level of redundancy that now exists to prevent inadvertent door opening in flight, the

Safety
Board has classified Safety Recommendations A-91-83 and -84 as "Closed-Reconsidered. The Board will closely monitor incidents related to
the uncommanded opening of cargo doors on 747 airplanes to further document this position.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-70-53
Last Updated: 09-21-94
[O] Our staff member who participated in the irish/british investigation of theaer lingus b-707-349c depressurization incident that occurred en
route shannon to london on september 24, 1970, has briefed your flight standards personnel on details of the involved fuselage skin fractures,
and has supplied your personnel with photographs of the fracture area. As you know, a 3- by 4-foot section of the fuselage sidewall blew out
while the aircraft was flying at 25,000 feet, at a cabin pressure differential of 8.2p.S.I., causing a rapid depressurization of the cabin and
deployment of thepassenger oxygen masks. The crew initiated an emergency descent and landed the aircraft at london without further
incident. The royal aeronautical establishment metallurgical laboratory at farnsborough has confined the presence of fatigue in the fracture of
the outer main cargo doorskin in the area between fuselage station 540 and 560. Multiple fatigue nuclei were found at numerous rivet holes
near the center of the approximate 22-inch primary fracture line. Heavy nicotine staining on the skin and adjacent frames

indicated that cabin
air had been exiting through the skin crack forsome time. The area had last been inspected 368 hours before the depressurization incident.
The total aircraft time was 20,820 hours.
Recommendations:
A-70-53. 1) that the faa issue an Airworthiness Directive requiring the inspection of all b-707 and b-727 cargo doors for evidence of fatigue
cracking at 150-hour intervals. 2) that faa reevaluate the design safety features of the single, actuator-type door, and assess the need for and
feasibility of incorporation of a dual actuator system to reduce door flexing loads.
variousdooraccidents.html Accounts of various cargo door accidents/incidents.
forwardcargodoorpict.html Contents to links on door on site
Schematic1 Door Drawing
Schematic2 Door Drawing
Schematic3 Door Drawing
Boeing 747 nose picts right side cargo door
cargodoorfaraway.html Pictures near, close and faraway
811doordraw 747 argo cdoor drawing from 811 report
811picture UAL 811 cargo door hole picture
More pictures of UAL 811 cargo door hole

#Comment Doors open all the time with varying degrees of consequence.
#
Boeing747historycontents.html
DC-10crashcontents.html
103reportcontents.html
811reportcontentpage.html

AirIndiareportcontents.html
800newsreports.html
800newsreports1.html
800newsreports2.html
800newsreports3.html
pressurization1.html
aerodynamics.html
314accidentreport.html
811skiesdoorcontents.html
Contents
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: March 4, 2001 12:47:09 PM PST
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **More cargo doors open in flight than bombs go off**

Various cargo door/depressurization accidents:

T96-01-51 BOEING

TRANSMITTED AS FOLLOWS IS TELEGRAPHIC
AIRWORTHINESS
DIRECTIVE T96-01-51 FOR IMMEDIATE TRANSMITTAL
TO ALL OWNERS
AND OPERATORS OF BOEING MODEL 747-100 SERIES
AIRPLANES
MODIFIED IN ACCORDANCE WITH SUPPLEMENTAL
TYPE CERTIFICATES

(STC) SA2322SO AND A MODEL 747-200 SERIES AIRPLANE MODIFIED
IN ACCORDANCE WITH STC SA4227NM-D.
THE FAA HAS RECENTLY RECEIVED A REPORT THAT THE
FLIGHTCREW ON A BOEING MODEL 747-100 SERIES AIRPLANE NOTED
AN ABNORMAL CABIN ALTITUDE RATE OF CLIMB. ALTHOUGH THE
PRESSURIZATION VENT DOOR LIGHT WAS NOT ILLUMINATED (WHICH
INDICATED TO THE FLIGHTCREW THAT THE DOOR WAS CLOSED AND
LOCKED), THE FLIGHTCREW WAS UNABLE TO PRESSURIZE THE
AIRPLANE. THE FLIGHTCREW ALSO NOTED THAT THE MAIN DECK SIDE
CARGO "DOOR UNLOCKED" LIGHT ILLUMINATED SHORTLY AFTER
TAKEOFF. INVESTIGATION REVEALED THAT 11 OF THE 12 LATCHES
ON THE MAIN DECK SIDE CARGO DOOR WERE UNLATCHED AND
UNLOCKED. HOWEVER, THE PRESSURIZATION VENT DOOR WAS CLOSED
AND LOCKED, WHICH WOULD INDICATE A MALFUNCTION OF THE SAFETY
INTERLOCK SYSTEM.
A PROPERLY FUNCTIONING SAFETY INTERLOCK SYSTEM ELECTRO-
MECHANICALLY PREVENTS THE PRESSURIZATION VENT DOOR FROM
CLOSING UNTIL ALL OF THE LATCHES ARE IN THE

FULLY LATCHED
AND LOCKED POSITION. IF THE PRESSURIZATION VENT DOOR IS NOT
CLOSED THE AIRPLANE CANNOT BE PRESSURIZED.
ALTHOUGH THE ORIGINAL CAUSE OF THE FAILURE TO PROPERLY
LATCH THE DOOR MAY BE ATTRIBUTABLE TO HUMAN ERROR, THE
PURPOSE OF THE INTERLOCK SYSTEM IS TO ENSURE THAT SUCH
ERRORS ARE DETECTED SO THAT THE AIRPLANE CANNOT BE
PRESSURIZED UNLESS THE MAIN DECK SIDE CARGO DOOR IS PROPERLY
LATCHED AND LOCKED. MALFUNCTION OF THE SAFETY INTERLOCK
SYSTEM OF THE MAIN DECK SIDE CARGO DOOR, IF NOT CORRECTED,
COULD RESULT IN AN IN-FLIGHT OPENING OF THE MAIN DECK SIDE
CARGO DOOR, AND SUBSEQUENT RAPID DECOMPRESSION OF THE
AIRPLANE.
THE AIRPLANE IN THE REPORTED INCIDENT WAS MODIFIED IN
ACCORDANCE WITH SUPPLEMENTAL TYPE CERTIFICATE (STC)
SA2322SO. THE MODIFICATION ENTAILED INSTALLATION OF A MAIN
DECK SIDE CARGO DOOR AS PART OF A CONVERSION THAT
RECONFIGURED THE AIRPLANE FROM A PASSENGER CONFIGURATION TO

A SPECIAL FREIGHTER CONFIGURATION.
SINCE STC SA2322SO FOR MODEL 747-100 SERIES AIRPLANES IS
SIMILAR IN DESIGN TO STC SA4227NM-D FOR A MODEL 747-200
SERIES AIRPLANE, THE FAA HAS DETERMINED THAT THE UNSAFE
CONDITION MAY ALSO EXIST ON A MODEL 747-200 SERIES AIRPLANE
THAT HAS BEEN MODIFIED IN ACCORDANCE WITH STC SA4227NM-D.
THIS STC CONVERTED A MODEL 747-200 SERIES AIRPLANE FROM A
PASSENGER CONFIGURATION TO A SPECIAL FREIGHTER
CONFIGURATION.
SINCE AN UNSAFE CONDITION HAS BEEN IDENTIFIED THAT IS
LIKELY TO EXIST OR DEVELOP ON OTHER AIRPLANES OF THIS SAME
TYPE DESIGN, THIS TELEGRAPHIC AIRWORTHINESS DIRECTIVE IS
ISSUED TO REQUIRE REPETITIVE INSPECTIONS OF THE LATCH SAFETY
PINS OF THE MAIN DECK SIDE CARGO DOOR.
THIS TELEGRAPHIC AD ALSO REQUIRES DEACTIVATION OF THE
"LATCHES UNLOCKED" LIGHT AT THE DOOR OPERATING PANEL AND THE
"DOOR UNLOCKED" LIGHT AT THE FLIGHT ENGINEER PANEL, AND
FABRICATION AND INSTALLATION OF A PLACARD TO INDICATE THAT

THE "DOOR UNLOCK" LIGHT AT THE FLIGHT ENGINEER (F/E) PANEL
HAS BEEN DEACTIVATED, IN ACCORDANCE WITH A METHOD APPROVED
BY THE FAA.
THIS TELEGRAPHIC AD PROVIDES FOR TERMINATION OF THE
REQUIREMENT TO REPETITIVELY INSPECT THE PINS AND REMOVAL OF
THE PLACARD FOLLOWING ACCOMPLISHMENT OF A MODIFICATION THAT
POSITIVELY ADDRESSES THE UNSAFE CONDITION AND THAT HAS BEEN
APPROVED BY THE FAA.
THIS IS CONSIDERED TO BE INTERIM ACTION UNTIL FINAL
ACTION IS IDENTIFIED, AT WHICH TIME THE FAA MAY CONSIDER
FURTHER RULEMAKING.
THIS RULE IS ISSUED UNDER 49 U.S.C. SECTION 44701
(FORMERLY SECTION 601 OF THE FEDERAL AVIATION ACT OF 1958)
PURSUANT TO THE AUTHORITY DELEGATED TO ME BY THE
ADMINISTRATOR, AND IS EFFECTIVE IMMEDIATELY UPON RECEIPT OF
THIS TELEGRAM.

T96-01-51 BOEING: TELEGRAPHIC AD ISSUED ON JANUARY 3,
1996. DOCKET NO. 96-NM-01-AD.
APPLICABILITY: MODEL 747-100 SERIES AIRPLANES HAVING

SERIAL NUMBERS 19637, 19638, 19642, 19647, 19648, 19657,
19725, 20320, AND 20347, THAT HAVE BEEN MODIFIED IN ACCORDANCE WITH SUPPLEMENTAL TYPE CERTIFICATE (STC)
SA2322SO, AND MODEL 747-200 SERIES AIRPLANE HAVING SERIAL
NUMBER 20010 THAT HAS BEEN MODIFIED IN ACCORDANCE WITH STC
SA4227NM-D, CERTIFICATED IN ANY CATEGORY.
NOTE 1: THIS AD APPLIES TO EACH AIRPLANE IDENTIFIED IN
THE PRECEDING APPLICABILITY PROVISION, REGARDLESS OF WHETHER
IT HAS BEEN MODIFIED, ALTERED, OR REPAIRED IN THE AREA
SUBJECT TO THE REQUIREMENTS OF THIS AD. FOR AIRPLANES THAT
HAVE BEEN MODIFIED, ALTERED, OR REPAIRED SO THAT THE
PERFORMANCE OF THE REQUIREMENTS OF THIS AD IS AFFECTED, THE
OWNER/OPERATOR MUST USE THE AUTHORITY PROVIDED IN PARAGRAPH
(D) OF THIS AD TO REQUEST APPROVAL FROM THE FAA. THIS
APPROVAL MAY ADDRESS EITHER NO ACTION, IF THE CURRENT
CONFIGURATION ELIMINATES THE UNSAFE CONDITION; OR DIFFERENT
ACTIONS NECESSARY TO ADDRESS THE UNSAFE CONDITION DESCRIBED
IN THIS AD. SUCH A REQUEST SHOULD INCLUDE AN

ASSESSMENT OF
THE EFFECT OF THE CHANGED CONFIGURATION ON THE UNSAFE
CONDITION ADDRESSED BY THIS AD. IN NO CASE DOES THE
PRESENCE OF ANY MODIFICATION, ALTERATION, OR REPAIR REMOVE
ANY AIRPLANE FROM THE APPLICABILITY OF THIS AD.
COMPLIANCE: REQUIRED AS INDICATED, UNLESS ACCOMPLISHED
PREVIOUSLY.
TO PREVENT MALFUNCTION OF THE SAFETY INTERLOCK SYSTEM OF
THE MAIN DECK CARGO DOOR AND SUBSEQUENT RAPID DECOMPRESSION
OF THE AIRPLANE DUE TO IN-FLIGHT OPENING OF THE MAIN DECK
SIDE CARGO DOOR, ACCOMPLISH THE FOLLOWING:
(A) NOTWITHSTANDING THE REQUIREMENTS OF PARAGRAPH E. OF
AD 90-09-06, AMENDMENT 39-6581, WITHIN 3 DAYS AFTER RECEIPT
OF THIS TELEGRAPHIC AD, DEACTIVATE THE "LATCHES UNLOCKED"
LIGHT AT THE DOOR OPERATING PANEL AND THE "DOOR UNLOCKED"
LIGHT AT THE F/E PANEL, AND FABRICATE AND INSTALL PLACARDS;
IN ACCORDANCE WITH A METHOD APPROVED BY THE MANAGER, ATLANTA
AIRCRAFT CERTIFICATION OFFICE (ACO), FAA, SMALL AIRPLANE
DIRECTORATE.

(B) WITHIN 3 DAYS AFTER RECEIPT OF THIS TELEGRAPHIC AD,
ACCOMPLISH THE REQUIREMENTS OF PARAGRAPHS (A)(1), (A)(2),
(A)(3), (A)(4), (A)(5), AND (A)(6) OF THIS AD. REPEAT THESE
PROCEDURES THEREAFTER PRIOR TO EACH FLIGHT. THESE
PROCEDURES MUST BE PERFORMED BY PROPERLY TRAINED AND
QUALIFIED MAINTENANCE PERSONNEL.
(1) CLOSE THE MAIN DECK SIDE CARGO DOOR IN
ACCORDANCE WITH NORMAL OPERATIONS PROCEDURES.
(2) UNSCREW, LIFT, AND SECURE THE DOOR LOWER ACCESS
PANELS IN THE "UP" POSITION.
(3) PERFORM A VISUAL INSPECTION OF ALL 12 LATCH AND
LOCK ARMS TO ENSURE THAT THEY ARE OVERCENTER IN THE "LOCKED"
POSITION AND THAT ALL ALIGNMENT MARKS LINE-UP CORRECTLY.
(4) PERFORM A DETAILED VISUAL INSPECTION TO ENSURE
THAT THE TEN PHOTO SCANNER ALIGNMENT HOLES IN LATCHES 2
THROUGH 11 HAVE NO OBSTRUCTIONS.
(I) COUNTING FORWARD TO AFT, INSTALL PINS IN
PHOTO SCANNER ALIGNMENT HOLES IN LATCH ASSEMBLIES 2 THROUGH
11. THE SAFETY PINS MUST ENGAGE LOCK ARM AND LATCH ARM

LEVER AND GO COMPLETELY THROUGH LATCH
ASSEMBLY.
(II) ALL LATCH SAFETY PINS MUST BE FASTENED
TOGETHER WITH A SAFETY CABLE, AND THE SAFETY
CABLE MUST BE
ATTACHED TO THE MAIN DECK DOOR SILL
PROTECTOR.
(III) LOWER AND SECURE THE LOWER ACCESS PANELS
IN PLACE.
(IV) OPEN CIRCUIT BREAKER HC5, LOCATED ON
P-10, MAIN POWER CENTER-LEFT.
(5) TO CLOSE THE PRESSURE VENT DOOR ON THE
MAIN DECK
SIDE CARGO DOOR, ACCOMPLISH PARAGRAPHS (A)(5)
(I),
(A)(5)(II), (A)(5)(III), AND (A)(5)(IV) OF THIS AD.
(I) REMOVE PRESSURE VENT DOOR COVER,
(II) MANUALLY RETRACT THE TWO SOLENOID VALVES
TO ALLOW PRESSURE VENT DOOR CLOSURE,
(III) CLOSE PRESSURE VENT DOOR, AND
(IV) REPLACE VENT DOOR COVER.
(6) ALL SAFETY PINS MUST BE REMOVED BEFORE
OPENING
OR OPERATING CARGO DOOR, AND
(C) ACCOMPLISHMENT OF A MODIFICATION IN
ACCORDANCE WITH
A METHOD APPROVED BY THE MANAGER, ATLANTA,
ACO CONSTITUTES
TERMINATING ACTION FOR THE REQUIREMENTS OF
THIS AD.
(D) AN ALTERNATIVE METHOD OF COMPLIANCE OR
ADJUSTMENT OF
THE COMPLIANCE TIME THAT PROVIDES AN

ACCEPTABLE LEVEL OF
SAFETY MAY BE USED IF APPROVED BY THE
MANAGER, ATLANTA ACO.
OPERATORS SHALL SUBMIT THEIR REQUESTS
THROUGH AN APPROPRIATE
FAA PRINCIPAL MAINTENANCE INSPECTOR, WHO MAY
ADD COMMENTS
AND THEN SEND IT TO THE MANAGER, ATLANTA ACO.
NOTE 2: INFORMATION CONCERNING THE EXISTENCE
OF
APPROVED ALTERNATIVE METHODS OF COMPLIANCE
WITH THIS AD, IF
ANY, MAY BE OBTAINED FROM THE ATLANTA ACO.
(E) SPECIAL FLIGHT PERMITS MAY BE ISSUED IN
ACCORDANCE
WITH SECTIONS 21.197 AND 21.199 OF THE FEDERAL
AVIATION
REGULATIONS (14 CFR 21.197 AND 21.199) TO OPERATE
THE
AIRPLANE TO A LOCATION WHERE THE
REQUIREMENTS OF THIS AD CAN
BE ACCOMPLISHED.
(F) INFORMATION PERTINENT TO THIS RULEMAKING
ACTION MAY
BE EXAMINED AT THE FAA, TRANSPORT AIRPLANE
DIRECTORATE, 1601
LIND AVENUE, SW., RENTON, WASHINGTON; OR AT THE
FAA, SMALL
AIRPLANE DIRECTORATE, ATLANTA AIRCRAFT
CERTIFICATION OFFICE,
CAMPUS BUILDING, 1701 COLUMBIA AVENUE, SUITE
2-160, COLLEGE
PARK, GEORGIA 30337-2748.

(G) TELEGRAPHIC AD T96-01-51, ISSUED ON JANUARY 3, 1996,
BECOMES EFFECTIVE UPON RECEIPT.
FOR FURTHER INFORMATION CONTACT: RANDY AVERA, AEROSPACE
ENGINEER, SYSTEMS AND EQUIPMENT BRANCH, ACE-130A, FAA, SMALL
AIRPLANE DIRECTORATE, ATLANTA AIRCRAFT CERTIFICATION OFFICE,
CAMPUS BUILDING, 1701 COLUMBIA AVENUE, SUITE 2-160, COLLEGE
PARK, GEORGIA 30337-2748; TELEPHONE (404) 305-7381; FAX
(404) 305-7348.

NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-80-20
Last Updated: 09-21-94
[O] On march 8, 1980, a swearingen sa-226 at, n720r, with a crew of two and sixpassengers, experienced a rapid decompression at 16,000 feet
when most of the aft cargo compartment door separated in flight. About 3/4 of the door along with interior furnishings, including an
unoccupied passenger seat, separated from the aircraft. Two passengers were injured slightly during the decompression and the empennage
was damaged slightly when some of the material from the cargo

door or the cabin struck the upper fuselage and thevertical stabilizer. Some
of the material from the cabin lodged around thecontrol surfaces in the empennage. A safe landing was made in albany, new york. Although
ground search continues for the separated items, only baggage has thus far been recovered.
Recommendations:
A-80-20. Issue a telegraphic ad requiring an immediate inspection of the door latching mechanism of the aft cargo doors on all swearingen
SA-226 aircraft to assure proper adjustment and structural integrity.
Responses:
FAA LTR DTD: 05/13/80
Emergency telegraphic airworthiness directive (ad), no. T80sw14, applicable to operators of swearingen model sa226tc airplanes, was issued
march 15, 1980. The ad required an immediate inspection of the door latching mechanism of the aft cargo door to assure proper adjustment,
operation, and structural integrity, and prohibited flight operation with pressurized cabin. Later on 3/15, ad t80sw 14 was amended by adding a
clarifying paragraph requiring compliance prior to further flight. On 3/19, telegraphic ad t80sw 15 was issued, superseding ad t80sw 14, as
amended. This ad t80sw 15 includes the provisions of ad t80sw 14 and provides for inspection at 250-hour intervals to assure proper adjustment,
operation, an structural integrity of the door system. Enclosed are copies of all referenced ads. We are in receipt of the ntsb letter dated may 5

and note that recommenda- tions a-80-20 and 21 are now classified in a closed--acceptable action status.
NTSB LTR DTD: 05/05/80
The safety board has examined emergency telegraphic airworthiness directive (ad), no. 580sw14, dated march 15, 1980, as amended, and
emergency telegraphic ad t80sw15, dated march 19, 1980. We are satisfied that compliance with these ad's will fulfill safety recommendations
a-80-20 and 21, which are now classified in a closed-- acceptable action status.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-80-21
Last Updated: 09-21-94
[O] On march 8, 1980, a swearingen sa-226 at, n720r, with a crew of two and sixpassengers, experienced a rapid decompression at 16,000 feet
when most of the aft cargo compartment door separated in flight. About 3/4 of the door along with interior furnishings, including an
unoccupied passenger seat, separated from the aircraft. Two passengers were injured slightly during the decompression and the empennage
was damaged slightly when some of the material from the cargo door or the cabin struck the upper fuselage and thevertical stabilizer. Some
of the material from the cabin lodged around thecontrol surfaces in the empennage. A safe landing was made in albany, new york. Although
ground search continues for the separated items, only baggage has thus far been recovered.
Recommendations:

A-80-21. Issue an ad restricting the cabin pressure differential in swearingen SA-226 aircraft until the cause of the aft cargo door failure can be
determined and an appropriate corrective action carried out.
Responses:
NTSB LTR DT: 05/05/80
The safety board has examined emergency telegraphic airworthiness directive (ad), no. T80sw14, dated march 15, 1980, as amended, and
emergency telegraphic ad, t80sw15, dated march 19, 1980. We are satisfied that compliance with these ad's will fulfill safety recommendations
a-80-20 and 21, which are now classified in a closed-- acceptable action status.
FAA LTR DTD: 05/13/80
Emergency telegraphic airworthiness directive (ad), no. T80sw14, applicable to operators of swearingen model sa226tc and sa226at airplanes,
was issued on march 15, 1980. The ad required an immediate inspection of the door latching mechanism of the aft cargo door to assure
proper adjustment, operation, and structural integrity, and prohibited flight operation with a pressurized cabin. Later on march 15, ad t80sw 14
was amended by adding a clarifying para- graph requiring compliance prior to further flight. On march 19, telegraphic ad t80sw 15 was issued,
superseding ad t80sw 14 as amended. This ad t80sw 15 includes the provisions of ad t80sw 14 and provides for inspection at 250-hour intervals
to assure proper adjustment, operation, and structural integrity of the door system. Enclosed are copies of all referenced ads. We are in

receipt of the ntsb letter dated mary 5 and note that recommendations a-80-20 and 21 are now classified in a closed--acceptable action status.

NTSB Safety Recommendation Brief

Data_Source: U.S. NTSB Safety Recommendations

Rprt_Nbr: A-80-76

Last Updated: 09-21-94

[O] On march 8, 1980, a swearingen sa-226 at, n720r, with a crew of two and sixpassengers, experienced a rapid decompression at 16,000 feet
when most of the aft cargo compartment door separated in flight. About 3/4 of the door along with interior furnishings, including an
unoccupied passenger seat, separated from the aircraft. Two passengers were injured slightly during the decompression and the empennage
was damaged slightly when some of the material from the cargo door or the cabin struck the upper fuselage and thevertical stabilizer. Some
of the material from the cabin lodged around thecontrol surfaces in the empennage. A safe landing was made in albany, new york. Although
ground search continues for the separated items, only baggage has thus far been recovered.

Recommendations:

A-80-76. Issue a telert maintenance bulletin to alert operators of swearingen models sa226-at and sa226-tc aircraft of the dangers of machining
or filing any component of the latch or receptacle to ease the engagement.

Responses:

FAA LTR DTD: 10/30/80

The faa concurs with a-80-76 and 77. Our southwest region has

issued a telert maintenance bulletin advising all regions to notify operators who
re operating swearingen models sa-226at and sa226tc aircraft of the dangers of machining or filing any component of the latching mechanisms
to ease engagement. Further, we have included in this bulletin instructions to advise operators of unsafe conditions which can result from
forcing the latching mechanism during operations when the latches are mis- aligned or not properly adjusted. In addition, a general aviation
airworthiness alert has been prepared for in ac 43-16 which willreflect the information contained in both recommenda-tions. A copy of both
these documents is enclosed. The faa considers action on a-80-76 and 77 completed.
NTSB LTR DTD: 12/03/80
The safety board is pleased to note that on october 2, 1980, the faa issued a telert maintenance bulletin a-80-76, and that a general aviation
airworthiness alert has been prepared for insertion in ac 43-16 to fulfill a-80-77. Both these recommendation are now classified in a
closed--acceptable action status.
NTSB Accident/Incident Brief
Data_Source: NTSB Aviation Accident/Incident Data
Rprt_Nbr: DCA89MA035
Event_Lcl_Date: 03/18/1989
Time (Lcl): 216 CST
Loc_State_Code: TX
Loc_City_Name: SAGINAW
Loc_Arpt_Name: CARSWELL AFB
Loc_Arpt_Id_Code: FWH

Event_Acdnt_Incdnt_Code: ACCIDENT
Inj_Hi_Deg_Code: FATAL
Rprt_Status_Code: FINAL
Event_Mid_Air_Code: No
--- Aircraft Information ---
Opn_Cat_Code: SCH121
Acft_Type_Code: AIRPLANE
Acft_Dmg_Code: DESTROYED
Flt_Phase_Code: 580 MANEUVERING
Acft_Manf_Name: MCDONNELL-DOUGLAS
Acft_Series_Name: DC-9-33F
Aic_Make_Id: DOUG
Aic_Ac_Id: DC-9-33F
Acft_Hm_Built_Flag: No
Oprtr_Biz_Name:
Oprtr_Name:
Oprtr_Desigtr_Code:
Owner_Name: EVERGREEN INTL AIRLINES
--- Narrative ---
AS THE ACFT ROTATED FOR TKOF, THE CARGO DOOR (CD) OPENED. THE CREW CONTD
TKOF & TURNED TO A DWNWND LEG TO LND ON RWY 17. THEY ANSWERED TWR INSTRNS
TO RPRT "BASE." THIS WAS THE LAST TMTN THEY RCVD, THO THEY TRIED SVRL
TIMES TO CTC TWR OR APCH CTL. AS THE ACFT TURNED ON BASE LEG (WITH A TAIL
WND AT TFC PATTERN ALT), RADAR DATA INDCD ACFT WOULD CROSS THE RWY
CENTERLINE. RADAR CTC WAS THEN LOST; THE ACFT CRASHED IN A STEEP DSCNT.
THERE WAS EVIDENCE THAT BFR FLT, THE 1ST OFFICER MISINTERPRETED THE

EXTERNAL LOCKPIN MANUAL CTL HANDLE PSN TO MEAN THE CD WAS LOCKED (AS A
RESULT OF INCORRECT MARKINGS). ALSO, THERE WAS A MALFUNCTION OF A CD OPEN
WARNING LGT SW, PREVENTING OPN OF THE WARNING LGT. ADDITIONALLY, SVRL SVC
BULLETINS (SB'S) CONCERNING THE CD HAD NOT BEEN COMPLIED WITH. THESE SB'S
WOULD HAVE PROVIDED AN EXTRA SAFETY FEATURE OF THE CD WARNING LGT SYS, A
DOOR VENTING SYS & A LOCKPIN VIEWING WINDOW FOR THE DOOR. THERE WAS NO
EMERG PROC OR SPECIFIC GUIDANCE TO AID DC-9 CREWS FOR THIS SITUATION,
THOUGH SVRL CD OPENINGS HAD OCCURRED. (SEE: NTSB/AAR-90/02)
--- Sequence of Events ---
Occurrence #: 1 130 AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION
Phase of Operation: 501 STANDING - PRE-FLIGHT
----- Findings -----
Subj - Mod - Pers C/F
1b. 24119(S) - 3124(M) - 4121(P) Factor
MAINTENANCE, SERVICE BULLETINS - NOT FOLLOWED - COMPANY/OPERATOR MANAGEMENT
1ind. 90000(S) - 6110(P) Factor
INADEQUATE SURVEILLANCE OF OPERATION - FAA (ORGANIZATION)
2a. 10505(S) - 1213(M)
DOOR, CARGO/BAGGAGE - NOT SECURED
3a. 12015(S) - 1134(M)
ELECTRICAL SYSTEM, ELECTRIC SWITCH - FAILURE, PARTIAL

4a. 13107(S) - 1150(M)
WARNING SYSTEM (OTHER) - INOPERATIVE
6b. 24032(S) - 3115(M) - 4121(P) Factor
PROCEDURES/DIRECTIVES - INADEQUATE - COMPANY/
OPERATOR MANAGEMENT
6ind. 91200(S) - 6110(P) Factor
INSUFFICIENT STANDARDS/REQUIREMENTS, AIRCRAFT
- FAA (ORGANIZATION)
Occurrence #: 2 430 MISCELLANEOUS/OTHER
Phase of Operation: 522 TAKEOFF - INITIAL CLIMB
----- Findings -----
Subj - Mod - Pers C/F
1a. 10505(S) - 1202(M) Factor
DOOR, CARGO/BAGGAGE - DISENGAGED
Occurrence #: 3 250 LOSS OF CONTROL - IN FLIGHT
Phase of Operation: 563 APPROACH - VFR PATTERN - BASE
LEG/BASE TO FINAL
----- Findings -----
Subj - Mod - Pers C/F
1b. 25000(S) - 3001(M) - 4001(P) Cause
REASON FOR OCCURRENCE UNDETERMINED - -
4a. 21103(S) - 2104(M) Factor
AIRCRAFT MANUALS, PROCEDURE INFORMATION -
INADEQUATE
4b. 24032(S) - 3115(M) - 4123(P) Factor
PROCEDURES/DIRECTIVES - INADEQUATE -
MANUFACTURER
Occurrence #: 4 230 IN FLIGHT COLLISION WITH
TERRAIN/WATER
Phase of Operation: 553 DESCENT - UNCONTROLLED
----- Findings -----
Subj - Mod - Pers C/F
--- Probable Cause ---

THE LOSS OF CONTROL OF THE AIRPLANE FOR
UNDETERMINED REASONS FOLLOWING THE
INFLIGHT OPENING OF THE IMPROPERLY LATCHED
CARGO DOOR. CONTRIBUTING TO
THE ACCIDENT WERE: INADEQUATE PROCEDURES
USED BY EVERGREEN AIRLINES AND
APPROVED BY THE FAA FOR PREFLIGHT VERIFICATION
OF CARGO DOOR SECURITY,
EVERGREEN'S FAILURE TO MARK PROPERLY THE
AIRPLANE'S EXTERNAL CARGO DOOR
LOCKPIN MANUAL CONTROL HANDLE, AND THE
FAILURE OF MCDONNELL DOUGLAS TO
PROVIDE FLIGHTCREW GUIDANCE AND EMERGENCY
PROCEDURES FOR AN INFLIGHT
OPENING OF THE CARGO DOOR. ALSO CONTRIBUTING
TO THE ACCIDENT WAS THE
FAILURE OF THE FAA TO MANDATE MODIFICATION TO
THE DOOR-OPEN WARNINGSYSTEM
FOR DC-9 CARGO-CONFIGURED AIRPLANES, GIVEN
THE PREVIOUS KNOWN OCCURRENCES
OF INFLIGHT DOOR OPENINGS.
Acft_Nbr_Seat_Qty: 3
Opn_Biz_Code: Code Not Found
Opn_Biz_Otr_Desc:
Fltcndct_Code: 14 CFR 121
Fltcndct_Otr_Desc:
Opn_Sked_Code: SCHEDULED
Opn_Dom_Intnl_Code: DOMESTIC
Opn_Psgr_Cargo_Code: CARGO
Regist_Nbr: 931F
Owner_Cert_Held_Flag: Code Not Found
Oprtr_Cert_Acr_Type_Code: FLAG CARRIER/DOMESTIC
(121)

Oprtr_Cert_Otr_Acft_Flag: Code Not Found
Oprtr_Cert_Rotor_Ag_Code: Code Not Found
Acft_Fire_Code: ON GROUND
Injuries
Fatal Serious Minor None
Crew 2 0 0 0
Pass 0 0 0 0
Other 0 0 0 0
Invlvd 2 0 0 0
Lndgr_Type_Fix_Code: TRICYCLE-RETRACTABLE
Acft_Crtfyd_Max_Wt_Lb_Qty: 114000
Eng_Manf_Name: P&W
Eng_Model_Name: JT8D-9A
Acft_Nbr_Eng_Qty: 2
Eng_Typ_Code: TURBO FAN
Eng_Rated_Pwr_Hpwr_Qty: 0
Eng_Rated_Pwr_Thrust_Lb_Qty: 14500
Elt_Instld_Flag: No
Elt_Oprtd_Flag: Code Not Found
Stall_Warn_Instl_Flag: Yes
--- Environment/Operations Information ---
Wx_Brfg_Srce_Code:
Wx_Brfg_Mthd_Code:
Wx_Brfg_Cmplt_Code: WEATHER NOT PERTINENT
Wx_Flt_Cond_Code: VISUAL METEOROLOGICAL CONDITIONS (VMC)
Wx_Wind_From_Vrbl_Flag: Code Not Found
Wx_Wind_Degm_Qty: 320
Wx_Wind_Type_Code: Code Not Found
Wx_Wind_Spd_Kt_Qty: 6
Wx_Vis_Sm_Qty: 10
Wx_Vis_Rvr_Ft_Qty: 0
Wx_Vis_Rvv_Sm_Qty: 0

Wx_Cloud_Code: THIN BROKEN
Wx_Cloud_Hgt_Agl_Ft_Qty: 25000
Wx_Cig_Code: NONE
Wx_Cig_Hgt_Agl_Ft_Qty: 0
Wx_Vis_Rstr_Fix_Code: NONE
Wx_Precip_Type_Fix_Code: NONE
Wx_Cond_Lgt_Code: NIGHT (DARK)
Dep_Point_Flag: Yes
Dep_Point_Arpt_Id_Code: FWH
Dep_Point_City_Name:
Dep_Point_State_Code:
Destn_Same_Lcl_Code: Code Not Found
Destn_Arpt_Id_Code: TIK
Destn_City_Name: OKLAHOMA CITY
Destn_State_Code: OK
Fltplan_Filed_Code: INSTRUMENT FLIGHT RULES (IFR)
Clnc_Atc_Type_Code: IFR
Apch_Vfr_Fix_Code: TRAFFIC PATTERN
Loc_Event_Code: OFF AIRPORT/AIRSTRIP
Rwy_Used_Id_Sffx_Code:
Rwy_Used_Id_Code: 17
Rwy_Len_Ft_Qty: 12000
Rwy_Wid_Ft_Qty: 300
Rwy_Sfc_Type_Fix_Code: CONCRETE
Rwy_Status_Type_Fix_Code: DRY
--- Personnel Information ---
Plt_Cert_Type_Code: COMMERCIAL, AIRLINE TRANSPORT
Pltrtng_Plane_Code: SINGLE ENGINE LAND, MULTIENGINE LAND
Pltrtng_Non_Plane_Code: NONE
Pltrtng_Inst_Code: AIRPLANE
Plt_Bfr_Flag: Yes
Plt_Last_Bfr_Mo_Qty: 2

Plt_Bfr_Acft_Make_Name: SIMULATOR
Plt_Bfr_Acft_Model_Name: DC9 SI
Plt_Med_Cert_Code: CLASS 1
Plt_Med_Cert_Vldty_Code: VALID MEDICAL-NO WAIVERS/
LIMITATIONS
Flight Time (Hours)
Total : 7238 Last 24 Hrs : 4
Make/Model: 1938 Last 30 Days: 0
Instrument: 0 Last 90 Days: 0
Multi-Eng : 0 Rotorcraft : 0
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-90-86
Last Updated: 09-21-94
[O] On March 18, 1989, an Evergreen International Airlines McDonnell Douglas DC-9-33F, registered in the United States as N931F, crashed
during the turn to final approach as the pilot was attempting to return to Carswell Air Force Base (AFB), Fort Worth, Texas after a cargo door
opened. This cargo flight was on an instrument flight rule (IFR) flight plan and was being operated in accordance with Title 14 Code of Federal
Regulations (CFR) Part 121. Night visual meteorological conditions existed at the time of the accident. The captain and first officer, the only
persons onboard, were killed.
Recommendations:
A-90-86. Require that McDonnell Douglas amend its DC-9 Flight Crew Operating Manual "Cargo Door Opens After Takeoff" procedure to
include the fact that the possibility exists that variations in indicated airspeed and altitude can exist during flight with an

open cargo door.
Responses:
FAA LTR DTD: 8/28/90
The FAA agrees with the intent of these safety recommendations, but cannot "require" that changes or revisions be made to the Flight Crew
Operations Manual. Since the operations manual is not an FAA-approved document, the FAA has no direct control over the content of the
information contained in these manuals. The FAA will consider the issuance of an airworthiness directive (AD) to require a revision to the
Airplane Flight Manual to include the information requested in Safety Recommendation A-90-86. If an AD is issued, the FAA will request that
the manufacturer amend the Flight Crew Operations Manual to reflect the changes made to the Airplane Flight Manual.
I will provide the Board with a copy of any document that may be issued.
NTSB LTR DTD: 11/5/90
The Safety Board notes that the FAA agrees with the intent of these safety recommendations and is considering the issuance of an
airworthiness directive (AD) to require a revision to the airplane flight manual. If the AD is issued, the FAA will request that the manufacturer
amend the flight crew operational manual to reflect the changes made to the airplane flight manual. Pending the FAA's further report, these
safety recommendations are classified as "Open--Acceptable Response."
FAA LTR DTD: 2/15/91
The McDonnell Douglas Aircraft Corporation revised its DC-9

Flight Crew Operating Manual to incorporate a revision to the emergency
procedure when the main cargo door opens after takeoff. I have enclosed a copy of the manual revision for the Board's information.
I consider the FAA's action to be completed on this safety recommendation.
NTSB LTR DTD: 5/7/91
The Safety Board notes that McDonnell Douglas has revised the DC-9 Flight Crew Operating Manual to meet the intent of Safety Recommendation A-90-86. Based on the above information, Safety Recommendation A-90-86 is reclassified as "Closed--Acceptable Action."
<WEBMASTER>
NTSB Accident/Incident Brief
Data_Source: NTSB Aviation Accident/Incident Data
Rprt_Nbr: FTW89MA047
Event_Lcl_Date: 02/09/1989
Time (Lcl): 100 MST
Loc_State_Code: UT
Loc_City_Name: SALT LAKE CITY
Loc_Arpt_Name:
Loc_Arpt_Id_Code:
Event_Acdnt_Incdnt_Code: ACCIDENT
Inj_Hi_Deg_Code: FATAL
Rprt_Status_Code: FINAL
Event_Mid_Air_Code: No
Opn_Cat_Code: SCH121
Acft_Type_Code: AIRPLANE
Acft_Dmg_Code: NONE
Flt_Phase_Code: 530 CLIMB
Acft_Manf_Name: MCDONNELL DOUGLAS
Acft_Series_Name: DC-9-32F

Aic_Make_Id: DOUG
Aic_Ac_Id: DC-9-32F
Acft_Hm_Built_Flag: No
Oprtr_Biz_Name:
Oprtr_Name:
Oprtr_Desigtr_Code: EIAA
Owner_Name: EVERGREEN INTL AIRLINES
--- Narrative ---
AS 1ST OFFICER (FO) WAS FLYING ACFT, DRG CLB AFTER TKOF, CABIN WOULDN'T
PRESSURIZE. HE BGN LVL OFF AT 16,000', BUT CAPT ORDERED HIM TO CONT CLBG
TO ASSIGNED FLT LVL (FL 330), WHILE HE (THE CAPT) WENT AFT TO FND PRBLM.
FO DISLIKED THE ORDER, BUT COMPLIED RATHER THAN CONFRONT CAPT. CAPT LEFT
COCKPIT WITH PORTABLE "ON DEMAND" OXYGEN (O2) SYS, WHICH HAD 15 MIN SUPPLY
OF O2. WHEN CAPT DIDN'T RTRN, FO TRIED SIGNALING HIM. THO RELUCTANT TO
COUNTERMAND CAPT'S ORDER, FO MADE SERIES OF DSCNTS TO 13,000'. AFTER ABT
30 MIN, HE LEFT COCKPIT & FND CAPT UNCONSCIOUS & UNRESPONSIVE IN FWD CARGO
AREA WITH O2 MASK ON HIS FACE. CAPT'S FOOT WAS ENTANGLED IN CARGO NET
WHICH CVRD A PALLET. FO TRIED TO REVIVE CAPT, TO NO AVAIL, THEN DECLARED
EMERG & LNDD AT LUBBOCK. CAPT WAS RUSHED TO HOSPITAL, BUT WAS DEAD ON
ARRIVAL. EXAM REVEALED AFT PRESSURE BULK- HEAD WAS NOT INSTALLED. IT HAD
BEEN REMOVED FOR MAINT BFR FLT. PORTABLE O2

SYS WAS STILL FULL, INDCG CAPT
HAD LITTLE OR NO USE OF O2; IT WAS TESTED &
FUNCTIONED NMLY. GROUP OF 8
FORENSIC PATHOLOGISTS CONCLUDED CAPT DIED FM
HYPOXIC HYPOXIA.
--- Sequence of Events ---
Occurrence #: 1 430 MISCELLANEOUS/OTHER
Phase of Operation: 530 CLIMB
----- Findings -----
Subj - Mod - Pers C/F
1a. 10510(S) - 1205(M) Factor
DOOR, INSPECTION - NOT INSTALLED
1b. 24102(S) - 3115(M) - 4107(P) Factor
MAINTENANCE, INSPECTION OF AIRCRAFT -
INADEQUATE - COMPANY MAINTENANCE PERSONNEL
2a. 10003(S) - 1163(M) Factor
FUSELAGE, CABIN - NO PRESSURE
3b. 24010(S) - 3109(M) - 4000(P) Cause
IN-FLIGHT PLANNING/DECISION - IMPROPER - PILOT IN
COMMAND
4b. 24527(S) - 3102(M) - 4001(P) Factor
CLIMB - CONTINUED -
6b. 24624(S) - 3136(M) - 4000(P) Factor
CREW/GROUP COORDINATION - POOR - PILOT IN
COMMAND
7b. 23308(S) - 3110(M) - 4000(P) Cause
OXYGEN SYSTEM - IMPROPER USE OF - PILOT IN
COMMAND
7dir. 33211(S) - 5000(P) Cause
INCAPACITATION (ANOXIA/HYPOXIA) - PILOT IN
COMMAND
--- Probable Cause ---
IMPROPER IN-FLIGHT PLANNING/DECISION BY THE

CAPTAIN (PILOT-IN-COMMAND)
AND HIS IMPROPER USE OF THE PORTABLE OXYGEN
SYSTEM, WHICH RESULTED IN HIS
INCAPACITATION DUE TO HYPOXIA. FACTORS
RELATED TO THE ACCIDENT WERE:
INADEQUATE MAINTENANCE/INSPECTION OF THE
AIRCRAFT BY COMPANY MAINTENANCE
BY FAILING TO REINSTALL THE AFT PRESSURE
BULKHEAD HATCH (INSPECTION DOOR)
AND POOR CREW COORDINATION.
--- Detail ---
Acft_Nbr_Seat_Qty: 2
Opn_Biz_Code: Code Not Found
Opn_Biz_Otr_Desc:
Fltcndct_Code: 14 CFR 121
Fltcndct_Otr_Desc:
Opn_Sked_Code: SCHEDULED
Opn_Dom_Intnl_Code: DOMESTIC
Opn_Psgr_Cargo_Code: CARGO
Regist_Nbr: 935F
Owner_Cert_Held_Flag: Code Not Found
Oprtr_Cert_Acr_Type_Code: SUPPLEMENTAL
Oprtr_Cert_Otr_Acft_Flag: Code Not Found
Oprtr_Cert_Rotor_Ag_Code: Code Not Found
Acft_Fire_Code: NONE
Injuries
Fatal Serious Minor None
Crew 1 0 0 1
Pass 0 0 0 0
Other 0 0 0 0
Invlvd 1 0 0 1
Lndgr_Type_Fix_Code: TRICYCLE-RETRACTABLE
Acft_Crtfyd_Max_Wt_Lb_Qty: 108000

Eng_Manf_Name: P&W
Eng_Model_Name: JT8D-9A
Acft_Nbr_Eng_Qty: 2
Eng_Typ_Code: TURBO FAN
Eng_Rated_Pwr_Hpwr_Qty: 0
Eng_Rated_Pwr_Thrust_Lb_Qty: 14000
Elt_Instld_Flag: No
Elt_Oprtd_Flag: Code Not Found
Stall_Warn_Instl_Flag: Yes
--- Environment/Operations Information ---
Wx_Brfg_Srce_Code: MILITARY
Wx_Brfg_Mthd_Code: IN PERSON
Wx_Brfg_Cmplt_Code: WEATHER NOT PERTINENT
Wx_Flt_Cond_Code: VISUAL METEOROLOGICAL CONDITIONS (VMC)
Wx_Wind_From_Vrbl_Flag: Code Not Found
Wx_Wind_Degm_Qty: 120
Wx_Wind_Type_Code: Code Not Found
Wx_Wind_Spd_Kt_Qty: 8
Wx_Vis_Sm_Qty: 15
Wx_Vis_Rvr_Ft_Qty: 0
Wx_Vis_Rvv_Sm_Qty: 0
Wx_Cloud_Code: CLEAR
Wx_Cloud_Hgt_Agl_Ft_Qty: 0
Wx_Cig_Code: NONE
Wx_Cig_Hgt_Agl_Ft_Qty: 0
Wx_Vis_Rstr_Fix_Code: NONE
Wx_Precip_Type_Fix_Code: NONE
Wx_Cond_Lgt_Code: NIGHT (DARK)
Dep_Point_Flag: Code Not Found
Dep_Point_Arpt_Id_Code: KHIF
Dep_Point_City_Name: OGDEN
Dep_Point_State_Code: UT

Destn_Same_Lcl_Code: Code Not Found
Destn_Arpt_Id_Code: KSKF
Destn_City_Name: SAN ANTONIO
Destn_State_Code: TX
Fltplan_Filed_Code: INSTRUMENT FLIGHT RULES (IFR)
Clnc_Atc_Type_Code: IFR
Apch_Vfr_Fix_Code: PRECAUTIONARY LANDING
Loc_Event_Code: OFF AIRPORT/AIRSTRIP
Rwy_Used_Id_Sffx_Code:
Rwy_Used_Id_Code: 0
Rwy_Len_Ft_Qty: 0
Rwy_Wid_Ft_Qty: 0
Rwy_Sfc_Type_Fix_Code:
Rwy_Status_Type_Fix_Code:
--- Personnel Information ---
Plt_Cert_Type_Code: AIRLINE TRANSPORT, FLIGHT INSTRUCTOR
Pltrtng_Plane_Code: SINGLE ENGINE LAND, MULTIENGINE LAND
Pltrtng_Non_Plane_Code: NONE
Pltrtng_Inst_Code: AIRPLANE
Plt_Bfr_Flag: Yes
Plt_Last_Bfr_Mo_Qty: 4
Plt_Bfr_Acft_Make_Name: DOUGLAS
Plt_Bfr_Acft_Model_Name: DC-9
Plt_Med_Cert_Code: CLASS 1
Plt_Med_Cert_Vldty_Code: VALID MEDICAL-NO WAIVERS/ LIMITATIONS
Flight Time (Hours)
Total : 11000 Last 24 Hrs : 5
Make/Model: 232 Last 30 Days: 62
Instrument: 0 Last 90 Days: 152
Multi-Eng : 10000 Rotorcraft : 0

<WEBMASTER>
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-80-77
Last Updated: 09-21-94
[O] On march 8, 1980, a swearingen sa-226 at, n720r, with a crew of two and sixpassengers, experienced a rapid decompression at 16,000 feet
when most of the aft cargo compartment door separated in flight. About 3/4 of the door along with interior furnishings, including an
unoccupied passenger seat, separated from the aircraft. Two passengers were injured slightly during the decompression and the empennage
was damaged slightly when some of the material from the cargo door or the cabin struck the upper fuselage and thevertical stabilizer. Some
of the material from the cabin lodged around thecontrol surfaces in the empennage. A safe landing was made in albany, new york. Although
ground search continues for the separated items, only baggage has thus far been recovered.
Recommendations:
A-80-77. Issue an addition to the general aviation airworthiness alerts, Advisory Circular 43-16, to alert operators of sa226 aircraft to the unsafe
condition which can result from forcing the latching mechanism while the latches are not properly engaged.
Responses:
FAA LTR DTD: 10/30/80

The faa concurs with a-80-76 and 77. Our southwest region has issued a telert maintenance bulletin advising all regions to notify

operators who
are operating swearingen models sa-226at and sa226tc aircraft of the dangers of machining or filling any component of the latching
mechanisms to ease engagement. Further, we have included in this bulletin instructions to advise operators of the unsafe conditions which
can result from forcing the latching mechanism during operations, when the latches are misaligned or not properly adjusted. In addition, a
general aviation airworthiness alert has been prepared for insertion in ac 43-16 which will reflect the information contained in both
recommendations. A copy of both these documents is enclosed. The faa considers action on a-80-76 and 77 completed.
NTSB LTR DTD: 12/03/80
The safety boards is pleased to note that on october 2, 1980, the faa issued a telert maintenance bulletin fulfilling a -80-76, and that a general
aviation airworthiness alert has been prepared for insertion in ac 43-16 to fulfill a-80-77. Both these recommendations are now classified in a
closed--acceptable action status.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-74-27
Last Updated: 09-21-94
[O] The ntsb is investigating an accident involving an american airlines mcdonnell douglas dc-10-10, n103aa, which occurred shortly after
takeoff from detroit metropolitan-wayne county airport on june 12, 1972. The aft left-hand cargo door opened while the aircraft was at

approximately 12,000 feet. The cabin floor over this cargo compartment then failed as a result of depressurization loading, and the floor
dropped partially into the cargo compartment. This displacement of the floor caused serious disruption of the control cables which are routed
through the floor beams to the empennage control systems and the engine controls. With the exception of the right rudder pedal cable, all of
the cables on the left side of the fuselage broke. The cable guides tore from their attachments to the floor beams, and the cables were
deflected downward by the floor structure.
Recommendations:
A-74-27. Require that the provisions of the McDonnell-Douglas Service Bulletin 52-49 entitled doors-cargo-install revised 'closed loop' cargo
door locking mechanism be made mandatory by the immediate issuance of an airworthiness directive.
Responses:
FAA LTR DTD: 04/04/74
On march 22, 1974, the faa issued their second ad which included the requirement for compliance with the mcdonnell douglas service bulletin
(sb) 52-49 by july 1, 1974. Prior to the issuance of the ad, sb 52-49 would not have been completed on all aircraft for another 20-24 months.

NTSB LTR DTD: 04/26/74
Closed--acceptable action.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-72-97

Last Updated: 09-21-94
[O] The ntsb is investigating an accident involving an american airlines mcdonnell douglas dc-10-10, n103aa, which occurred shortly after
takeoff from detroit metropolitan-wayne county airport on june 12, 1972. The aft left-hand cargo door opened while the aircraft was at
approximately 12,000 feet. The cabin floor over this cargo compartment then failed as a result of depressurization loading, and the floor
dropped partially into the cargo compartment. This displacement of the floor caused serious disruption of the control cables which are routed
through the floor beams to the empennage control systems and the engine controls. With the exception of the right rudder pedal cable, all of
the cables on the left side of the fuselage broke. The cable guides tore from their attachments to the floor beams, and the cables were
deflected downward by the floor structure.
Recommendations:
A-72-97. Require a modification to the DC-10 cargo door locking system to make it physically impossible to position the external locking
handle and vent doorto their normal door locked positions unless the locking pins are fully engaged.
Responses:
FAA LTR DTD: 07/07/72
Additional modifications to the cargo door locking and pressurization systems are being considered as part of a continued investi-gation
effort. While a preliminary investigation indicates that it may not be feasible to provide complete venting between cabin and cargo

compartments, your recommendations will be considered with respect to further action taken.
NTSB LTR DTD: 12/11/74
The safety board is aware of your continued efforts toward modifying the dc-10 cargo compartment doors to insure the integrity of fuselage
pressure containment. However, the safety board believes that critical control systems must be protected against a loss of cargo compartment
pressurization, which may occur for any reason. Therefore, we are specifically interested in corrective actions to strengthen the passenger
compartment floor, to vent or partially vent the aft cargo compartment, and to isolate or otherwise protect critical systems which pass through
the passenger compartment floor structure. The safety board would appreciate a status report on actions taken or contemplated by the faa to
implement safety recommendation a-72-98.
NTSB LTR DTD: 06/01/75
Closed--acceptable action.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-72-98
Last Updated: 09-21-94
[O] The ntsb is investigating an accident involving an american airlines mcdonnell douglas dc-10-10, n103aa, which occurred shortly after
takeoff from detroit metropolitan-wayne county airport on june 12, 1972. The aft left-hand cargo door opened while the aircraft was at
approximately 12,000 feet. The cabin floor over this cargo compartment then failed as a result of depressurization loading,

and the floor
dropped partially into the cargo compartment. This displacement of the floor caused serious disruption of the control cables which are routed
through the floor beams to the empennage control systems and the engine controls. With the exception of the right rudder pedal cable, all of
the cables on the left side of the fuselage broke. The cable guides tore from their attachments to the floor beams, and the cables were
deflected downward by the floor structure.
Recommendations:
A-72-98. Require the installation of relief vents between the cabin and aft cargo compartment to minimize the pressure loading
depressurization of the cargo compartment.
Responses:
FAA LTR DTD: 07/07/72
Additional modifications to the cargo door locking and pressurization system are being considered as part of a continued investi- gation
effort. While a preliminary investigation indicates that it may not be feasible to provide complete venting between cabin and cargo compart-
ments, your recommendations will be considered with respect to further action taken.
NTSB LTR DTD: 02/23/73
With respect to recommendation a-72-98, you observed that a preliminary investigation indicated that it may not be feasible to provide
complete venting between cabin and cargo compartments. When your investigation is complete, the board would appreciate knowing if the

installation of vents similar to those on other dc-10 cargo compartments is feasible in the aft cargo compartment. If complete venting is not
possible, partial venting would be beneficial. Such venting could prevent the collapse of the aft cabin floor, or it couldreduce the amount of
floor deflection, and attendant control cable damage in a dc-10.
FAA LTR DTD: 03/15/73
We have requested that the manufacturer reassess the dc-10 with regard to the effects on safety of probable large openings in the pressurized
fuselage. The manufacturer is to consider rerouting of vital systems, reinforcement of the floor as well as incorporation of additional venting
between compartments. These alternatives will include considera- tion of various degrees of venting as recommended in your letter.
FAA LTR DTD: 01/17/75
Major discussions were held with mcdonnell-douglas on march 15, april 30, june 6 and 7, september 25, october 2, 3, and 4, 1974, and most
recently on january 7. We have also reviewed the l-1011 and b727 designs with lockheed and boeing representatives on april 30 and may 1,
1974. These many discussions covered specific design improvements including external door designs, floor structure and strengthening,
intercompartment venting and isolation of critical systems, and other features. We can advise you shortly of the results of our investigation
and the corrective measures to be required. This should be prior to january 31.
NTSB LTR DTD: 06/01/75

Closed--acceptable action.
NTSB Accident/Incident Brief
Data_Source: NTSB Aviation Accident/Incident Data
Rprt_Nbr: NYC92IA030
Event_Lcl_Date: 11/13/1991
Time (Lcl): 445 EST
Loc_State_Code: OH
Loc_City_Name: TOLEDO
Loc_Arpt_Name:
Loc_Arpt_Id_Code:
Event_Acdnt_Incdnt_Code: INCIDENT
Inj_Hi_Deg_Code: NONE
Rprt_Status_Code: FINAL
Event_Mid_Air_Code: No
--- Aircraft Information ---
Opn_Cat_Code: NSC121
Acft_Type_Code: AIRPLANE
Acft_Dmg_Code: MINOR
Flt_Phase_Code: 530 CLIMB
Acft_Manf_Name: DOUGLAS
Acft_Series_Name: DC-8-63
Aic_Make_Id: DOUG
Aic_Ac_Id: DC-8-63
Acft_Hm_Built_Flag: No
Oprtr_Biz_Name:
Oprtr_Name: FLAGSHIP EXPRESS
Oprtr_Desigtr_Code: RAXA
Owner_Name: AERO LEASE FINANCIAL GROUP INC
--- Narrative ---
THE MAIN CARGO DOOR OPENED IN FLIGHT AND THE AIRPLANE RETURNED FOR A
NORMAL LANDING. OF THE TWO CIRCUIT BREAKERS

REQUIRED TO BE PULLED PRIOR
TO TAKEOFF, ONE WAS FOUND STILLENGAGED. A
CONFORMITY INSPECTION ON THE
CARGO DOOR INSTALLATION REVEALED SEVERAL
AREAS OF NONCONFORMITY INCLUDING
DOOR LOCKS OF LESS THAN REQUIRED STRENGTH,
LACK OF PAINT ON DOOR LOCKS
WHICH IS USED FOR VISUAL IDENTIFICATION, AND
DAMAGED WIRES IN A BUNDLE.
THE WIRES WERE PART OF THE DOOR CLOSING, DOOR
LOCKED INDICATING SYSTEM.
THE INVESTIGATION REVEALED IT WAS POSSIBLE FOR
THE DOOR TO BE NOT
COMPLETELY CLOSED AND HAVE THE DOOR WARNING
LIGHT GO OUT, INDICATING IT
WAS FULLY LOCKED.
--- Sequence of Events ---
Occurrence #: 1 140 DECOMPRESSION
Phase of Operation: 531 CLIMB - TO CRUISE
----- Findings -----
Subj - Mod - Pers C/F
1a. 10505(S) - 1147(M) Factor
DOOR, CARGO/BAGGAGE - IMPROPER
1b. 24111(S) - 3109(M) - 4108(P) Factor
MAINTENANCE, INSTALLATION - IMPROPER - OTHER
MAINTENANCE PERSONNEL
2a. 12013(S) - 1113(M) Factor
ELECTRICAL SYSTEM, ELECTRIC WIRING - CHAFED
2b. 24002(S) - 3109(M) - 4102(P) Cause
AIRCRAFT PREFLIGHT - IMPROPER - FLIGHT ENGINEER
--- Probable Cause ---
THE FAILURE OF THE FLIGHT ENGINEER TO CONDUCT
A PROPER PREFLIGHT

INSPECTION AND ENSURE THE MAIN CARGO DOOR
WAS FULLY CLOSED AND LOCKED.
FACTORS RELATED TO THE ACCIDENT WERE
THEDAMAGED WIRES IN THE BUNDLE, AND
THE IMPROPER MAIN CARGO DOOR INSTALLATION.
--- Detail ---
Acft_Nbr_Seat_Qty: 0
Opn_Biz_Code: Code Not Found
Opn_Biz_Otr_Desc:
Fltcndct_Code: 14 CFR 121
Fltcndct_Otr_Desc:
Opn_Sked_Code: NON-SCHEDULED
Opn_Dom_Intnl_Code: DOMESTIC
Opn_Psgr_Cargo_Code: CARGO
Regist_Nbr: 794AL
Owner_Cert_Held_Flag: Code Not Found
Oprtr_Cert_Acr_Type_Code: SUPPLEMENTAL
Oprtr_Cert_Otr_Acft_Flag: Code Not Found
Oprtr_Cert_Rotor_Ag_Code: Code Not Found
Acft_Fire_Code: NONE
Injuries
Fatal Serious Minor None
Crew 0 0 0 3
Pass 0 0 0 0
Other 0 0 0 0
Invlvd 0 0 0 3
Lndgr_Type_Fix_Code: TRICYCLE-RETRACTABLE
Acft_Crtfyd_Max_Wt_Lb_Qty: 355000
Eng_Manf_Name: PRATT & WHITN
Eng_Model_Name: JT3D-7
Acft_Nbr_Eng_Qty: 4
Eng_Typ_Code: TURBO FAN
Eng_Rated_Pwr_Hpwr_Qty: 0

Eng_Rated_Pwr_Thrust_Lb_Qty: 19000
Elt_Instld_Flag: Code Not Found
Elt_Oprtd_Flag: Code Not Found
Stall_Warn_Instl_Flag: Yes
--- Environment/Operations Information ---
Wx_Brfg_Srce_Code: COMPANY
Wx_Brfg_Mthd_Code:
Wx_Brfg_Cmplt_Code: WEATHER NOT PERTINENT
Wx_Flt_Cond_Code: VISUAL METEOROLOGICAL CONDITIONS (VMC)
Wx_Wind_From_Vrbl_Flag: Code Not Found
Wx_Wind_Degm_Qty: 0
Wx_Wind_Type_Code: Code Not Found
Wx_Wind_Spd_Kt_Qty: 0
Wx_Vis_Sm_Qty: 0
Wx_Vis_Rvr_Ft_Qty: 0
Wx_Vis_Rvv_Sm_Qty: 0
Wx_Cloud_Code: Code Not Found
Wx_Cloud_Hgt_Agl_Ft_Qty: 0
Wx_Cig_Code: Code Not Found
Wx_Cig_Hgt_Agl_Ft_Qty: 0
Wx_Vis_Rstr_Fix_Code:
Wx_Precip_Type_Fix_Code: NONE
Wx_Cond_Lgt_Code: NIGHT (DARK)
Dep_Point_Flag: Yes
Dep_Point_Arpt_Id_Code:
Dep_Point_City_Name:
Dep_Point_State_Code:
Destn_Same_Lcl_Code: Code Not Found
Destn_Arpt_Id_Code: LAX
Destn_City_Name: LOS ANGELES
Destn_State_Code: CA
Fltplan_Filed_Code: INSTRUMENT FLIGHT RULES (IFR)

Clnc_Atc_Type_Code: IFR
Apch_Vfr_Fix_Code: PRECAUTIONARY LANDING
Loc_Event_Code: OFF AIRPORT/AIRSTRIP
Rwy_Used_Id_Sffx_Code:
Rwy_Used_Id_Code: 0
Rwy_Len_Ft_Qty: 0
Rwy_Wid_Ft_Qty: 0
Rwy_Sfc_Type_Fix_Code: Code Not Found
Rwy_Status_Type_Fix_Code:
--- Personnel Information ---
Plt_Cert_Type_Code: COMMERCIAL, AIRLINE TRANSPORT
Pltrtng_Plane_Code: SINGLE ENGINE LAND, MULTIENGINE LAND
Pltrtng_Non_Plane_Code: NONE
Pltrtng_Inst_Code: AIRPLANE
Plt_Bfr_Flag: Yes
Plt_Last_Bfr_Mo_Qty:
Plt_Bfr_Acft_Make_Name: DOUGLAS
Plt_Bfr_Acft_Model_Name: DC-8
Plt_Med_Cert_Code: CLASS 1
Plt_Med_Cert_Vldty_Code: VALID MEDICAL-NO WAIVERS/ LIMITATIONS
Flight Time (Hours)
Total : 8000 Last 24 Hrs : 0
Make/Model: 6300 Last 30 Days: 0
Instrument: 0 Last 90 Days: 0
Multi-Eng : 0 Rotorcraft : 0
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-72-78
Last Updated: 09-21-94
[O] A fatal aircraft accident, which the ntsb is currently investigating, and a recent aircraft incident have indicated to the

board that a safety
problem exists on twin-engined general aviation aircraft which have baggage compartments located in the nose section.
Recommendations:
A-72-78. Provide for double failure protection by means of a secondary locking device or cargo restraint system on those cargo doors where
inadvertent opening in flight would seriously jeopardize the safety of flight of the aircraft or the safety of its occupants on all so affected
aircraft.
Responses:
FAA LTR DTD: 07/13/72
With respect to the beechcraft 99 inadvertent door opening incident, proposed rulemaking action is being considered to require a thirdcargo
door latch device which is in addition to the two existing latches now in use. The new double failure protection device is provided in accordance
with beech service instruction 051-113 sent to all owners and operators on 20 june 1972. With the proposed modification to the beech 99, and
with proper maintenance, the cargo compartments of both the beech 65 and the beech 99 should adequately restrain cargo and fulfill the
requirements of the regulation. Therefore, we do not concur that rulemaking under part 135 be recommended.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-89-94
Last Updated: 11-06-96
[O] On February 24, 1989, United Airlines, Inc., (UAL), Flight 811, a Boeing 747-122, N4713U, with 3 flight crewmembers, 15

cabin crewmembers,
and 337 passengers on board, experienced an explosive decompression as a result of the in-flight loss of the right forward lower lobe cargo
compartment door and a part of the right cabin fuselage.
Recommendations:
A-89-94. Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for
conceivable human errors in addition to electrical and mechanical malfunctions.
Responses:
FAA LTR DTD: 11/3/89
The FAA will determine its course of action to address this safety recommendation as soon as its review in response to Safety Recommendation A-89-93 is completed.
As stated in our response to Safety Recommendation A-89-93, 14 CFR 25.783 and AC 25.783-1 consider human factors in the routine operation
of closing and locking doors to ensure that the latch and lock systems are fail-safe. To emphasize the importance of human factors, the FAA
has developed a training program for FAA certification personnel to enhance their knowledge of human factors in aircraft design. This
training program will be offered to approximately 100 certification personnel during the next year. I believe that this training program will
result in more effective review of designs for human factor considerations as required by present regulations.
I will keep the Board apprised of the FAA's progress on this safety recommendation.
NTSB LTR DTD: 4/16/90

The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all
jet-powered transport category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight.
The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against
criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted
in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock
systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification
personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100
certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as
"Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using
non-plug doors and that the FAA should not be limiting this review to only those transports which are jet-powered.
FAA LTR DTD: 6/29/93
The FAA is considering the issuance of an NPRM to address this safety recommendation. The FAA has asked the Aviation Rulemaking

Advisory Committee to participate in the drafting of this document.
I will provide the Board with a copy of any document that may be issued.
FAA LTR DTD: 9/5/96
The Federal Aviation Administration (FAA) asked the aircraft industry to form an industry task group to review cargo door designs on the
fleet of transport airplanes and to provide the FAA with recommendations regarding any deficiencies found as a result of the review.
Subsequently, the FAA issued airworthiness directives (AD's) in accordance with the recommendations received from the task group to
prevent nonplug cargo doors from opening in flight. Copies of the AD's were provided to the Board in response to Safety Recommendation
A-89-93. The FAA is satisfied that the task group reviewed these designs in an effective and comprehensive manner and that the resultant
AD's ensure that human factors considerations in both 14 CFR 25.783 (as amended by Amendment 25-72) and Advisory Circular 25.783-1 are
adequate for the current fleet of transport category airplanes.

The FAA also developed a training course for aircraft certification engineers to address the fail-safe design requirements and the human
factors aspects of proper door locking and latching mechanisms. All certification engineers assigned to work on door issues have received the
training.
I believe that the FAA has taken appropriate action to address

this safety recommendation, and I consider the FAA's action to be completed.
NTSB LTR DTD: 10/29/96
The Safety Board notes that the FAA urged the aircraft industry to form a task group to review cargo door designs and to provide the FAA
with recommendations regarding any deficiencies noted during the review. Subsequently, the FAA issued airworthiness directives in response
to the recommendations developed by the task group to prevent non-plug cargo doors from opening in flight. The FAA also developed a
training course for all aircraft certification engineers to address the fail-safe design requirements and the human factors aspects of proper
door locking and latching mechanisms. All certification engineers assigned to work on door issues have received the training.
In view of the actions taken by the FAA, the Safety Board classifies Safety Recommendation A-89-94 "Closed Acceptable Action."
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-92-21
Last Updated: 09-21-94
[O] On February 24, 1989, United Airlines flight 811, a Boeing 747-122 (B-747), N4713U, was operating as a regularly scheduled flight from Los
Angeles, California, to Sydney, Australia, with intermediate stops in Honolulu, Hawaii, and Auckland, New Zealand. There were 3 flight
crewmembers, 15 flight attendants, and 337 passengers aboard the airplane.

The flightcrew's first indication of a problem was while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed of 300
knots. They heard a sound, described as a "thump," which shook the airplane. This sound was followed immediately by a "tremendous
explosion." The airplane had experienced an explosive decompression. Power was lost from the Nos. 3 and 4 engines because of damage from
foreign object ingestion.
The airplane made a successful emergency landing in Honolulu, and the occupants evacuated the airplane. An examination of the evidence
at the time revealed that the forward lower lobe cargo door had separated in flight, causing extensive damage to the fuselage and cabin
structure adjacent to the door. As a result, nine of the passengers were ejected from the airplane and lost at sea.
Recommendations:
A-92-21. Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all
electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the
door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits.
Responses:
FAA LTR DTD: 6/22/92
The FAA has initiated a review of all outward opening nonplug cargo doors on transport-category airplanes. One aspect of this review is to

verify that all electrical power to the doors (except for any indicating circuit power necessary to provide positive indication that the door is
properly latched and locked) is removed in flight. The FAA has completed its review of the Boeing Models 747, 757, 767, 737, and 727 and
concluded that the power is removed from the doors in flight. Consequently, the FAA does not plan to initiate mandatory action on these
moels.
I will keep the Board apprised of the FAA's progress on its review of other transport category airplanes.
NTSB LTR DTD: 8/31/92
Safety Recommendation A-92-21 states that the FAA should require that the electrical actuating systems for nonplug cargo doors on
transport category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating
circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of
uncommanded actuator movements caused by wiring short circuits. The Safety Board notes that the FAA has completed its review of one
aspect of this recommendation and has concluded that electrical power is removed from the circuit on the doors in flight on Boeing Models
747, 757 767, 737, and 727. However, the intent of this safety recommendation is to insure that no electrical power is available to actuating
systems for nonplug cargo doors on transport-category aircraft after closure of the doors.

The Safety Board stated in the accident report involving United Airlines flight 811 that the door opening was attributed to a faulty switch or
wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door
closure and before takeoff. The Safety Board believes that by requiring that all electrical power be removed from door actuating circuits after
closure, the possibility of uncommanded actuator movements caused by wiring short circuits that might occur between the time that the door
is closed and the time that the airplane takes off is eliminated. Pending further information, the Safety Board classifies Safety Recommendation A-92-21 as "Open--Await Response."
FAA LTR DTD: 4/20/93
The FAA has completed its review of this safety recommendation and agrees with the intent. The FAA has evaluated the door designs of all
large transport category airplanes for isolation of power to the doors during flight. All of the nonplug doors on these category airplanes have
been modified as necessary to achieve this objective. Nonplug doors already have a separate power switch at the door operator's station that
removes power from the door. Some switches operate directly while others, such as the power switches on the Boeing Models 737, 747, and 767,
are operated by the lock handle. The Boeing Models 727 and 757 have separate disarm switches. On the lighter transport category airplanes,
the outward opening doors without powered latches and locks do not have the potential safety problems associated with

inadvertent operation
due to electrical shorts.
Additional automatic protection against electrical shorts is provided on the Boeing Model 747 airplanes. The ground handling bus is the sole
source of electrical power for all of the airplanes' nonplug doors. During departure from the gate once ground power has been disconnected
from the airplane and an engine generator has been placed on line, power is removed from the ground handling bus. Additional protection
against an inadvertent power source is provided by the operation of a relay which opens when the main landing gear leaves the ground and
the air-ground squat switch opens.
The current policy as stated in Advisory Circular 25.783-1 requires an additional warning for doors that could create a hazard in the event they
open during takeoff. These doors require a red light to announce an unsafe door condition and some configurations may require an aural
warning during the initial takeoff run.
The FAA's review of the nonplug door configurations currently installed on the large transport category airplanes showed that electrical power
is removed from all of these doors before the airplane leaves the gate. On some of these airplanes, all of the electrical power to the door
operating controls is removed as soon as an engine is started and its associated generator placed on-line. In addition, the warning systems on
the doors of these airplanes meet the policies contained in Advisory Circular 25.783-1. Any inadvertent change of the

positioning of the door
lock mechanisms would be annunciated to the flightcrew. Based on these data, the FAA believes that the present door configuration provides
adequate protection against the possibility of an inadvertent power application caused by an electrical short.
I consider the FAA's action to be completed on this safety recommendation.
NTSB LTR DTD: 8/10/93
The Safety Board notes that during the past year the FAA has worked with and encouraged the airline industry in the development of new
methods for removal of electrical power from nonplug cargo door actuating systems on transport-category aircraft. Furthermore, the FAA has
reviewed the nonplug cargo door configurations currently installed on large transport-category airplanes and found that electrical power is
removed from all of these doors before the airplane leaves the gate.
Additionally, on some of these airplanes, all electrical power to the door operating controls is removed as soon as an engine is started and its
associated generator is placed on-line. Any inadvertent change in the position of the door lock mechanisms that occurred before the removal
of electrical power would be annunciated to the flightcrew. The review verified that the warning systems on the doors of these airplanes meet
the policies contained in Advisory Circular 25.783-1.
The Safety Board accepts the FAA position that removal of electrical power from door circuits before taxi in conjunction with redundant and

reliable lock position warning systems as described in the AC meet the intent of Safety Recommendation A-92-21. Thus, Safety
Recommendation A-92-21 is classified "Closed--Acceptable Alternate Action."

NTSB Safety Recommendation Brief

Data_Source: U.S. NTSB Safety Recommendations

Rprt_Nbr: A-89-92

Last Updated: 09-21-94

[O] On February 24, 1989, United Airlines, Inc., (UAL), Flight 811, a Boeing 747-122, N4713U, with 3 flight crewmembers, 15 cabin crewmembers,
and 337 passengers on board, experienced an explosive decompression as a result of the in-flight loss of the right forward lower lobe cargo
compartment door and a part of the right cabin fuselage.

Recommendations:

A-89-92. Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have
torque-limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical
operation of the latch cams.

Responses:

FAA LTR DTD: 11/3/89

The FAA evaluated this safety recommendation and has determined that Boeing 747 cargo doors with lock sectors, modified in compliance
with Airworthiness Directive (AD) 88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams because the
latch cam actuators incorporate at least one torque-limiting

device. Based on this information, the FAA does not plan to issue an AD as
requested by this safety recommendation.
NTSB LTR DTD: 4/16/90
The FAA responded to Safety Recommendations A-89-92 through -94 on November 3, 1989. During its evaluation of Safety Recommendation
A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with Airworthiness Directive (AD)
88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams because the latch cam actuators incorporate at
least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this, Safety
Recommendation A-89-92 has been classified as "Closed--Reconsidered."
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-89-93
Last Updated: 09-21-94
[O] On February 24, 1989, United Airlines, Inc., (UAL), Flight 811, a Boeing 747-122, N4713U, with 3 flight crewmembers, 15 cabin crewmembers,
and 337 passengers on board, experienced an explosive decompression as a result of the in-flight loss of the right forward lower lobe cargo
compartment door and a part of the right cabin fuselage.
Recommendations:
A-89-93. Issue an Airworthiness Directive for non-plug cargo doors on all transport category airplanes requiring the installation of positive

indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently.
Responses:
FAA LTR DTD: 11/3/89
The FAA is reviewing all outward opening (nonplug) doors on all jet-powered transport category airplanes to determine what, if any,
modifications are needed to ensure that these doors will not open in flight. The door latch indicating system is only part of this review. Door
designs are being evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in
Advisory Circular (AC) 25.783-1, Fuselage Doors, Hatches, and Exits. These standards were adopted in 1980 and account for human factors
involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe.
I will keep the Board apprised of the FAA's progress on this safety recommendation.
NTSB LTR DTD: 4/16/90
The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all
jet-powered transport category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight.
The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against
criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted

in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock
systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification
personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100
certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as
"Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using
non-plug doors and that the FAA should not be limiting this review to only those transports which are jet-powered.
FAA LTR DTD: 6/29/93
The FAA has issued five final rules and one notice of proposed rulemaking (NPRM) which address this safety recommendation. On
November 28, 1989, the FAA issued a final rule applicable to certain McDonnell Douglas DC-9 series airplanes, and on February 27, 1990, the
FAA issued a final rule applicable to certain DC-8 series airplanes. These two rules require installation of a main cargo door hydraulic
isolation valve; installation of an additional (and modification of an existing) door-open indicating system; installation of a main cargo door
lock pin viewing window; installation of a main cargo door vent system; installation of a "vent door-open" indicating system; installation of a

main cargo door hinge pin retainer; and modification to the main cargo door latch operating mechanism.
Effective May 29, 1990, the FAA issued Airworthiness Directive 90-09-06 applicable to certain B-747 series airplanes to prevent the inadvertent
opening of lower lobe forward and aft cargo doors and main side cargo doors. The terminating action includes inspections, repairs, tests,
and placard installations.
On August 14, 1990, the FAA issued a final rule applicable to certain DC-10 series airplanes to require the installation of a main deck cargo
door "vent door-open" indicating system and installation of cargo door hinge pin retainers. On September 25, 1992, the FAA issued a final
rule applicable to certain B-737 series airplanes to require modification of the main deck cargo door lock, viewing windows, and warning
indication system.
I have enclosed copies of these final rules for the Board's information.
On March 10, 1993, the FAA issued an NPRM applicable to certain Lockheed Model L-1011 series airplanes. This NPRM proposes to require
inspection of the cargo door components for cracks and corrosion and require modification, rework, or replacement of discrepant parts.
I have also enclosed a copy of the NPRM for the Board's information. I will provide the Board with a copy of the final document as soon as it is
issued.
FAA LTR DTD: 7/20/94
In response to this safety recommendation, the Federal Aviation

Administration (FAA) reviewed all outward opening (nonplug) doors on all
jet-powered transport category airplanes for both design deficiencies and for service-related safety problems. The nonplug door review
included an examination of the door latch indicating system, as well as all other design criteria specified in 14 CFR 25.783 and the policy
material published in Advisory Circular 25.783-1, Fuselage, Doors, Hatches, and Exits. As a result of this review, the FAA issued five final rules
that addressed different aspects of nonplug doors on transport category aircraft. The final rules, which were provided to the Board on June 29,
1993, addressed McDonnell Douglas DC-9, DC-10, and certain DC-8 series airplanes, and Boeing 747 and 737 series airplanes. On December
6, 1993, the FAA issued Airworthiness Directive (AD) 93-24-12 applicable to the L-1011-385 series airplane. The issuance of AD 93-24-12
completes the FAA's action to prevent nonplug cargo doors from opening in flight. I have enclosed a copy of AD 93-24-12 for the Board's
information.

The FAA's review of this issue included only jet-powered transport category airplanes. The service history of nonjet-powered transport
category airplanes does not indicate safety issues that needed to be addressed through the door review effort.

The actions taken by the FAA address the full intent of this safety recommendation. Consequently, I consider the FAA's action to be
completed, and I plan no further action on this issue.

NTSB LTR DTD: 8/30/94
The Safety Board notes that the FAA has completed a review of all non-plug doors on jet-powered transport-category airplanes. The review
resulted in the issuance of five rules that addressed changes to the McDonnell Douglas DC-9, DC-10, and DC-8; Boeing 737 and 747; and
Lockheed L-1011-385 series airplanes.
The Safety Board agrees that these actions address the intent of Safety Recommendation A-89-93 and classifies this recommendation "Closed
Acceptable Action."
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-91-84
Last Updated: 03-13-95
[O] On June 13, 1991, United Airlines (UAL) maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B,
N152UA, at John F. Kennedy Airport (JFK), Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between
Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.
Recommendations:
A-91-84. Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and
issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the
provisions recommended in A-91-83.
Responses:

FAA LTR DTD: 11/01/91
The FAA agrees with the intent of these safety recommendations and is considering the issuance of a notice of proposed rulemaking to
address these issues. I will provide the Board with a copy of any document that may be issued.
NTSB LTR DTD: 11/27/91
These recommendations were issued as a result of the Board's investigation of an incident in which the rear cargo door on a Boeing 747-222B
initially would not open electrically and then opened electrically without activation of the door open switches. Your letter indicates that the
Federal Aviation Administration agrees with the intent of these recommendations and is considering the issuance of a notice of proposed
rulemaking to address these issues. The Board urges the FAA to move expeditiously on the recommendations. Pending receipt of additional
information concerning the action to be taken by the Federal Aviation Administration, the Safety Board is classifying Safety Recommendations A-91-83 and -84 as "Open--Acceptable Action."

FAA LTR DTD: 4/5/93
The Federal Aviation Administration (FAA) agrees with the intent of these recommendations. On February 18, 1992, the FAA issued a notice of
proposed rulemaking (NPRM) applicable to certain Boeing Model 747 series airplanes. This NPRM proposed to require inspection of the
flexible conduit, wiring, and support brackets between the fuselage and the forward and aft cargo doors. Since the issuance

of this NPRM, the
FAA has further reviewed the circumstances surrounding this door opening incident and has confirmed that an inadvertent in-flight opening
of the cargo door cannot be caused solely by wire chafing. The FAA has determined that in addition to chafing at least four independent
failures must also occur in order to drive the door latches to the open position. In light of these findings, the FAA determined that the
requirements proposed by the NPRM were unnecessary. On December 21, 1992, the FAA withdrew the NPRM. I have enclosed a copy of the
notice of withdrawal for the Board's information.
Airworthiness Directive (AD) 90-09-06 (Docket No. 89-NM-148-AD) mandates the installation of a door warning switch located on the lock
sector, as well as a reinforcement of the lock sector to ensure that the latches remain locked against backdriving of the latches by the latch
power drive unit. Failure of lock sectors that are reinforced in accordance with AD 90-09-06 has been shown to be unlikely and, even in the
event of such a failure, an indication by means of the door warning switch will warn the flightcrew of the problem. The modifications, tests, and
inspections required in AD 90-09-06 provide an acceptable level of safety to preclude inadvertent actuation of the cargo door power drive unit
and possible injury to maintenance or cargo handling personnel. I have enclosed a copy of the AD for the Board's information. The FAA
believes that the current requirements of AD 90-09-06 address

the full intent of these safety recommendations to preclude an uncommanded
opening of the forward and aft cargo doors.
I consider the FAA's action to be completed, and I plan no further action on Safety Recommendations A-91-83 and -84.
NTSB LTR DTD: 11/8/93
The National Transportation Safety Board has reviewed the Federal Aviation Administration (FAA) response of April 5, 1993, to Safety
Recommendations A-91-83 and -84. These recommendations asked that the FAA issue an airworthiness directive applicable to all Boeing 747
airplanes with a flexible conduit protecting the wiring bundle between-the-fuselage and aft cargo door to require an expedited inspection of:
(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test
method or visual examination); (2) the conduit support bracket and attached standoff pin-on the upper arm of the forward lift actuator
mechanism; (3) the flexible conduit for the presence of cracking in the convoluted innercore.
The Board further recommended that wires with damaged insulation be repaired before further service. Damage to the flexible conduit,
conduit support bracket, and standoff pin should result in an immediate replacement of the conduit as well as. the damaged parts. The
inspection should be repeated at an appropriate cyclic interval.
The Safety Board then asked, in Safety Recommendation A-91-84, that the FAA evaluate the design, installation, and operation of the forward

cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an airworthiness directive for inspection and repair
of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in Safety Recommendation
A-91-83.
The FAA's April 5, 1993, response listed a number of findings of an FAA review of the circumstances surrounding the subject door opening.
Among the findings, the FAA confirmed that an inadvertent inflight opening of the cargo door cannot be caused solely by wire chafing.
Further, the FAA determined that at least four independent failures must occur to drive the door latches to the open position. The FAA also
stated that failure of lock sectors that are reinforced in accordance with AD 90-09-06 has been shown to be unlikely and, even in the event of
such a failure, the door warning switch would warn the flightcrew, of the problem.
Based on these findings, the FAA has decided that the requirements of AD 90-09-06 address the full intent of these recommendations-to
preclude an uncommanded opening of the forward and aft cargo doors.
FAA staff has also expressed concern that the recommended inspections could result in damage to the wire bundle insulation during the
intrusive inspection. Therefore, based on the level of redundancy that now exists to prevent inadvertent door opening in flight, the Safety
Board has classified Safety Recommendations A-91-83 and -84 as "Closed-Reconsidered. The Board will closely monitor

incidents related to
the uncommanded opening of cargo doors on 747 airplanes to further document this position.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-91-83
Last Updated: 03-13-95
[O] On June 13, 1991, United Airlines (UAL) maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B,
N152UA, at John F. Kennedy Airport (JFK), Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between
Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.
Recommendations:
A-91-83. Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between
the fuselage and aft cargo door to require an expedited inspection of:
(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test
method or visual examination);
(2) the conduit support bracket and attached standoff pin on
the upper arm of the forward lift actuator mechanism;
(3) the flexible conduit for the presence of cracking in the convoluted innercore.
Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and
standoff pin should result in an immediate replacement of the

conduit as well as the damaged parts. The inspection should be repeated at an
appropriate cyclic interval.
Responses:
FAA LTR DTD: 11/1/91
The FAA agrees with the intent of these safety recommendations and is considering the issuance of a notice of proposed rulemaking to
address these issues. I will provide the Board with a copy of any document that may be issued.

NTB LTR DTD: 11/27/91
These recommendations were issued as a result of the Board's investigation of an incident in which the rear cargo door on a Boeing 747-222B
initially would not open electrically and then opened electrically without activation of the door open switches. Your letter indicates that the
Federal Aviation Administration agrees with the intent of these recommendations and is considering the issuance of a notice of proposed
rulemaking to address these issues. The Board urges the FAA to move expeditiously on the recommendations. Pending receipt of additional
information concerning the action to be taken by the Federal Aviation Administration, the Safety Board is classifying Safety Recommendations A-91-83 and -84 as "Open--Acceptable Action."
FAA LTR DTD: 4/5/93
The Federal Aviation Administration (FAA) agrees with the intent of these recommendations. On February 18, 1992, the FAA issued a notice of
proposed rulemaking (NPRM) applicable to certain Boeing

Model 747 series airplanes. This NPRM proposed to require inspection of the
flexible conduit, wiring, and support brackets between the fuselage and the forward and aft cargo doors. Since the issuance of this NPRM, the
FAA has further reviewed the circumstances surrounding this door opening incident and has confirmed that an inadvertent in-flight opening
of the cargo door cannot be caused solely by wire chafing. The FAA has determined that in addition to chafing at least four independent
failures must also occur in order to drive the door latches to the open position. In light of these findings, the FAA determined that the
requirements proposed by the NPRM were unnecessary. On December 21, 1992, the FAA withdrew the NPRM. I have enclosed a copy of the
notice of withdrawal for the Board's information.

Airworthiness Directive (AD) 90-09-06 (Docket No. 89-
NM-148-AD) mandates the installation of a door warning switch located on the lock
sector, as well as a reinforcement of the lock sector to ensure that the latches remain locked against backdriving of the latches by the latch
power drive unit. Failure of lock sectors that are reinforced in accordance with AD 90-09-06 has been shown to be unlikely and, even in the
event of such a failure, an indication by means of the door warning switch will warn the flightcrew of the problem. The modifications, tests, and
inspections required in AD 90-09-06 provide an acceptable level of safety to preclude inadvertent actuation of the cargo door power drive unit

and possible injury to maintenance or cargo handling personnel. I have enclosed a copy of the AD for the Board's information. The FAA
believes that the current requirements of AD 90-09-06 address the full intent of these safety recommendations to preclude an uncommanded
opening of the forward and aft cargo doors.
I consider the FAA's action to be completed, and I plan no further action on Safety Recommendations A-91-83 and -84.
NTSB LTR DTD: 11/8/93
The National Transportation Safety Board has reviewed the Federal Aviation Administration (FAA) response of April 5, 1993, to Safety
Recommendations A-91-83 and -84. These recommendations asked that the FAA issue an airworthiness directive applicable to all Boeing 747
airplanes with a flexible conduit protecting the wiring bundle between-the-fuselage and aft cargo door to require an expedited inspection of:
(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test
method or visual examination); (2) the conduit support bracket and attached standoff pin-on the upper arm of the forward lift actuator
mechanism; (3) the flexible conduit for the presence of cracking in the convoluted innercore.

The Board further recommended that wires with damaged insulation be repaired before further service. Damage to the flexible conduit,
conduit support bracket, and standoff pin should result in an immediate replacement of the conduit as well as. the damaged

parts. The
inspection should be repeated at an appropriate cyclic interval.

The Safety Board then asked, in Safety Recommendation A-91-84, that the FAA evaluate the design, installation, and operation of the forward
cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an airworthiness directive for inspection and repair
of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in Safety Recommendation
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Among the findings, the FAA confirmed that an inadvertent inflight opening of the cargo door cannot be caused solely by wire chafing.
Further, the FAA determined that at least four independent failures must occur to drive the door latches to the open position. The FAA also
stated that failure of lock sectors that are reinforced in accordance with AD 90-09-06 has been shown to be unlikely and, even in the event of
such a failure, the door warning switch would warn the flightcrew, of the problem.

Based on these findings, the FAA has decided that the requirements of AD 90-09-06 address the full intent of these recommendations-to
preclude an uncommanded opening of the forward and aft cargo doors.

FAA staff has also expressed concern that the recommended inspections could result in damage to the wire bundle insulation during the
intrusive inspection. Therefore, based on the level of redundancy that now exists to prevent inadvertent door opening in flight, the Safety
Board has classified Safety Recommendations A-91-83 and -84 as "Closed-Reconsidered. The Board will closely monitor incidents related to
the uncommanded opening of cargo doors on 747 airplanes to further document this position.
NTSB Safety Recommendation Brief
Data_Source: U.S. NTSB Safety Recommendations
Rprt_Nbr: A-70-53
Last Updated: 09-21-94
[O] Our staff member who participated in the irish/british investigation of theaer lingus b-707-349c depressurization incident that occurred en
route shannon to london on september 24, 1970, has briefed your flight standards personnel on details of the involved fuselage skin fractures,
and has supplied your personnel with photographs of the fracture area. As you know, a 3- by 4-foot section of the fuselage sidewall blew out
while the aircraft was flying at 25,000 feet, at a cabin pressure differential of 8.2p.S.I., causing a rapid depressurization of the cabin and
deployment of thepassenger oxygen masks. The crew initiated an emergency descent and landed the aircraft at london without further
incident. The royal aeronautical establishment metallurgical laboratory at farnsborough has confined the presence of fatigue

in the fracture of
the outer main cargo doorskin in the area between fuselage station 540 and 560. Multiple fatigue nuclei were found at numerous rivet holes
near the center of the approximate 22-inch primary fracture line. Heavy nicotine staining on the skin and adjacent frames indicated that cabin
air had been exiting through the skin crack forsome time. The area had last been inspected 368 hours before the depressurization incident.
The total aircraft time was 20,820 hours.
Recommendations:
A-70-53. 1) that the faa issue an Airworthiness Directive requiring the inspection of all b-707 and b-727 cargo doors for evidence of fatigue
cracking at 150-hour intervals. 2) that faa reevaluate the design safety features of the single, actuator-type door, and assess the need for and
feasibility of incorporation of a dual actuator system to reduce door flexing loads.
variousdooraccidents.html Accounts of various cargo door accidents/incidents.
forwardcargodoorpict.html Contents to links on door on site
Schematic1 Door Drawing
Schematic2 Door Drawing
Schematic3 Door Drawing
Boeing 747 nose picts right side cargo door
cargodoorfaraway.html Pictures near, close and faraway
811doordraw 747 argo cdoor drawing from 811 report
811picture UAL 811 cargo door hole picture
More pictures of UAL 811 cargo door hole

#Comment Doors open all the time with varying degrees of

consequence.
#
Boeing747historycontents.html
DC-10crashcontents.html
103reportcontents.html
811reportcontentpage.html
AirIndiareportcontents.html
800newsreports.html
800newsreports1.html
800newsreports2.html
800newsreports3.html
pressurization1.html
aerodynamics.html
314accidentreport.html
811skiesdoorcontents.html
Contents
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: March 8, 2001 2:18:24 PM PST
To: sterns@trial-law.com
Subject: **Possible case for you**

Jerry Sterns,
Sterns, Walker & Lods

Dear Mr. Sterns,

There is a possible case for you involving explosive decompression in an airliner leading to fatalities.

Are you interested assuming the cause is just and the fees reasonable?

Details upon request.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.

From: Jerry <Sterns@trial-law.com>
Date: March 8, 2001 2:51:21 PM PST
To: barry@pop.redshift.com
Subject: **Re: Fwd: Possible case for you**

Barry, we are always willing to look at any possible meritorious case involving aviation matters. I know we have been in touch before, but I don't remember the case. Can you refresh my memory? Please forward whatever information you can and we will have a look. Mailing address 901 Clay Street, Oakland 94607; ph 510 267 0500; fax -0506. Thanx for thinking of us. Regards, G Sterns

At 02:41 PM 3/8/01 -0800, you wrote:

X-Sender: barry@pop.redshift.com
Date: Thu, 8 Mar 2001 14:18:23 -0800
To: sterns@trial-law.com

From: John Barry Smith <barry@corazon.com>
Subject: Possible case for you

Jerry Sterns,
Sterns, Walker & Lods

Dear Mr. Sterns,

There is a possible case for you involving explosive decompression in an airliner leading to fatalities.

Are you interested assuming the cause is just and the fees reasonable?

Details upon request.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.

From: Jerry <Sterns@trial-law.com>
Date: March 8, 2001 5:18:32 PM PST
To: barry@pop.redshift.com
Subject: **exlo decompression**

belay last communication. i just saw your latest with the client contact info. thanx. G for Gerald; J for Jerry. From my mother.

From: John Barry Smith <barry@corazon.com>
Date: March 9, 2001 9:26:38 AM PST
To: psi@interchange.ubc.ca
Subject: **Introduction**

Dear Mr. Parmjit Singh,

My name is John Barry Smith and I am the discoverer and proponent of the wiring/cargo door/explosive decompression explanation for four early model Boeing 747s including Air India 182. Details at www.corazon.com

I am available to answer questions from you at your convenience.

Cheers,
Barry
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: "PSi" <psi@interchange.ubc.ca>
Date: March 9, 2001 9:19:04 PM PST
To: "John Barry Smith" <barry@corazon.com>
Subject: **RE: Introduction**

Hi John,

Please call me Parmjit. Thank you for your kind email. I have been reading
posts about your story and website with great interest from the time I saw
the first post. I think your website is probably well known to many Sikhs
around the world by now. It is reassuring to know that there are people like
yourself who are willing to step forward and speak and volunteer their
expertise. Young educated Sikhs in Vancouver know about John Barry Smith and
www.corazon.com. It is an effort that restores the faith of many in the
human activism and kindness after being shaken by seeing how Sikhs are
prosecuted today in Canada.

I look forward to your involvement in this. You seem to have much
experience, knowledge, and integrity. I have a feeling that at some juncture
down the road, your message is not only going to reach the judge but the
global media. There seem to be many forces at work in a highly politicized
case. I have faith that you will hang in there, persevere through the layers
of lawyers and protocol, and set an example for the human spirit.

-----Original Message-----
From: John Barry Smith [mailto:barry@corazon.com]
Sent: Friday, March 09, 2001 9:27 AM
To: psi@interchange.ubc.ca
Subject: Introduction

Dear Mr. Parmjit Singh,

My name is John Barry Smith and I am the discoverer and proponent
of the wiring/cargo door/explosive decompression explanation for
four early model Boeing 747s including Air India 182. Details at
www.corazon.com

I am available to answer questions from you at your convenience.

Cheers,

Barry
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Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Date: March 10, 2001 5:00:29 PM PST
To: "John Barry Smith" <barry@corazon.com>
Subject: **Re: Questions, questions...**

*** This e-mail is private*** Please do not forward without permission.

Dear Mr. Smith,

My name is Jaspreet Singh Malik. I am the eldest son of Mr. Ripudaman Singh
Malik who stands accused of plotting to blow up Air India flight 182 and
plotting to put a bomb on another Air India plane that killed two baggage

handlers at Narita Airport in Japan.

I am also a recent graduate of the UBC Law School and am currently Articling
at a Criminal Defence law firm. I know you have been in contact with
Sundeep and Paramjit, two friends of mine who are currently in Law School.

First, I would like to thank you for the time and effort you are putting in
to help us with this case. As far as I can tell you have nothing but pure
motives and only wish to have the truth revealed. I will try to answer your
questions to the best of my ability.

--- John Barry Smith <barry@corazon.com> wrote:
Well, questions....why no preliminary hearing for
Mr. Malik?

The Crown has sought and the Attorney General has granted a Direct
Indictment. In common practice an accused would have an Preliminary Hearing
in which his lawyers would get to test the Crown's evidence. All the
Crown's witnesses would be forced to testify unless specifically excused by
the accused's lawyer. This is of a great benifit to an accused as he gets
to test the evidence without being required to testify. It is not an

error
in law for the Crown to get a Driect Indictment. In complex cases the Crown
may seek a Direct Indictment so as to be able to speed up the process and
avoid having to offer the Crown's evidence twice.

What's next on April 4th?

The next court appearance but nothing of any significance.

What are the discovery rules in Canada?
The Law in Canada is the the Crown must disclose everything that it has in
its possesion. Even if that evidence leads to the conclusion that the
accused are innocent. The challenge in this case will be to get the Crown
to disclose everything they have. Unfortunately you don't know what your
missing unless you stumble upon it.

Can Mr.
Malik ask for and
receive the following items below:

Can he have computer in cell?

We have requested that but we have to deal with Corrections officials who do
not have such exceptions in their manuals. Obviously we have tried to work
this out with the Crown and with the Judge so we can meet the

constitutional
right to make full answer in defence.

Can he have internet access via phone lines?

I do not believe that will be possible but we can look into it.

Can he receive and send out removable disks for
laptop computer?

Once he gets access to a computer we can request to send in
disks or CDs

Is he eligible for assistance from the Crown for a
legal expert and
technical expert?

Such requests require Crown consent or Judge approval. I
understand that
currently there are preliminary negotiations underway so that
each party has
adequate funding.

What is the sequence of prosecution from arrest to
hearing to trial to appeal?

From here a Trial calendar will be set up. hopefully sooner
rather than
later we can start with all the pretrial motions. Our best hope is
that in
January 2002 a trial will start and will finish some 4-6 months
later. If
an Appeal of the case was to be filed it would be heard about 1

year after
the end of the case.

Is he a joint defendant with Mr. Bagri or
independent?

They are charged jointly and will be tried jointly unless an application for
severance is made and granted. Usually such applications are not successful. The Courts like it better when people charged with the same
crime are tried together.

What is a realistic timetable for future legal
milestones?

See trial calender above.

Can an American (California) aviation trial attorney practice in
Canada or what capacity can he assist?

I'm not sure I'll have to look into that.

I find it interesting that the document that concludes a crime was
committed, which implies a criminal, was made by an Indian judge at a
hearing. It was not Canadian, not a trial, and it was not aircraft
investigators. In essence Mr. Malik is being accused of an event
labelled a crime by a judge far away and unable to

be deposed or
cross examined in Canada. What is your opinion about
the
jurisdictional issues of that?

In Canada there is not ability to force a Judge or Justice of the
Peace to
testify. So even if it was Canadian Judge you wouldn't be able to
call them
to testify. However, I think that a lawyer would be able to
critique the
finding and the gaps in the evidence.

Thanks for helping, it is a complex lengthy case. We
have only just begun.

I was wondering if you had any contact with the Defence team
for the men
charged with blowing up a plane over Lockerbie, Scotland. I
wanted to know
if they used the same type of argument over there and if they had
any
success. I know one man was convicted and one was aquitted.

Jaspreet Singh Malik

From: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Date: March 11, 2001 8:48:29 PM PST
To: "John Barry Smith" <barry@corazon.com>
Subject: **Re: Flight Plan**

Dear John,

My contact info. is:

Jaspreet S. Malik
6475 Marguerite St.
Vancouver, BC
V6M 3L5
jsmalik@wwdb.org
Cell: 604-861-8858

As for a resume you have my introduction e-mail which lists all I have to say for now.

Jaspreet

----- Original Message -----
From: John Barry Smith
To: jsmalik@wwdb.org ; aniljitsingh@hotmail.com ; khalsaq@yahoo.com ; maan100@worldonline.nl ; KaurSingh@webtv.net ; AMARDEEP@klse.com.my ; npsingh@wans.net
Sent: Saturday, March 10, 2001 6:50 PM
Subject: Flight Plan

Plan the flight; fly the plan.

Dear Crew,

I have been in the military and understand how command structure works, as a student how the college administrative works, and now Mr. Malik is learning how the prison system works. They are all basically the same, Commanding Officer/Principal/Warden and then officer/teacher/guard then non commissioned officer/teacher's aide/trustee then enlisted/student/inmate then civilian/clerks/visitor respectively for military/school/jail. That system is autocratic, unyielding, inflexible, and prone to personality conflicts.

My model shall be aircrew. I shall be the pilot, Santokh my co-pilot, Aniljit the navigator, the attorney the bombardier, others as needed, and the main passenger is Mr. Malik, the person we are trying to get to where he wants to go, freedom. Mr. Malik is the ultimate boss, he pays the bills and bears the consequences of any mistakes by us, the crew. My authority to be pilot comes from him as he said he wants me to assemble the team and to lead the team. Should he change his mind at any time, that is fine and I will of course defer to his wishes. Below is preliminary flight planning and subject to change at any moment.

Regarding legal strategy: That is of course up to the attorney/solicitor/counsel/lawyer who knows best the workings of the Canadian legal system. Right now I do not understand why the preliminary hearings are being bypassed. There is a reason for preliminary hearings. Some legal questions are asked at end of this email.

The prosecution team for PA 103 is meeting with the prosecution team for AI 182. It would be a good idea for the defence team of PA 103 to meet with the defence teams for AI 182. The error of the PA 103 defence team is they never denied there was a bomb on board, just argued about where it was placed. There was no bomb on PA 103 either and that claim is as outrageous as the no bomb claim for AI 182. They are outrageous claims to the authorities who say there were bombs on board but not outrageous to those who examine the evidence in an objective manner. Both accident reports have statements from those objective investigators as well as the biased opinions of others.

Since I've been an airplane passenger, aircrewmember, mechanic, navigator, bombardier, and pilot, I know a few things about teamwork, responsibility and competence. I know to trust those that know more than I do and rely on them when appropriate. For instance Santokh knows more about Boeing 747s than all of us and a Boeing 747 is the victim in this case with other victims inside. I know about cargo doors. The attorney will know how best to present our data to persuade the right people. Aniljit will steer us through the rocky politics of Vancouver.

Our vehicle shall be the wiring/cargo door/explosive decompression explanation for AI 182. We shall know all about it, we shall check it, we shall pre-flight it, and only then, when all systems check and all the crew reports ready, then we taxi out and go on the mission.

The crew is being assembled. This is a volunteer mission. (And you know what they say, "Never Volunteer.") There shall be intimidation from others to not go. There shall be risk of wasted time and expense. Our reputations may suffer and relations with our friends, family, and business associates impaired. One way or the other our lives will be irrevocably changed, for better or for worse.

So be it. My ultimate cause is pure: saving lives. Specifically saving lives from crashes in commercial airliners with known faulty wiring and badly designed outward opening nonplug doors with inadequate latching. My short term goal is free an accused person from jail for something he did not do. I do this because injustice infuriates me. It is not right that someone is being punished for something he did not do as we speak while dangerous aircraft fly overhead risking innocent lives also as we speak. Both injustices need to be corrected and the sooner the better.

Every stage of the mission will be difficult. I have been preparing for twelve years and it is not getting easier. Assembling the team is proving harder than I thought:

It seems many potential crewmembers are for us on our trip and wish us the best of luck but they don't want to go on the ride. Their replies are below. Let us be understanding and say thank you anyway and we respect their judgment to not get involved directly. We shall continue to find qualified crew and ask if they would like to participate. I'm listening to all suggestions.

As pilot, I must insist on excellent communication among us. That means phone numbers, snail main addresses, and of course, the best: Email. We shall take advantage of high tech and the internet. This shall be our main tool. We shall use it for research and communication.

Everyone shall submit and confirm the three items above. Here's mine:

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

We can use the website at www.corazon.com for updates for wide spread dissemination.

Each of us shall make up an address book with the individual names and one address that includes all of us. I prefer to hear and

read everything so send me as much stuff as you can. If I send irrelevant material, just save it in an archive. Storage on magnetic media is so cheap that everything we do should be saved for later review. My address book for AI 182 is:
John Barry Smith, barry@corazon.com
Santokh Singh, maan100@worldonline.nl
Shyrone Kaur, KaurSingh@webtv.net
Amardeep Kaur, AMARDEEP@klse.com.my
Aniljit Singh, aniljitsingh@hotmail.com
Sundeep Dhaliwal, <khalsaq@yahoo.com> .
Didar Reyat, dsreyat@hotmail.com
Narinder Malik, npsingh@wans.net
Jaspreet Malik jsmalik@wwdb.org

Regarding security: We are the good guys, always remember that. We will act like good guys which is open, honest, forthright, and accurate. In fact, the RCMP, the TSB, the legal system and the defence crew have the same goal: Public safety. We should not consider ourselves in an adversarial relationship with the authorities. They may consider us as adversaries, but let us treat them as potential allies. The RCMP always gets their man when there is a man to get. In this case, no crime, no criminal, no man to get. The TSB wants aviation safety for the citizens they are charged to protect and want to stop airplane crashes. We know there is danger and we will report it to the TSB and they will come over to our side. The legal system wants to punish the guilty to keep public peace. To find the guilty, the system has rules and safeguards against error. We shall use those safeguards and rules to free the innocent person and accuse the guilty machine.

There are no conspiracies going on here. Everyone is acting in their own best interest and if those interests coincide, that is not a conspiracy. Boeing, the BC Supreme Court, Air India, RCMP, TSB, the Indian Court, the media, and politicians do not believe that wiring is causing cargo doors to open in Boeing 747s and trying to hide that knowledge by blaming someone they don't like to shift the blame and avoid responsibility. The groups above really do believe, much to their relief, a bomb blew AI 182 and PA 103 out of the air and that Sikhs and Libyans did it.

The groups above may try to shoot us down, figuratively, because they feel if we get through to the target they will be in trouble, and they are right, but they are not trying to deter us from our mission because they know we are right and they are wrong and trying to stop the truth from coming out. What difference does it make? None, the opposition is real and does not matter why. We hurt our cause if we ever blame our failures to persuade on conspiracy of unnamed enemies against us. That is exactly what the authorities are doing, explaining the mystery failure of a plane crash as a conspiracy of terrorist bombers and avoiding the hard science which puts blame and responsibility too close to home.

We must assume all these emails and all our telephone calls are being monitored. Fine, no problem, remember, we are the good guys. Do not say anything or write anything you do not believe in, that you you can not back up with documentation, and leave the flaming hatred and frustration elsewhere. In other words, say only that which you believe in and can support with facts. We never advocate any sort of violence, public disobedience, or disturbance; we abhor such tactics as counter productive. In fact, authorities may unwittingly attempt to provoke us into a public display of anger which would be a mistake on our part. We must always present a calm, reasonable, and plain spoken approach to others.

The press must be included sooner or later in our quest to show that AI 182 was not a bomb but a mechanical explanation. The authorities use press conferences to influence public opinion and we shall have to also. That will require a public spokesperson who is attractive, knowledgeable, and persuasive.

The person to present our side to the public has yet to be chosen. We may all have our turn at that.

Once the concept of wiring/cargo door/explosive decompression for AI 182 is out in the open, the world's aviation press will attempt to discredit it. We shall welcome that because we know it to be impossible to be discredited by facts. Many opinions will say it's wrong, but the opinions will never be accompanied by factual support. I've run into this for years. The mechanical explanation is always rebutted by unsubstantiated opinion, never by documented fact. That is also why every time we are asked to comment on the wiring/cargo door/explosive decompression explanation, all our statements will be supported by photographs, charts, and documents usually provided by the governments themselves. We do not need, nor will we use wild inaccurate accusations of wrongdoing against the manufacturer, government agencies, the media, or the airlines, even though we may feel the statements to be justified. The public perception of Sikhs as wild eyed funny looking men with knives fully capable of putting two bombs on two 747s at one time at one airport even though the reality of that is ludicrous. So, everyone connected with AI 182 must be thoughtful, well dressed, polite, and well informed when interacting with media or the public.

A good crew is professional, well informed, polite, calm, and very focused.

Easier said than done. Being well informed means reading a lot about Boeing 747s. www.corazon.com has hundreds of pages about them from construction, to history, to accidents. There is much more on the web. FAA and NTSB and AAIB has web sites full of data on bombings, fires, and electrical problems in airliners. There are many civilian aviation websites with data on them that may be relevant.

The focused near term goal is to show to a judge that the wiring/cargo door/explosive decompression explanation is more likely than a bomb explanation for AI 182 and that therefore, Mr. Malik should be released on bail pending trial.

The judge will not respect our maybe no bomb/maybe yes mechanical opinion but will respect the opinion of the TSB accident investigators who state it officially. We will have to prepare and meet with them at some time and persuade them that the Indian Court was mostly wrong in 1985 but only because it did not have the information we now have of subsequent events such as UAL 811. The TSB needs to be persuaded that any error of judgment made by the AAIB and TSB and Indian Court of 1985 was understandable and that it is perfectly reasonable to continue to investigate the still open case of AI 182 by a further examination of one of the original premises as stated in the AI 182 report: Explosive decompression as the initial event leading to structural failure. In other words, a mechanical explanation and not a criminal one for a machine failure.

I believe we can do it. The meeting with TSB is crucial. Setting it up will be difficult. It may have to be ordered by a judge in a preliminary hearing. If the accusations of planting a bomb come from aircraft investigators who say a bomb existed, then the defence has the right to meet and question those accusers. It is better if done voluntarily through persuasion rather than from an order from a judge.

The flight plan will have three main thrusts: The first is to deny that Mr. Malik had anything to do with anything that happened to AI 182 or Narita airport. If the problem is a person, they have the wrong person. That area will be to show that Mr. Malik did not have the motive, the means, or the opportunity to do they things he is accused of doing.

The second is to provide reasonable doubt as to whether a bomb exploded on AI 182. That will be part of the refuting the bomb strategy. That work has been done and shows that the 'experts' are divided themselves as to: Bomb existing at all, some say no, some say yes; placement of the bomb, some say aft, some say forward, some don't know; size of bomb, some says half a kilo of something, some say 5 kilos of something; makeup of bomb, some say plastic, some say dynamite; sound of bomb, some say sound is bomb, some say it's not a bomb; damage of bomb, some say fragments are injuries are bomb injuries, some say not. When real bombs go off on real airplanes enough to destroy them, there is real evidence in damage, fragments, and sound, and the experts easily agree what kind of bomb and where it was placed and what it was made of. To have as much disagreement among experts as to the AI 182 'bomb' is to create enough reasonable doubt to any fair evaluator, such as a jury, judge, or accident investigator.

The persons to deny Mr. Malik's involvement with AI 182 and refute the bomb explanation have not yet been decided upon.

It is one thing to deny an accusation, but to provide the real culprit and prove it is to make one doubly innocent. That is where the wiring/cargo door/explosive decompression explanation comes in. It not only makes Mr. Malik and the Sikhs not guilty, it makes them innocent, which is an entirely different legal category.

I will handle the wiring/cargo door/explosive decompression explanation for AI 182. To do so will take more evidence, such as that listed below, and also brings in the other three Boeing 747 accidents. Bringing up PA 103 as not a bomb is essential although it has its risks as being so outrageous as to be instantly rejected. However, the authorities are always bringing in PA 103 and I agree with them, the two accidents are intimately related and we shall use that pairing as support. PA 103 is also linked to PA 125, a sister ship on the construction line, when PA 125 took off out of Heathrow, London, in 1987 and suffered an open forward cargo door in flight. For us to say the same happened to PA 103 has precedent. PA 125 had open cargo door, then PA 103 had open cargo door, then AI 182 had open cargo door as PA 103 and AI 182 are often linked together.

There are actually many aircraft incidents and accidents that bear on AI 182 such as: Comet crashes, DC 10 ground test, Windsor AA 96, Turkish Paris DC 10, AI 182, PA 125, PA 103, UAL 811, UAL preflight, TWA 800, El Al Amsterdam, Wanli China Airlines, and JAL 46E. The listed incidents and accidents were warnings gone unheeded.

The technical aspects of wiring/cargo door/explosive decompression explanation are mainly three. As the explanation states, explosive decompression needs to be clearly stated and understood. By the way, there were many signs of explosive decompression on the victim's bodies such as baro-trauma, hypoxia, and lung damage. Next, the entire cargo door mechanisms on Boeing 747s needs to be clearly stated and understood. There is of course much documentation support for ruptured/open cargo door for AI 182 and in fact, the Kirpal Report implies that the 'bomb' was placed on the right side forward of the wing which caused the forward cargo door to become shattered and frayed from an 'outward force'. The report also opines that an open cargo door in flight would cause the damage observed. The key here is 1989 UAL 811 accident with its many significant matching similarities to AI 182; evidence the 1985 investigators did not have access to. Then comes wiring. Wiring is where it all starts and it is well documented by government authorities and manufacturer the inherent failure of the Poly X wiring used in all early model Boeing 747s to include, PA 103, PA 125, UAL preflight, TWA 800, and UAL 811. This wire easily chafes to bare wire especially in the presence of water. Whole fleets of military jets have been grounded to never fly again because they were made with this type of insulated wire which spontaneously caught fire when shorted.

All the hundreds of early model Boeing 747s now flying around the world have this dangerous wire installed. In fact, should another Boeing 747 come apart in the air leaving a sudden loud sound on the CVR and an abrupt power cut to the FDR, we must be ready to present the wiring/cargo door/explosive decompression for AI 182 and the new accident as a matching pair. Of course the cause of the new accident will initially be called a 'bomb', as it was for AI 182, PA 103, UAL 811 and TWA 800, that's part of the matching pattern also.

If you understand, and I think we all do, the principles behind why a balloon pops and makes a noise, lightning, and a hand moving backward by force of air, then we understand what happened to AI 182 and others. We need to educate others about those principles also.

I'd like to have an acknowledgement of this email by a return email. Call it a radio check. I would also like some sort of resume from each of us to give the others our background and experience. Please tell us how you would like to be addressed: I prefer Barry. My general resume is:

John Barry Smith
551 Country Club Drive,
Carmel Valley, CA 93924
Home: 831 659 3552
Cell: 5946493
www.corazon.com
barry@corazon.com

Experience and Skills

Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C
*

Teaching. I have taught soldiers and sailors in the use of hearing protective devices, in the value of hearing conservation, and the anatomy and physiology of the ear.

Writing. I have created several web sites of several hundred pages each. In my military service I wrote many reports and proofread the reports of others in my supervisory position.

Awards, Citations,
*

Various Medals and Ribbons for Military Service in combat and peacetime.

Relevant Work History
*

US Navy. Various Naval Air Stations around the world. Enlisted aircrewman, officer bombardier navigator on Navy carrier jets. 1961-1969
US Army. Various bases around the world. Audiologist working in hospitals evaluating hearing disorders in active duty troops, dependents, and retirees until retirement as major after twenty four years of military service. 1974-1984

Education and Training
*

Monterey Peninsula College, AA, 1970-1971

California State University Fresno, BA and MA in Communicative Disorders, 1971-1974

References available upon request.

Crew, I shall end on this note from the AI 182 report:

3.4.6.16 In conclusion, Mr. Davis reported as follows :-
"It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182.
"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.
"Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. Such a situation would be most unusual, if not unique, in that we have never failed to detect sounds of structural failure, decompression, explosives etc., on any accident CVR, even though the event occurred at the rear of the aircraft. If such a device was used on AI 182 it is considered that it would have to be a very small device in order not to be detected (unlikely in itself). Such a device would be unlikely to cause the sudden total destruction which occurred in this instance. It is considered that a device of sufficient power to produce this effect could not fail to be detected on the CVR. The B-747 explosions referred to earlier, blew holes several feet wide in the structure but the crew were still able to control and operate the aircraft.
"It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

The cause has now been identified and established based on evidence not available at the time, UAL 811 of 1989 and the cause is wiring/cargo door/explosive decompression.

Sincerely,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

At 3:40 AM +0800 3/9/01, John Sampson wrote:
X-From_: sampson@iinet.net.au Thu Mar 8 11:40:04 2001
From: "John Sampson" <sampson@iinet.net.au>
To: "John Barry Smith" <barry@corazon.com>
Subject: Re: Can you help?
Date: Fri, 9 Mar 2001 03:40:05 +0800
X-Priority: 3

JBS
Flattered to be considered matey, but unfortunately I'm centre-piece in a
few IASA plots and plans right now and flat out like a lizard drinking. I'll
think about it and see if I can come up with someone who might be of some
use to you. I'll drop their names on you first.
Get back to you on that.
Nobody can call you a quitter.

regards
John Sampson

At 3:11 PM +0800 3/9/01, John Sampson wrote:
Alex
I received this email from John Barry Smith who runs www.corazon.com (not sure whether you are aware of it). It's generally known as the "747 cargo door" site. JBS is quite a zealot and he has been a thorn in the side of the FAA, NTSB and Boeing for quite some time over the fact that their 747 cargo doors never were fool-proof. And of course a non-plug door just has to be. They thought they were, but in the case of UAL 811 it was eventually proven that they were not - after the door was raised from many thousands of feet of Pacific Ocean. So in that case an electrical failure combined with a mechanical weakness in the mid-span latches allowed a door to open midflight and suck quite a few to their deaths.

JBS has put together a quite convincing case for an alternative theory on the four accidents mentioned below. It's one that I personally like better than bombs, missiles or EMI. Obviously also it's not a theory that the airlines or regulator would like to stick. They would be very vulnerable to all sorts of litigation. Proving it might be impossible, but JBS always seems to come up with a plausible rebuttal to all the official rebuffs that he's had. Anyway, JBS tells the story much more ably than I can because he's intimately involved with the detail. I am myself involved with a number of IASA projects that suck 15 hours a day seven days a week so I cannot help him out. But when I saw the specifications for a JBS pilot helper on his team, I naturally thought of you.

I'll let JBS explain it to you. You can always say no.

regards
John S

At 9:35 PM +1000 3/10/01, Alex Paterson wrote:
Dear Barry,

We have liased in the past regarding your theories pertaining to B747 cargo door failures. I admire your singleminded resolve to pursue this issue and I certainly think your theories have merit and are worthy of further research. That said, I am tied up with other matters at the moment and do not have the time to do justice to the task you have in mind.

It is worth noting that practically ALL substantive change of attitude within society and technological advance has come through the efforts of dissenters like yourself who question the prevailing orthodoxy of their time and highlight the flaws in that orthodoxy.

I thank you for pursuing this issue and feel sure you are having a positive effect, even if that effect is not apparent.

Stay in touch.

Fond regards,
Alex

At 4:30 AM -0500 3/10/01, John King wrote:
From: "John King" <jking1@mediaone.net>
To: "John Barry Smith" <barry@corazon.com>
Subject: Re: Can you help?
Date: Sat, 10 Mar 2001 04:30:43 -0500
X-Priority: 3
Status:
John I am concerned that these guys are accused of not only AI 182 but apparently another attempt destined to go out on flight 301. Their associations with these additional parties will hardly lend itself to a "sympathetic audience".

Proving something from 15 years ago is, in itself an tall obstacle, much less the elusive nature of a wiring fault which is so easlily obscured by post-crash damage or fire. I've had this very discussion with Ed Block when he said he stood in the hulk of TWA 800 and saw one burned wire bundle along-side a unburned one. "How do we know that this instant of burning occurred as the result of the breakup sequence (severing/shorting wires elsewhere) versus it being a iniating event" ? He didn't like it but it nevertheless is our problem.

I think you will agree it would be an 'easier task' if these guys had only the charge to AI 182.

You know that Ed and I have made a career out of trying to get knock down the many defenses of the FAA as they say wiring isn't a danger and it's no surprize that the real force behind this resistance and lies is the industry total support including that of the world class giant, Boeing Co. Inc. (they can't hardly say their product has a inherent flaw can they ?)

It's been a terrible fight all along and Ed's bid for voting status on the FAA's (actually run by the ATA) wiring study committees has just been knocked off the table by the FAA as they went out of their way to insert another man whose wiring related resume isn't 1/3rd of Ed's. moreover, Ed has the legal requisite (professional background) of a "wiring expert" but I do not.

I understand and deeply appreciate your zeal to demonstrate the truer role of electrical malfuctions in so many of these so called 'aviation mysteries' but I just wonder if hitching our horses too close these guy's wagons may take us on a wild and diversionary ride.

For the moment let me pass this attachment on to you as it offers the most comprehensive history to date that Ed and I have to offer of actual wiring events. Give it a read through and let me know how it may fit your needs.

Have you seen that 1996 Danish AAIB Final Report to that SAS MD-87 close call of 1993 ? I have it here in PDF. It's a beaut and shows the NTSB and the FAA particpating in a investigation where Kapton wire was blamed for setting Mylar insulation blankets afire back then. Contrast that to their claims that this stuff is all 'new' in just the past two years.

JK
--

At 11:40 AM +0100 3/10/01, Santokh Singh wrote:
--------from Parmjit-------------------------
#1

Santokh I am happy to assist how I can. I don't have any formal
PR
expertise, opinions mostly. Unfortunately, I am again very busy. I
don't
want to mislead you into thinking that I may be able to do much.
I have
exams now & temporary job upcoming, wife is pregnant with
2nd child and
often nauseous.

Where i live it is quite possible that my phone, email etc are
susceptible
to monitoring. Although there is nothing to hide, it may be a
consideration
as I am not convinced that this conviction is about justice rather
than
political strategy. I am sure resources are being wasted on
monitoring Sikh
email groups, however they become of interest for the political
aspect. If I
knew that I could make a big difference, it would not matter.

Another thing to think about because of the sensitive nature of
this is that
those more closely involved may (or may not) have a problem if
they find out
that someone they don't really know within Vancouver is "in the
loop". It is
a very sensitive issue here. One possibility is I can let Sundeep

Kaur know,
that way there is nothing hidden about my involvement as she is someone who
is much more involved with the inside.

Being where I am and how this investigation has gone. It would not surprise
me if the authorities decided that they wanted to pursue this and come to my
house with search warrants or harass me etc. There are many here that have
and continue to point fingers based on almost nothing, in the local
community for their personal gain. The local media will go out of their way
to shut someone down, discredit etc. if they are making any effects. There
have been suggestions some made up, some blown entirely out of proportion,
that witnesses were being harassed, evidence was being disclosed on the net,
despite a media ban, etc etc. So someone could suggest that I am unduly
influencing witnesses or making suggestions about the case or? knowing very
well that to become a member of the Bar in BC to practice I have to have a
crystal clear record. I asked a lawyer for advice on my resume the other
day. He looked at the line that said "Past Executive Sikh Student's
Association, UBC". UBC is a well respected university in Canada, as was that

Sikh organization. However the lawyer said I might not want to include this
because of the "image that it conjures up". Of course, I will ignore him but
I am telling you this, and all of the above to get a sense of the environment here and why I can't just say "of course".

Maybe Amardeep as a practicing lawyer, although in Singapore could advise. I
know Indo/Sikh lawyers/law students here who are privately aware of the
witch-hunt atmosphere and will not speak out anywhere and even begin to
rationalize the conduct publicly because they want to ultimately come out of
this without any personal discomfort and without being labelled. I am not
afraid of labels or discomfort, but I want to work wisely and not do more
harm by the nature of my location in the process of attempting to help.

I know I can trust your judgement. Tell me exactly what the parameters are
of the purpose (is there more than encouraging Barry?).

#2
you wrote
>Just input of common sense is needed from you for now, but maybe more in
>2-3 years.

Santokh, sorry was way behind in my email, reading fast and I

missed the
above line in yours.

In 2-3 years we can see where i'm at. For now, input of common sense sounds
harmless. just keep in mind my concerns. Also it is probably better that it
be kept low key about my involvement, since I am in Vancouver. Otherwise
there is a risk that some exaggerated story will be made about my role.

BTW superb job, it can get really difficult to see the forest from the trees
in this city and people outside taking an interest and lead is essential.

Discovery evidence requested.

Aircraft:
AI 182:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the RCMP and TSB.
2. Access to all hard evidence of the wreckage which was retrieved from ocean.
3. Interviews with TSB, AAIB, and NTSB investigators who contributed to the AI 182 report through deposition or voluntary meeting.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.

7. CVR and FDR printouts.

PA 103: The same officials who worked on the AI 182 report also worked on the PA 103 AAIB report.
1. Interviews with NTSB metallurgists and Boeing explosive expert and British law enforcement involved with the investigation.
2. Copies of all videotapes, photographs, interview notes, and sketches now held by the AAIB and Scotland Yard.
3. Access inside the hangar at Farnborough of the Pan Am 103 wreckage for at least 40 hours (five days at 8 hours a day) by at least five of your team.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

TWA 800: The same officials who worked on AI 182 and PA 103 worked on TWA 800.
1. Access to the hangar where the wreckage of TWA 800 is stored for at least 40 hours (five days at 8 hours a day) by at least five of your team.
2. Copies of all photographs, videotapes, interviews about TWA 800 now held by FBI and NTSB.
3. Interviews with NTSB metallurgists, explosive expert and American law enforcement involved with the investigation.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

UAL 811:
1. Copies of all videotapes, photographs, interview notes, and

sketches now held by the NTSB.
2. Access to any existing wreckage.
3. Interviews with NTSB metallurgists, explosive expert and American law enforcement involved with the investigation.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

Airport:
Narita:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the RCMP and TSB and Japanese airport and police authorities
2. Transcripts of the trial

Manufacturer:
Boeing:
1. Copies of all memos, data, and information about cargo doors and cargo holds on Boeing 747s.
2. Copies of all memos, data, and information about cargo doors and cargo holds on DC-10, MD-11, and MD-12.

Airlines:
Pan Am, TWA, Air India, United Airlines:
1. Copies of all videotapes, photographs, interview notes, and sketches regarding PA 103, AI 182, TWA 800, and UAL 811
2. Access to any existing wreckage held by them.
3. Interviews with airline staff involved with the accidents.
4. Maintenance logs for the accident aircraft long before and just before the fatal flights.

Miscellaneous:

1. Copies of all data about Canadian Pacific Air Flight 003, another Boeing 747 supposed to have a bomb on board and by inference, abetted by you, sir, or your fellow Sikh, Mr. Reyat.
2. Copies of all Data about Airworthiness Directives about cargo door on commercial airliners held by FAA and NTSB databanks.
3. Bruntingthorpe 747 evidence.
4. DC 10 CVR data, explosive decompression accidents, Windsor and Paris.

From: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Date: March 12, 2001 8:47:31 AM PST
To: "John Barry Smith" <barry@corazon.com>
Subject: **Re: Contact**

hey Barry!

My last e-mail was not meant to convey a sense of mistrust. I just don't want to send a resume. I'm 25 years old and other than graduating from law school have no experience of any relevance to this case.

I also prefer contact via e-mail but you can see that you can occasionally find miscommunication there as well.

Jaspreet

----- Original Message -----
From: John Barry Smith
To: Jaspreet S. Malik
Sent: Sunday, March 11, 2001 10:21 PM
Subject: Contact

Dear Jaspreet, call me Barry.

Call me at your convenience so you can check me out. I sense distrust.

What you see is what you get with me.

Sincerely,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Dear John,

My contact info. is:

Jaspreet S. Malik
6475 Marguerite St.
Vancouver, BC
V6M 3L5
jsmalik@wwdb.org
Cell: 604-861-8858

As for a resume you have my introduction e-mail which lists all I have to say for now.

Jaspreet

At 2:52 PM -0800 3/11/01, John Barry Smith wrote:
To: PSi <psi@interchange.ubc.ca>
From: John Barry Smith <barry@corazon.com>
Subject: Apology
Cc:
Bcc:
X-Attachments:
Dear Parmajit,

I'm sorry if I quoted you without permission. I fully appreciate the pressures you are under and respect your decision on how to proceed. I often worry about Boeing coming down on me because for four years I have had a web site that essentially says their airplanes are unsafe. It's best to be prudent sometime.

Sincerely,
Barry

From: "Jaswinder Parmar" <jaswinderp@hotmail.com>
Date: March 12, 2001 11:21:59 PM PST
To: barry@corazon.com
Subject: **Re: What are the risks?**

Barry,

Thank you for emailing me this information. It is a pleasure to make your aquantance. I am in the process of going through information provided by crown and am sure you will be of assistance.

The crown gave us 26 CD ROMs of information that they have gathered over the past 15 years. The CD's contain scanned images of documents they have collected. I am in the process of converting those images to text documents. Once this process is done the defence team will better be able to do searches using standard boolean expressions.

I am also in the process of creating a web site with forum that will alow us to communicate over the internet. I am looking into different ways to make sure the site is secure.

Jaswinder

>From: John Barry Smith

>To: jsmalik@wwdb.org, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my, npsingh@wans.net, jaswinderp@hotmail.com

>Subject: What are the risks?

>Date: Mon, 12 Mar 2001 11:03:43 -0800

>MIME-Version: 1.0

>Received: from [216.228.2.99] by hotmail.com (3.2) with ESMTP id MHotMailBC7668C90082400431D4D8E40263C3CF0; Mon Mar 12 11:04:48 2001

>Received: from mail.redshift.com (mail.redshift.com [216.228.2.86])by outgoing.redshift.com (8.11.2/8.11.2) with ESMTP id f2CJ4ea12562;Mon, 12 Mar 2001 11:04:40 -0800

>Received: from [216.228.4.97] (pm2-97.corp.redshift.com [216.228.4.97])by mail.redshift.com (8.11.2/8.11.1) with ESMTP id f2CJ43x08473;Mon, 12 Mar 2001 11:04:03 -0800

>From barry@corazon.com Mon Mar 12 11:06:09 2001

>X-Sender: barry@pop.redshift.com

>Message-Id:

>--============_-1227698652==_mr============

>

><< 811bigholecompresss.JPG >>

From: John Barry Smith <barry@corazon.com>
Date: July 13, 2001 3:27:12 PM PDT
To: box2026@msn.com
Subject: **Appraisal set for 930AM Wed for 541 CCDr.**

Dear Randa, the appraiser from Bank of America called and we set up an appointment for the appraisal for Wed 930AM at 54 Country Club Drive.

His name is Chris Daniels. Mike Webber was called and will meet us there. I think my wife and I will do walk through at that time and save Webber a trip out there.

Please inform Mr. Swartz of the appraisal date and that Mr. Webber has agreed to the time.

Please acknowledge this email so we know we have solid communication.

Looking forward to hearing about the CAR offer.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: AHSWARTZ@aol.com
Date: August 30, 2001 4:28:43 PM PDT
To: barry@corazon.com
Subject: **Re: Deal done, thanks**

Very intriguing Can you tell me more about it?????Andy Swartz

From: AHSWARTZ@aol.com
Date: August 31, 2001 4:02:43 PM PDT
To: barry@corazon.com
Subject: **Re: Shorted wiring/forward cargo door rupture/ explosive decompression/infligh...**

Dear Mr. Smith Thank you for the description of your case. It is well
beyond our capabilities to handle such a case. I suggest the great airplane

crash specialist located in LA called Magana Cathcart (Bill Wimsatt) good
luck. Andy Swartz

From: AHSWARTZ@aol.com
Date: September 1, 2001 2:26:13 PM PDT
To: barry@corazon.com
Subject: **Re: Shorted wiring/forward cargo door rupture/ explosive decompression/infligh...**

You are correct. I have no doubt you have the ability to prbably handle the
action by yourself. You certainly have the courage to do so. The problem is
the massive legal maneuvers to be expected by the other side. In any event
good luck and I sincerely thank you for considering me as your counsel. Andy
Swartz 9/1/01

From: CBCNEWS <nwonline@toronto.cbc.ca>
Date: September 18, 2001 12:33:05 PM PDT
To: kausingh@webtv.net, palmbeachsingh@webtv.net, barry@corazon.com
Subject: **CBCNEWS - Lawyer says Reyat needs separate trial**

This email has been sent to you by kaursingh@webtv.net
The following is a news item posted on CBC NEWS ONLINE
at http://cbc.ca/news

LAWYER SAYS REYAT NEEDS SEPARATE TRIAL
WebPosted Mon Sep 17 20:19:27 2001

VANCOUVER--The lawyer for the third man charged in the Air India bombing
says Inderjit Singh Reyat should not be standing trial with the other
two.

David Martin says his client should not be part of the indictment involving Rupudaman Singh Malik and Ajaib Singh Bagri.

However Martin refuses to give any reason why he thinks Reyat should be
tried separately.

The three are accused of the murder of 329 people on board an Air India
flight in 1985.

Martin says he may also ask for a delay in the trial, which is set to
begin in Vancouver in February.

He says he needs time to look at 15 years of evidence related to the
case.

From: "Keith Hamilton" <keithrh@telus.net>
Date: October 15, 2001 1:08:55 PM PDT
To: <barry@corazon.com>

Subject: Air India Flight 182

Dear Mr. Smith:

I do not appear to have a mailing address for you, so I am sending you this email message instead.

I am one of the lawyers working on the defence team for Ajaib Singh Bagri, one of the three men charged with the Air India Flight 182 crash. Jaswinder Parmar suggested that I write to you, as I am reviewing the forensic evidence.

I have a copy of your report dated April 9, 2001, and the appendices. As you would expect, I have many reports that have been generated during the RCMP investigation and the various inquiries since 1985. I am working my way through them chronologically, and will be reading your's very closely within the next few weeks.

I have briefly reviewed your report, and it does raise several issues that do not appear to have been addressed in any of the other reports, and which I want to examine more closely.

When I have had an opportunity to read your report and appendices carefully, I expect that I will want to be in touch with you again, to discuss some specific issues.

Thank you for the interest you have expressed in our case. I will be in touch with you again, as my review of the reports continues.

Sincerely,

Keith Hamilton

From: Sundeep Dhaliwal <khalsaq@yahoo.com>

Date: February 22, 2006 7:45:37 PM PST
To: John Barry Smith <barry@qp6.com>
Subject: **Re: Refer John Hill to me, please**

I do not have any of his information. We have no dealings with the Reyat Family. Please contact Mr. Hill directly by looking his number up on the web.

Thank you

--- John Barry Smith <barry@qp6.com> wrote:

Could you ask John Hill who represents Mr. Reyat, to contact me at
barry@qp6.com?

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, CA, 93924
831 659 3552
barry@qp6.com

Sundeep K. Dhaliwal
Yaletown Law Corporation
Barristers & Solicitors
Suite 403 - 1028 Hamilton Street
Vancouver, BC V6B 2R9
Ph: 604-684-8898 Fax: 604-684-8608
skdhaliwal@yaletownlaw.com

From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Date: June 23, 2006 10:59:54 PM PDT
To: John Barry Smith <barry@qp6.com>
Subject: **Re: Commission of Inquiry**

Hi Mr. Smith,

I am not sure how you can go about it....I am sure if you contacted the Minister of Justice Federal Government office in Ottawa ...they can direct you in the right direction.

Sorry I cannot help anymoer than that.

Take care and good luck! Thanks for your committment to this cause.

Sundeep

John Barry Smith <barry@qp6.com> wrote:

Sundeep K. Dhaliwal
Yaletown Law Corporation
Barristers & Solicitors
Suite 403 - 1028 Hamilton Street
Vancouver, BC V6B 2R9
Ph: 604-684-8898 Fax: 604-684-8608
skdhaliwal@yaletownlaw.com

Dear Sundeep,   Wednesday, June 21, 2006

Do you have any information on how I can contact Air-India inquiry administrator Sheila-Marie Cook? I want to apply for standing so I can appear before the Commission of Inquiry.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
barry@qp6.com

At 11:37 AM -0700 6/21/06,
She said she expects to hear from interested parties after June 21. The first three hearing dates are July 18, 19 and 20, which will be to hear from people who would like standing at the inquiry and who would like to have funded legal representation.
Judge Major said he will begin putting other witnesses on notice in July that they are going to be subpoenaed to testify after the inquiry formally begins hearing evidence in late September.

Air India inquiry begins this week

Kim Bolan, CanWest News Service
Published: Monday, June 19, 2006

VANCOUVER - The judicial inquiry into the Air-India bombing will have done its job if victims' families feel like they are real Canadians despite the fact that many immigrated to Canada from India, retired Supreme Court Justice John Major says.

Close to 80 relatives are expected in Ottawa on Wednesday when Judge Major officially opens the long-awaited inquiry into the June, 1985, terrorist bombings with a brief statement outlining the terms of reference.

Judge Major said in an interview this week he is looking forward to helping bring resolutions to outstanding questions related to the unprecedented terrorist attack that was plotted and hatched in British Columbia and left 331 people dead.

Judge Major has held meetings across the country with victims' families -- many of whom have lobbied for 20 years for a public inquiry into Canada's worst mass murder.

Their lobby only picked up steam when two B.C. Sikh separatists -- Ripudaman Singh Malik and Ajaib Singh Bagri -- were acquitted in March, 2005, of all charges related to the bombings after a 19-month trial.

"If this commission can give them a sense that they are really Canadians despite the colour of their skin and that mistakes were made but they won't be made a second time, most of them -- from what they have said -- would feel that something's been accomplished," Judge Major said. "Accomplishing the second is easier than the first."

Judge Major said the simple act of then-prime minister Brian Mulroney sending a letter of condolence to Indian prime minister Rajiv Gandhi after the bombings pained family members, who were almost entirely Canadians or living in Canada. "They are owed some form of explanation for a letter of condolence going to India," he said.

But the bigger issue for Judge Major, who retired last year as chief justice of the Supreme Court of Canada, is reassuring Canadians such an act of terror could not be carried out again.

"The big interest is, 'could this happen again?' and I think that brings some public interest to the inquiry beyond what the tragedy is. Where are we with security?" he said. "I don't know how forthcoming the CSIS and the RCMP will be because they generally feel they are prejudicing the safety if they disclose too much, but we will see."

Part of his mandate -- as outlined when the inquiry was formally announced by Prime Minister Stephen Harper on May 1 -- is to look at whether a lack of information-sharing between agencies hampered the investigation into Sikh extremists prior to the bombing and during the subsequent bombing probe.

Judge Major said both the RCMP and CSIS "have expressed the willingness to co-operate fully."

"We will want to hear from the Department of Transport and they are doing their report. So, so far, there seems to be a willingness to see this thing through and hopefully reach some sensible conclusions," Judge Major said. "The mandate says that we are not to find fault and we don't make any awards."

Corporal Tom Seaman said the RCMP does not yet know who will be called as a witness. But he said the force is on board with the inquiry, even though the criminal investigation into the bombings continues.

Air India inquiry begins this week

Kim Bolan, CanWest News Service
Published: Monday, June 19, 2006

Judge Major said he has not heard from either of the two men acquitted about wanting to appear before the inquiry. Mr. Malik recently told journalists he was prepared to participate if asked to do so.
But then, nobody has yet made their intentions known, Air-India inquiry administrator Sheila-Marie Cook said on Friday.
She said she expects to hear from interested parties after June 21.
The first three hearing dates are July 18, 19 and 20, which will be to hear from people who would like standing at the inquiry and who would like to have funded legal representation.
Judge Major said he will begin putting other witnesses on notice in July that they are going to be subpoenaed to testify after the inquiry formally begins hearing evidence in late September.

"If the witnesses volunteer, they don't have to be subpoenaed," he said.

Mr. Major said most of the staff is already in place.

The lead counsel is Mark Freiman, a partner with McCarthy Tetrault in Toronto and a former deputy attorney-general of Ontario.

Lata Pada, a Mississauga, Ont. dancer, who lost her husband and two teenage daughters in the 1985 terrorist attack, will be in

Ottawa as the inquiry is officially launched. It is the same day the only man convicted in the bombing -- Inderjit Singh Reyat -- is to make another court appearance after being charged with perjury for his testimony at the Air-India trial.

Ms. Pada said she thinks the inquiry is particularly timely given the recent arrests in Ontario of suspected Islamic terrorists.

"I think the Air-India inquiry can certainly be a watershed moment in assessing Canada's preparedness for terrorist attacks," she said. "Air-India was really the precursor to everything we are seeing today with terrorism."

Ideally, whatever comes out at the inquiry should "serve to inform policy changes," Ms. Pada said. "We'll be watching it with keen interest."

Ms. Pada wants to make sure victims' families get independent counsel financed by the inquiry to represent their interests.

"There is a commitment and we hope that they keep that commitment," she said.

Dave Hayer, Surrey's Liberal Member of the Legislative Assembly, will also be in Ottawa, representing his late father Tara, who had agreed to be a witness in the Air-India case when he was assassinated in November, 1998.

Dave Hayer has been an advocate for victims' rights ever since, and has strong opinions about what more could be done to deal with terrorism cases and protect witnesses who risk a lot to testify.

"There should be some justice done for all the people killed in the Air-India bombing. Most of them -- 280 -- were Canadians. There were 20 Americans on the plane. We want to make sure that something like this never happens again," Mr. Hayer said. "And we want to make sure our judicial system has the tools to deal with cases like this."

From: Brent Olthuis <bolthuis@arvayfinlay.com>
Date: October 5, 2006 8:18:10 AM PDT
To: John Barry Smith <barry@johnbarrysmith.com>
Cc: "Murray L. Smith" <msmith@smithbarristers.com>
Subject: **RE: Air India Flight 182 mechanical probable cause.**

Mr. Smith:

Thank you for your correspondence, which we have brought to the attention of our client.

We write to let you know that we are unable to do anything at this stage with the information you provide. First, the mandate of the Commission in our opinion does not extend into a questioning of the prevailing theory that a bomb brought down the plane. Indeed, this is probably the reason that your standing application turned out as it did.

Further, as you may be aware, Commissioner Major gave our client only a limited standing before the Commission: Mr. Malik has the status of an intervener, and even then has only the ability to respond (in writing) to evidence that directly and adversely affects his reputation. As your information does not directly touch on Mr. Malik's reputation and does not do so adversely, we are not in a position to use or refer to it.

That said, we thank you again for your assistance.

Regards,

Brent Olthuis
Smith Barristers
Marine Building
Suite 1300
355 Burrard Street
Vancouver, BC
V6C 2G8
Tel: 604-689-4438
Fax: 604-689-4451

From: John Barry Smith [mailto:barry@johnbarrysmith.com]
Sent: 4-Oct-06 2:39 PM
To: Murray L. Smith; bolthuis@smithbarristers.com.
Subject: Air India Flight 182 mechanical probable cause.

Messrs. Murray L. Smith and Brent B. Olthuis
Smith Barristers,
Suite 1300 - 355 Burrard Street,
Vancouver, BC, V6C 2G8

Dear Mr. Smith and Mr. Olthuis, Wednesday, October 4, 2006

My name is John Barry Smith and I have evidence which will completely exonerate your client from suspicion and restore his reputation as well as that of his religion.

There was no bomb on Air India Flight 182, and therefore no bombers, no conspiracy, no crime, and no criminals. The cause was a mechanical systems failure, faulty wiring shorted on the forward cargo door unlatch motor which caused an explosive decompression leading to the inflight breakup.

Further details to substantiate the wiring/cargo door explanation are at http://www.ntsb.org and http://www.montereypeninsulaairport.com. The SmithAAR for Air India Flight 182 is available for download also which gives exhaustive details.

Mr. Malik previously was interested in the mechanical explanation in the early part of 2001 and I traveled to Vancouver to speak to his attorneys, Mr. Crossin and Mr. Donaldson, at Mr. Malik's request. I failed to impress. Let's hope I do better this time.

I recently went to Ottawa to try to achieve standing in front of the Commissioner of the Commission of Inquiry into the Bombing of Air India Flight 182. I was promised fifteen minutes of oral submission but was cut off after four. It appears I again failed to impress.

Well, never give up, especially since the evidence in the form of cockpit voice recorders, flight data recorders, twisted metal, and damaged engines supports a mechanical explanation over the conspiracy nonsense so emotionally tinged that up is down and inside out. In aviation matters I always defer to reality.

For the record: The only official Canadian aircraft accident investigator's opinion about the probable cause of Air India Flight 182 did not conclude it was a bomb, only an explosion. There are many potential causes for an explosion in the pressurized hull of an early model Boeing 747, the rarest of which is a bomb.

Aviation Occurrence Report of the Canadian Aviation Safety Board for Air India Flight 182 of January 22, 1986 "4.0 CONCLUSIONS The Canadian Aviation Safety Board respectfully submits as follows: 4.1 Cause-Related Findings 5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment."

The TSB (Air) has never given an official opinion.

In fact, the UK AAIB investigator ruled out a bomb in the original report: "Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K. 3.4.6.16 In conclusion, Mr. Davis reported as follows :- "It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182. There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified. It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

The cause Mr. Davis alluded to only became apparent four years later with United Airlines Flight 811, the model for the inflight breakups for early model Boeing 747s.

I have asked TSB and the Commissioner to request TSB (Air) to provide an updated supplement to the twenty year old Aviation Occurrence Report to the Commission for their consideration. That reasonable request would certainly be within your rights to ask for.

The Commissioner granted me leave to provide material to the Commission and I have done so. A pdf file of my fourteen additional submissions is attached to this email. Those submissions lay out the framework that debunks the bomb theory and substantiates the mechanical explanation.

There is an error of fact on the Commission Website which harms your client. It is the highly prejudicial error that states the CASB concluded it was a bomb; they did not. ("Yet, it was not until the following January that the Canadian Aviation Safety Board concluded that the destruction of this aircraft was caused by a bomb.") I have repeatedly asked the Commissioner to correct the error but he has not.

In the past few months of dealing with the Canadian government about Air India Flight 182 I realize what you are up against. You have Crown prosecutors who cheat, a Commissioner who lies, a police force who is confused and creative with facts, a media who loves intrigue and danger, and family members and a public lusting for revenge. Into that stew of emotion all I ask is that you check out a lead that is down to earth, offers confirmable evidence, follows rigid rules of logic, and offers reasonable explanations for tragic events.

You might tell Mr. Malik I followed his trial and offer him congratulations on his release. I have known he was innocent since he was arrested years ago. As was Mr. Bagri.

I've also been in written communication with Mr. Donaldson but may have offended him with my unkind comments about Mr. Crossin.

Regardless, if Mr. Malik wants his reputation restored, he will have to do better than a not guilty verdict by the honest Justice Josephson. The way to do that is to resort to science, not myth.

The shorted wiring/unlatch motor on/ruptured open forward cargo door/explosive decompression/inflight breakup explanation is science.

I am available for follow up questions or to clarify aspects of the explanation.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
1 831 241 0631 Cell
barry@johnbarrysmith.com
safety@ntsb.org
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5

From: "SALDEF INFO <Rajbir Datta>" <info@saldef.org>
Date: April 11, 2007 8:44:41 PM PDT
To: <barry@johnbarrysmith.com>
Cc: <infO@saldef.org>
Subject: **RE: Contact form submission**
Reply-To: <info@saldef.org>

Dear John Smith -

Thank you for forwarding the website addresses.

Best

Rajbir Singh Datta
Associate Director
=====================================

SALDEF: 10 years of Protecting, Engaging and Empowering the Sikh Community (1996 - 2006)
=====================================
Sikh American Legal Defense and Education Fund (SALDEF)

1413 K Street, N.W. 5th Floor
Washington, DC 20005
Phone: 202-393-2700, Ext. 27; Fax: 202-318-4433
E-mail: info@saldef.org; Web: www.saldef.org

About SALDEF: Founded in 1996, SALDEF is a Washington, DC-based national non-profit civil rights and educational organization. SALDEF protects and promotes the civil rights of Sikh Americans through legal aid, advocacy and educational outreach. SALDEF's mission is to create a fostering environment in the United States for future generations of Sikh Americans.

Sikhism is a distinct religious faith that is over five hundred years old. There are approximately half a million Sikhs living in the United States.

-----Original Message-----
From: contact@saldef.org [mailto:contact@saldef.org]
Sent: Wednesday, April 11, 2007 10:25 PM
To: info@saldef.org
Subject: Contact form submission

A user has completed Contact Us form.

Topic: General
Name: John Smith
Email: barry@johnbarrysmith.com
Phone: 831 659 3552
Comments: Air India Flight 182 was not blown up by Sikhs.

Details at http://www.montereypeninsulaairport.com http://www.ntsb.org Regards, John Barry Smith 541 Country Club Drive Carmel Valley, California 93924 1 831 659 3552 1 831 241 0631 Cell barry@johnbarrysmith.com http://www.montereypeninsulaairport.com http://www.ntsb.org

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:45 PM PDT
To: Aniljit Singh <aniljitsingh@hotmail.com>
Subject: **Re: 747 retired Sikh pilot**

Also I learned yesterday that the crown may refuse the funding for Keith
Hamilton, the joint defence lawyer and that we may have to go at it by
ourselves.

Aniljit Singh

Dear Aniljit,

Oh, very disappointing if confirmed. His presence would cut a lot of red tape in gaining access to the evidence in the hangars.

It's not fair that the Crown literally spends years and millions of dollars to prosecute a flimsy case against someone who will be bankrupted even if cleared.

However, there is a strong case for a successful suit against the Crown for not following up my contacts with them years ago. The RCMP and TSB both are aware of the wiring/cargo door explanation and if they had done their duty for public safety, they would not have arrested the accused; therefore there is a false arrest suit, and a wrongful harassment grievance in there somewhere. Malicious prosecution? I think so.

The quickest way to confirm the wiring/cargo door as cause for AI 182 and get charges dismissed is to positively match UAL 811 to AI 182. This can be done by examining the videotapes. Then to match AI 182 to PA 103 and that can be done by examining the wreckage in the hangar in Farnborough. Then to match AI 182 to TWA 800 which can be done by examining the evidence of the wreckage. Then all three can be matched to the model, UAL 811.

Rather than refute the lies and misleading statements by conspiracy minded witnesses, let the Crown try to refute the wiring/cargo door explanation for AI 182. It can't be done. I've tried for six years. The wiring/cargo door explanation always is confirmed from whatever angle I approach it.

It's impossible to rebut fantasy thinking of conspiracy people, it's all hearsay. Let the Crown refute the science of reality with wreckage, tapes, sounds, metal, and latches; they will not be able to. Your case is won.

You should be able to obtain some financial and legal assistance on such a major case. The Libyans had funding from the country. Canada should provide something.

If Mr. Hamilton is not to be a member, who will I meet in Vancouver?

The time is now and the people to be persuaded are the lead attorneys for both accused, Mr. Peck and Mr. Smart I believe, and the accused themselves need to read the four accident reports. It will them hope.

The sooner I meet with the lead attorneys the better.

Cheers,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:45 PM PDT
To: Aniljit Singh <aniljitsingh@hotmail.com>
Subject: **Matching evidence**

I am the contact person till such time that we find a more qualified
resource. I meet with Mr. Malik and Mr. Smart on almost a daily basis and I
will be discussing you with Mr. Smart or his partner Mr. Williams this
morning.

I admire your confidence and hope I can supplement it with the information
that you have requested.
Aniljit Singh

Dear Aniljit,

Fine, I shall answer all your questions and hopefully resolve all your doubts. It is a big mental shift from 15 years of 'bomb' to no bomb, I know. I've had twelve years of trying to persuade others of a mechanical problem and not the conspiracy nonsense.

I have faith in the facts, data, evidence, once it is allowed to be properly examined and evaluated by authorities to confirm.

The TSB should be brought in sooner or later because the safety issue exists as I type. The mechanical problem still exists in all these early model 747s with Poly X wiring.

If you or any of the staff want to come down here to Carmel Valley, I will be glad to show you my research and conclusions here.

Printing out all my emails would be good too as the pictures are very dramatic and persuasive. Below is not a bomb but wiring/cargo door caused event. It happened to AI 182 but the hole was bigger and the nose came off. The evidence matches both events.

Cheers,
Barry

Below is recent email to Santokh:

What explosive was used?
Residue?
Any on AI 182 wreckage?
If not, then why connect the two?

AirDisaster_Com Special Report Air India Flight 182.htm

As bags were being unloaded from a container, one piece of luggage exploded causing a blast which shook the whole airport. a hole was blown in the concrete floor, and the unloading area was extensively damaged. Two Japanese airport staff were killed and another four seriously injured. CP Air`s 747, Flight 003 from Vancouver, had arrived with a total of 390 people onboard, and had the aircraft been just half an hour late, there would have been a terrible disaster. Therewas no doubt that the force of the blast was sufficient to cause the destruction to something even as large as a 747.

First of all, Santokh, where did the author get all this information. I've checked the net for Narita and get nothing.
Second, a blast that big would bring down a 747 probably which means that the small 20 inch hole in Pan Am 103 was not caused by a 'bomb.
Third, of course you have been in a busy airport and know that baggage goes all which ways on many carts from many planes and often goes from and to the wrong destination so often people makes jokes about airlines losing baggage and having it sent 10000 miles the other way.
Fourth, the conclusion of bomb on CP003 means an entire 'bomb' investigation needs to be done as they would do on any 'bombing' for an airliner, and that means interviews, residue lab tests, passenger lists, forensic autopsies on the victims, etc.

The whole Narita 'bomb' thing stinks especially since Narita was a very controversial airport back then with farmers, whose land they took having protests weekly. They put up tall towers at the end of the runway to cause crashes. There was a motive for protest bombing by locals and a motive for the authorities to blame someone else, never themselves.

I'm getting requests from the Malik defence team for my reports so I assume they will actually read the raw data and see how flimsy bomb theory is and how strong wiring/cargo explanation is. All it takes is an objective unbiased view and some knowledge of physics and aerodynamics.

Why connect the two, you ask. The same reason all five Boeing 747s had 'bombs' on them, to absolve those responsible for the mechanical problems or security lapses. CP 003, AI 182, TWA 800, PA 013, UAL 811, all early 747s that authorities stated had bombs on board. And all never had the bomb go off on the first flight after it was 'planted'. No, the authorities have to go back a few flights and a few airports to find an enemy to blame.

Five! Conspiracy is everywhere. Ha!

Of course, all 5 747s were early models, did have outward opening non plug cargo doors, and now known to be faulty Poly X wiring in a water zone of the cargo door bilge, and the deadly precedent of UAL 811.

Bombs don't match, wiring/cargo door does.

I think your email to Aniljit was very good and they respect your opinion. It read very persuasive to me. Good work. Thank you. Let's keep it up. I am urging them to meet with me sooner rather than later. I can drive up there on short notice.

Cheers,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:45 PM PDT
To: Aniljit Singh <aniljitsingh@hotmail.com>
Subject: **Pattern is four**

Thank you for the e-mail. I am being flooded with information and am trying very hard to keep up. I have printed all the information you sent me and have copied one set for Narinderpal Singh who spoke to you earlier. He will be contacting you after he returns this weekend.

Dear Aniljit, flooded? Yes, it's because you are on to something. It has just begun.

I await Narinderpal's visit. I look forward to the discussion because he is an engineer and my wiring/cargo door explanation relies on science and not conspiracy fantasies.

I have literally thousands of pages of analysis over the past 12 years. I know printing is time consuming, but storing on a hard disk is cheap and easy and available for reference. www.corazon.com has about 20 percent of it.

I know you are concentrating on only AI 182 but the pattern is shown for four. The authorities made the error of only looking at their one accident and ignored the patten. All four are integral.

There is much data to assimilate and that is why I should be up there meeting with the staff to assist in separating the wheat from the chaff.

My urgency is that the wiring/cargo door hazard exists as we speak and the sooner the cause is confirmed the sooner the fix is started.

Your urgency might be that two innocent men are imprisoned and will be for possibly years and maybe the rest of their life. There is also a window of opportunity with PA 103 as the Defence prepares its appeal after partly failing with it's strategy of 'It was a bomb, but our guys did not plant it, although yes, the country has planted bombs in planes in the past...but not this time!"

Bail is mandated for the two accused for AI 182 just on my analysis alone.

And thanks for working on Saturday, Aniljit,. You care.

Cheers,
Barry

http://www.corazon.com/AI182essentials.html

Air India Flight 182 23 June 1985, 120 miles south of the Irish Coast, from Toronto, Canada to London. 31000 feet, 1/4 second muffled sound then 40 millisecond sharp bang, data recorder abrupt halt, bodies missing sat in front of plane, vanished from radar screens, forward cargo hold suspect area, pathologist states victims died from decompression, no evidence of bomb or explosive device. Official explanation: bomb. Pattern fits inadvertent opening of forward lower lobe cargo door in Fl 103, 811, and

800. Unknown and unreported: status of latches on cargo door, if EPR blip on data recorder on engine 3 just before event, if radar blip seen just before event, if engine three had baggage debris ingested, destruction pattern starting at forward cargo door. Miscellaneous information: India was in the middle of political crisis with assassinations and bombing. India did not share recorder information with other investigators.

Comments: So many similarities to 103, 811, 800 make it probable that cargo door popped open More info needed and difficult to get.

Boeing 747 Air India Flight 182 Essentials Canadian report

Fast and loose with cargo door. Took off late and at night. page 5

FDR hit and jolted or plane went left wing down. Abrupt power cut. page 22

Sound on CVR not like bomb. page 23

Sound matches explosive decompression of DC-10 caused by opening cargo door. page 23

No bomb; explosive decompression yes. page 24

Inflight damage severe on right side of aircraft. page 26

Right wing fillet inflight damage. page 29 and 30

Engine number 3 fodded, coming apart and fods engine 4. page 29

Wreckage plot, three areas. 1. Nose and wings, 2. Tail. 3. Engines. Three engines together and one alone near number 3 nacelle strut. page 32

Forward cargo door broken, damaged by outward force, important to retrieve but lost. page 34

Piece of forward cargo door has evidence of explosive force but no explosion residue or pitting from bomb. page 41

Could be explosive decompression as initial event. page 47

No fire or explosion in cabin or flight deck areas or on passengers. page 48

Right side of plane has inflight damage. Fod in engines 3 and 4. Failure of door would explain many observations. page 49 and 50

Explosion in forward cargo compartment explains observations. Explosive decompression which occurs when cargo door opens produces explosive effects.

Comment: Report received skewed from Canada and scanned as received. Observations by investigators are consistent with inadvertent opening of forward cargo door inflight.

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http://www.corazon.com/AI182essentials.html

Has excerpts of official documents for source and analysis.

Flight Summaries of Four Flights:
TWA Flight 800, UAL Flight 811, Pan Am Flight 103, Air India Flight 182

(From news sources:)
TWA Flight 800 was a scheduled passenger flight from New York to Paris.The flight was uneventful until after departure from New York. While climbing through 13,500 feet an event occurred which tore the nose off the aircraft. The nose fell into the sea. The rest of the aircraft continued on descending until approximately 9,500 feet where it exploded into a fireball and dropped into the sea. There were two wreckage trails. Luggage from front cargo hold was found nearest event site. A streak was seen near the aircraft just before destruction. A strange radar blip was seen before destruction falling with the aircraft. There were no calls from the crew to the ground. There were no survivors. Flight data recorders revealed a loud sound and then all recording ceased. No evidence of a bomb has been found on recovered wreckage. Front cargo door found in pieces. Engine number 3 retrieved and had evidence of FOD. The aircraft was a Boeing 747-131, an early 747 with high flight time and flight cycles.

Explanations for TWA Flight 800: Boeing 747-131 series high flight time aircraft are prone to cargo door malfunctions. Doors pop open in climb or just after. Door popping open exposes large hole in side of nose. Large hole in side of nose can tear nose off when subjected to high air pressure loads. Nose tearing off leaves rest of plane to crash resulting in two wreckage trails. Nose tearing off is sudden and total and leaves no time for calls to ground from crew or for recorder data to continue. Door opening and tearing off would be visible as streak as it reflects evening sun at 13500 feet near New York City on July 17th. Cargo door would be picked up as radar return as it spun away from aircraft. Contents from front baggage compartment would be first to leave plane after door and be found closest to event site. Fifteen missing bodies would have been sucked into engine number 3. Baggage would FOD number three engine. Door opened inadvertently because of various reasons consistent with other confirmed, documented, and witnessed cargo door openings such as design error, improper latching, electrical problems, wear and tear, or other unknown reason.

(From UAL Flight 811 Accident Report NTSB)
UAL Flight 811 was a scheduled passenger flight from Los Angeles to Sydney, Australia, with stops in Honolulu, Hi and Auckland, New Zealand. The flight was uneventful until after departure from Honolulu. While climbing from FL220 to FL230 the crew heard a "Thump" followed by an explosion. An explosive decompression was experienced and the #3 and #4 engines were shutdown because of FOD. The FLT returned to Honolulu and passengers were evacuated. Inspection revealed the forward lower lobe cargo door departed inflight causing extensive damage to the fuselage and cabin adjacent to the door. Investigation centered around design and certification of the door

which allowed it to be improperly latched, and the operation and maintenance to assure airworthiness of the door and latching mechanism.
Additional information extracted from report: Front cargo door found in two pieces. Crew erroneously reported bomb onboard to tower after hearing explosion. Radar tracked door down to ocean contact. Recorders played loud bang/sound then silence. Nine passengers were ejected and lost at sea. The aircraft was a Boeing 747-122, an early 747 with high flight time and flight cycles.

Explanations for UAL Flight 811: Boeing 747-122 series high flight time aircraft are prone to cargo door malfunctions. Doors pop open in climb or just after. Door popping open exposes large hole in side of nose. Large hole in side of nose can tear nose off depending of variables such as angle of attack, airspeed, turbulence and strength of fuselage. Cargo door would be picked up as radar return as it spun away from aircraft. Door opened inadvertently because of various reasons consistent with other confirmed, documented, and witnessed cargo door openings such as design error, improper latching, electrical problems, wear and tear, or other unknown reason.

(From Pan Am Flight 103 Accident Report Dept or Transport)
Pan Am Flight 103 was a scheduled passenger flight from London to New York. The flight was uneventful until seven minutes after leveling off after climb. While level at FL310 an event occurred which tore the nose off the aircraft. The nose fell to the ground. The rest of the aircraft continued on descending and crashing into the town of Lockerbie. There were two wreckage trails. Luggage from front cargo hold was found nearest event site and in engine number three. A strange radar

blip was seen before destruction. There were no calls from the crew to the ground. There were no survivors. Flight data recorders revealed a loud sound and then all recording ceased. Additional information extracted from report: Front cargo door found in two pieces. Blip on recorder for engine 3 EPR. Reconstruction shows cargo door area in first sequence of destruction. Eight passengers missing and not accounted for. The aircraft was a Boeing 747-121, an early 747 with high flight time and flight cycles.

Explanations for Pan Am Flight 103: Boeing 747-121 series high flight time aircraft are prone to cargo door malfunctions. Doors pop open in climb or just after. Door popping open exposes large hole in side of nose. Large hole in side of nose can tear nose off when subjected to high air pressure loads. Nose tearing off leaves rest of plane to crash resulting in two wreckage trails. Nose tearing off is sudden and total and leaves no time for calls to ground from crew or for recorder data to continue. Cargo door would be picked up as radar return as it spun away from aircraft. Contents from front baggage compartment would be first to leave plane after door and be found closest to event site. Engine 3 closest to door and affect EPR when Fodded. Door opened inadvertently because of various reasons consistent with other confirmed, documented, and witnessed cargo door openings such as design error, improper latching, electrical problems, wear and tear, or other unknown reason.

(From Canada and Indian accident report)
Air India Flight 182 23 June 1985, 120 miles south of the Irish Coast, from Toronto, Canada to London. 31000 feet, 1/4 second muffled sound then 40 millisecond sharp bang, data recorder abrupt halt, bodies missing sat in front of plane, vanished from radar screens, forward cargo hold suspect area, pathologist states

victims died from decompression, no evidence of bomb or explosive device. Official explanation: bomb.

Explanation for Air India Flight 182: Boeing 747 high time aircraft kept below 300 knots until nearing end of flight when airspeed crept up to 296 and door popped, nose separated, aircraft fell into sea. Cargo door found with fuselage skin attached but dropped on retrieval. No evidence of bomb residue, sound matched decompression of DC 10, and other evidence indicated explosive decompression in flight.

Summary of the Summaries: Four early Boeing 747-100 -200 series high flight time, high cycles aircraft with history of front cargo door malfunctions, in pressure differential mode of flight experience an event which tears a large hole in each right side of each nose at forward cargo door area. Four aircraft later exhibit destruction pattern starting at forward lower lobe cargo door. Four aircraft had flight data recorders record a thump/bang/loud sound, then silence. Three aircraft had radar blips recorded leaving aircraft before event. Three aircraft deposit front cargo doors in two or more pieces. Three aircraft have under thirty passengers not accounted for. Three noses are torn off which leaves two aircraft to crash leaving two wreckage trails each. Two nearest trails have contents of front baggage compartment indicating contents left first. Same three aircraft had no calls from crew to ground. Same three aircraft had no survivors. Two aircraft have three engines in one group and another engine apart. One aircraft erroneously reports a bomb explosion on board but lands safely allowing investigation to reveal cause of inflight explosion to be inadvertent opening of forward lower lobe cargo door due to design error, improper maintenance, and a faulty switch or wiring in the door control system.

For the 800 missile theorists: Streak was metal cargo reflecting summer evening sun as it spun away from Flight 800 at 13500 feet. Dark on ground, sunlight up high. Missile would have struck hot engine but no evidence of damage to engines.

For the bomber theorists:TWA Flight 800 had no blast, no bomb, but explosions yes. No blast or bomb in baggage compartment. Explosion when decompression occurred after cargo door opened and wind tore off nose at 13500 feet.Explosion when 40000 gallons of jet fuel from disintegrating wings ignited at 7500 feet.

UAL Flight 811 had no blast, no bomb, but explosion yes. Explosion when decompression occurred after cargo door opened and wind tore off side of nose at 22000 feet. Crew erroneously thought and reported bomb to explain explosion. Correct evaluation of opened cargo door made after safe landing.

Pan Am Flight 103 had blast, no bomb and two explosions. Eight by 50 inch blast hole possibly from "rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range." Page 19-20 Pan Am 103 accident report. Explosion when decompression occurred after cargo door opened and wind tore off nose at 31000 feet. Another explosion when remaining disintegrating structure strikes ground.

Air India Flight 182 had explosion decompression but no bomb.

For the center tank fire theorists: There was a center tank fire explosion in TWA 800 but after door opened and caused nose to separate allowing rest of aircraft to fall and disintegrate into fuel vapor and spinning jet engine number 3 as ignition source. No fireballs for UAL 811, Pan Am 103, (only falling engine number 3 was on fire) or Air India Flight 182 .

Unlikely that different bombers with different bombs attack random US airlines years apart and manage to place small device at same location in same baggage compartment of same type aircraft to provide similar destruction pattern when detonated at approximately the same time leaving similar evidence.

Likely that a similar defect in a similar type aircraft malfunctions under similar circumstances resulting in similar destruction patterns leaving similar evidence.

Comment: All statements above supported by documentation http://www.corazon.com/

Contents
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: aniljit singh uppal <aniljitsingh@hotmail.com>
Subject: **AI 182 report**

Canadian Aviation Bureau canadien Safety Board de la sécurité aérienne AVIATION OCCURRENCE AIR INDIA BOEING

747-237B VT-EFO CORK, IRELAND 110 MILES WEST 23 JUNE 1985 1.0 INTRODUCTION

Air India Flight 182, a Boeing 747-237B, registration VT-EFO, was on a flight from Mirabel to London when it disappeared from the radar scope at a position of latitude 51°O'N and longitude 12°50'W at 0714 Greenwich Mean Time (GMT), 23 June 1985, and crashed into the ocean about 110 miles west of Cork, Ireland. There were no survivors among the 329 passengers and crew members. The depth of the water at the crash site is about 6,700 feet.

At 0541 GMT, 23 June 1985, CP Air Flight 003 arrived at Narita Airport, Tokyo, Japan, from Vancouver. At 0619 GMT a bag from this flight exploded on a baggage cart in the transit area of the airport within an hour of the Air India occurence. Two persons were killed and four were injured. From the day of the occurrences, there have been questions about a possible linkage between the events.

This Submission examines the information available to the Canadian Aviation Safety Board (CASB) with respect to the circumstances surrounding the AI 182 accident. The sources of information include: information made public to the Indian Inquiry as a result of the RCMP investigation; the flight data recorder (FDR), cockpit voice recorder (CVR) and Shannon ATC tape recording analyses by Canadian, United Kingdom, and Indian authorities; the medical evidence obtained from Dr. Hill of the Accident Investigations Branch of the United Kingdom; and the evidence obtained by examination of the wreckage recovered, the wreckage distribution pattern, photographs, and videotapes of the wreckage on the ocean bottom.

2.0 EXAMINATION

2.1 Vancouver

On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight East Indian accent.* He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vancouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

On the same date at approximately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

On 20 June 1985 at about 1210 PDT (1910 GMT), a male appearing to be of East Indian origin purchased the tickets with cash from a CP Air ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to M. Singh. The telephone contact number was also changed. The final itinerary was as follows:

a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22 June 1985

*See Appendix A for chronology of events.

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22 June 1985

b) L. Singh - CP 003 Vancouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 (local time in Tokyo), 23 June 1985

On 22 June 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy East Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that he was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

On Saturday morning, 22 June 1985, a CP Air passenger agent worked check-in position number 26 at the CP Air ticket counter, Vancouver International Airport, and recalls dealing with a passenger booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto he could not interline his baggage. The passenger insisted and, as the line-ups were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that M. Singh checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage. The flight manifest for CP 003 shows that on the same day the person using the name of L. Singh with a ticket to Bangkok also checked in through the same counter, was assigned seat 38H, and checked one piece of baggage.

A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as M. and L. Singh did not board these respective flights.

2.2 Toronto

Air India Flight 181 from Frankfurt arrived at Toronto on 22 June 1985 at 1430 EDT (1830 GMT) and was parked at gate 107 of Terminal 2. All passengers and baggage were removed from the aircraft and processed through Canada Customs. Passengers continuing on the flight to Montreal were given transit cards, and on this flight 68 cards were handed out. These transit passengers are required to claim their luggage and proceed through Canada Customs. Prior to entering the public area, there is a belt which is designated for interline or transit baggage. Transit passengers deposit their luggage on this belt which carries it to be reloaded on the aircraft. This baggage was not subjected to X-ray inspection as it was presumed to have been screened at the passengers' overseas departure point. When the transit passengers checked in to proceed to Montreal, their carry-on baggage was subjected to the normal security checks in place on this date. Passenger and baggage security checks were conducted by Burns International Security Services Ltd. and all passenger and baggage processing for both off-loading and on-loading was handled by Air Canada staff.

Air India Flight 181 was composed of the following:

- passengers continuing to Montreal (68)
- passengers from connecting flights

AC	102	(Saskatoon)	2	
AC	106	(Edmonton)	4	
AC	192	(Winnipeg)	1	
AC	170	(Winnipeg)	4	
AC	136	(Vancouver)	10	
CP	060	(Vancouver)	1	Standby (M. Singh)

- passengers originating at Toronto
- diplomatic bags from the Vancouver India Consul General via AC 508
- produce cargo from India
- cargo in the form of 5th pod engine components loaded in the aft cargo compartment.

It should be noted that some passengers from India book flights to Montreal with their intended destination being Toronto. The reason is that the fare to Montreal is cheaper and therefore some passengers get off the flight in Toronto, claim their luggage and leave without reporting a cancellation of the trip to Montreal. It has been established that 65 of the 68 transit passengers reboarded the flight to Montreal.

Air India personnel were in charge for the overall operation at Toronto regarding the unloading and loading of both passengers and cargo. Although the actual work was performed by various companies under contract, Air India personnel oversaw the operation. The Air India station manager was away on vacation on 22 June 1985. The evidence does not clearly establish who had been assigned to replace the station manager and assume his duties.

Air Canada had stored in a hangar an engine that had failed on a previous Air India flight from Toronto on 8 June 1985. Air Canada received a message from Air India stating that the failed engine was to be mounted as a 5th pod on Flight 181/182 on 22 June 1985. The engine was prepared for loading and component parts were crated for loading into the aft cargo compartment. On 22 June, the component parts were taken from the hangar and placed outside to be delivered to the aircraft by MEGA International Air Cargo. The component parts were placed just inside the airport fence separating the restricted and unrestricted areas. The installation began immediately upon the arrival of Flight 181 and was completed at 1530 EDT (1930 GMT). The front engine cowling was crated but would not fit through the aft cargo door. The crating was rearranged, and the door stops on the cargo door were removed to permit the loading of the crate and the remaining engine parts were loaded on pallets. Due to problems with loading the 5th pod and component parts, the departure was delayed from 1835 EDT (2235 GMT) to 2015 EDT (0015 GMT, 23 June).

CP Air Flight 060 arrived in Toronto at 1610 EDT (2010 GMT) and docked at gate 44, Terminal 1. A number of passengers on this flight were interlined to other flights including passenger M. Singh wait-listed on Air India Flight 181/182. It has been established that this passenger did not board Flight CP 060 but did check baggage onto the flight. This baggage was to be interlined to the Air India flight departing from Terminal 2. In this case, CP Air employees would have off-loaded all baggage from CP 060 and deposited the baggage at Racetrack 6 on the ring road of Terminal 1 to be transported to the Air Canada sorting room at Terminal 2.

Consolidated Aviation Fuelling and Services (CAFAS) is a company which is contracted to pick up and deliver baggage from one terminal to the other. The CAFAS driver on duty at the time recalls picking up a bag from a CP Air flight originating in Vancouver and destined for Air India at Terminal 2. As this piece of luggage did not turn up as found luggage, it is deduced that normal practice was followed, and the luggage was interlined and loaded on AI 181/182.

MEGA International Air Cargo is a firm that handled air cargo and containers for Air India. Since the flight was carrying a 5th engine and component parts, no commercial cargo could be loaded at Toronto. MEGA delivered the engine component parts to be loaded in the cargo compartment by Air Canada employees. Later, MEGA received two diplomatic bags and delivered these to the aircraft. The bags were loaded into the valuable goods container (see Appendix B). These bags were not subjected to X-ray or any other security checks.

All checked-in baggage for AI 181/182 was to be screened by an X-ray machine which was located in Terminal 2 at the end of international belt number 4. This location would permit all baggage from the check-in counters and interline carts to be fed through the X-ray machine before being loaded. It has been established that this machine worked intermittently for a period of time and stopped working during the loading process at about 1700 EDT (2100 GMT). Rather than opening the bags and physically inspecting them, the Burns security personnel performing the X-ray screening were told by the Air India security officer to start using the hand-held PD-4 sniffer.

One Burns security officer checked the bags with the sniffer while another put stickers on the bags and forwarded them. The security officer forwarding the baggage recalls the sniffer making short beeping noises not long whistling ones. The security officer who used the sniffer claims it never went off, and the only time any sound was made was when it was turned on and off. At those times, it would emanate a short beep (refer to section 2.8 for further information regarding the PD-4 sniffer).

Burns International Security had a contract with Air India for the security of the aircraft while it was docked. The security arrangements contracted from Burns were as follows:

- security at the bridge door leading to the aircraft;
- security inside the aircraft from the time the passengers disembarked upon flight arrival until flight departure;
- security guards assigned the physical inspection of all carry-on baggage in the departure room; and
- security guards in the international baggage make-up room conducting screening of baggage using an X-ray machine and a hand-

held PD-4 sniffer.

The statements taken from Burns security personnel in Toronto indicated that a significant number of personnel, including those handling passenger screening, had never had the Transport Canada passenger inspection training program or, if they had, had not undergone refresher training within 12 months of the previous training.

As a result of official requests made by Air India in early June 1985 for increased security for Air India flights, the RCMP provided additional security as follows:

- one member in a marked police motor vehicle patrolling the apron area;
- one member in a marked police motor vehicle parked under the right wing from time of arrival until push-back;
- one member on foot patrol at Air India check-in counter; and
- one member at the loading bridge during boarding.

In addition, all RCMP members working in that particular area of Terminal 2 were aware of the Air India flight and would check in with the assigned personnel during their patrols in the area of the aircraft and check-in/boarding lounges. Uniformed members are to patrol and monitor security within the airport premises as detailed in section 2.5 below.

Passenger check-in was handled for Air India by Air Canada under contract with Air India. The check-in included passengers originating in Toronto and interline passengers but did not include the transit passengers to Montreal. The check-in passengers were numbered using a security control sheet in accordance with instructions from Air India; however, the check-in and interline baggage was not numbered, and no attempt was made to correlate baggage with passengers. Hence, any unaccompanied interline baggage would not have been detected.

The flight and cabin crew had been in Toronto for the week prior to this flight and were to take the aircraft to London where they would be replaced by another crew. The crew members themselves and their carry-on baggage were not subjected to any security checks; however, their checked-in baggage was screened in the same manner as other baggage.

2.3 Montreal

Air India Flight 181 from Toronto arrived at Mirabel International Airport at about 2100 EDT (0100 GMT, 23 June) and parked in supply area number 14 at 2106 EDT (0106 GMT). The 65 passengers destined for Montreal along with three Air India personnel deplaned and were transported by bus to the terminal building. The remaining passengers remained on board as transit passengers and were not permitted to disembark at Montreal. Air Canada baggage handlers off-loaded four containers of cargo, three containers of baggage and a valuables container. Two diplomatic pouches from the Indian High Commission in Ottawa were delivered to the aircraft by MEGA International Cargo. One pouch weighing one kilogram was hand-delivered to the flight purser for storage in a valuables locker within the cabin and the other pouch was loaded into the valuables container.

During the check of the aircraft at Montreal, the second officer pointed out to an Air Canada mechanic that a rear latch on the fan cowl for the 5th engine did not appear to be properly secured. The mechanic examined the latch and found it well secured, but the handle was not flush and was hanging about five degrees. The mechanic applied high-speed tape to the latch handle for aerodynamic smoothness. This repair was examined by the second officer who was satisfied with the work. No records were completed by Air Canada in connection with this temporary repair.

At about 1730 EDT (2130 GMT), Air Canada, which is Air India's contracted agent, opened its check-in counter to passengers who would be flying on Air India Flight 182. Burns security personnel were also assigned at this time to screen the checked baggage. Passenger tickets were checked, issued a number, and copies of the tickets were removed and retained by Air Canada. Boarding passes were then issued and affixed to the numbered tickets. Also attached to the ticket booklets were numbered tickets which corresponded to each piece of checked baggage. The numbered checked baggage was sent to the baggage area by Air Canada personnel to be security-checked by Burns security personnel.

The passengers for AI 182 after checking in were free to enter the departure area. At the entrance to the departure area, Burns security staff used X-ray units and metal detectors to screen passengers and carry-on baggage. At about 2100 EDT (0100 GMT), the passengers proceeded to gate 80 where they gave their boarding passes and numbered tickets to an Air Canada agent. The agent kept the numbered flight tickets and checked the numbers against the passenger list. Also, at gate 80, a secondary security check was done on passengers by a Burns security officer using a metal detector. Hand-carried baggage was subjected to further physical and visual checks. A total of 105 passengers boarded the flight at Mirabel Airport; there were no interline passengers.

Between 1900 (2300 GMT) and 1930 EDT (2330 GMT), Burns security personnel identified a suspect suitcase using the X-ray machine. The suitcase was placed on the floor next to the machine. The Burns security supervisor told Air India personnel that a suspect suitcase had been located and was advised within 15 to 20 minutes to wait for the Air India security officer who would be arriving on the flight from Toronto. Subsequently, a second suspect suitcase was identified and a little later a third. The three suitcases were placed next to the X-ray machine. Between 1930 (2330 GMT) and 1945 (2345 GMT), all the Burns security personnel at the X-ray machine were assigned to other duties and the three suspect suitcases remained in the baggage area without supervision. At about 2140 (0140 GMT), the Air India security officer went to the baggage room and inspected the three suitcases with the X-ray machine and a sniffer that was in the possession of the security officer. The Air India security officer decided to keep the three suitcases and, if further examination proved negative, send them on a later flight. At approximately 2155 (0155 GMT), the Air Canada Operations Centre supervisor contacted the airport RCMP detachment regarding the suspect suitcases. At about 2205 (0205 GMT), an RCMP member located the suitcases in the baggage room and requested that an Air India representative be sent to the baggage room. About five minutes later, the Air India security officer contacted the baggage room by telephone and advised that he could not come to the room immediately. The Air India security officer arrived in the baggage room at about 2235 (0235 GMT) and, when asked to determine the owners of the suitcases, informed the RCMP member that the flight had already departed [2218 (0218 GMT)]. The three suspect suitcases were later examined with negative results. The remainder of the checked baggage which cleared the security check was identified by a green sticker. The baggage was then forwarded to Air Canada personnel who loaded the baggage in containers to be placed on board the aircraft. A later check with Canada Customs and Air Canada at Mirabel revealed no unclaimed baggage associated with AI 181/182. A similar check at Dorval Airport was conducted with negative results.

No record was kept as to the location and number of individual pieces of checked-in luggage. Records were kept as to the location of the containers according to destination, where loaded and the number of pieces of luggage in each container (see Appendix B).

The Mirabel Detachment of the RCMP provided the following security at the airport on 22 June 1985:

- one member in a police vehicle for airside security;
- one member on patrol in the arrival and departure areas;
- one member on general foot patrol throughout the terminal; and
- one member as a telecommunications operator in the detachment office.

In addition, due to the increased threat to Air India flights, the RCMP provided the following supplementary coverage to Air India Flight 181/182 on 22 June 1985:

- one member in a police vehicle escorted the aircraft to and from the runway and the terminal building and remained with the aircraft while it was stationary;
- one member in a police vehicle remained at the entrance to the ramp;
- two members patrolled the area of the ticket counter and access corridors, and one of these members also served in a liaison capacity with the airline representatives.

2.4 International Standards and Recommended Practices

International security standards and recommendations to safeguard international civil aviation against acts of unlawful interference are listed in ICAO Annex 17 to the Convention on International Civil Aviation. Suggested security measures and procedures are amplified in the ICAO Security Manual for Safeguarding Civil Aviation Against Acts of Unlawful Interference.

Annex 17 requires contracting States of which Canada is one to "take the necessary measures to prevent weapons or any other dangerous devices, the carriage or bearing of which is not authorized, from being introduced by any means whatsoever, on board an aircraft engaged in the carriage of passengers."

In addition to other recommendations, Annex 17 recommends that contracting States should establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage, cargo, mail and stores to be carried on board aircraft.

The Security Manual specifies that,

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Recently, ICAO has proposed amendments to Annex 17. These proposals arise from a decision taken by the Council in its 115th Session on 10 July 1985. The Council instructed its Committee on Unlawful Interference, as a matter of urgency, to review the entirety of Annex 17 and to report on those provisions which might be immediately introduced, upgraded to Standards, strengthened or improved. Among the proposed amendments is the following upgrading in the Standards:

- Each contracting State ensure the implementation of measures at airports to protect cargo, baggage, mail stores and operator's supplies being moved within an airport to safeguard such aircraft against an act of unlawful interference.

2.5 Canadian Law

In terms of Canadian statutory requirements, the Civil Aviation Security Measures Regulations and the Foreign Aircraft Security Measures Regulations made pursuant to the Aeronautics Act require specified owners or operators of aircraft registered in Canada or specified owners or operators who land foreign aircraft in Canada to establish, maintain, and carry out security measures at airports consisting of:

- systems of surveillance of persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- systems of searching persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas that are inaccessible to any person other than a person who has been searched and the personnel of the owner or operator;
- a system that provides, at airports where facilities are available, for check-points at which persons intending to board the aircraft of an owner or operator can be searched;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas in which cargo, goods and baggage that have been checked for loading on aircraft are inaccessible to persons other than those persons authorized by the owner or operator to have access to those areas;
- a system of identification that prevents baggage, goods and cargo from being placed on board the aircraft if it is not authorized to be placed on board by the owner or operator; and
- a system of identification of surveillance and search personnel and the personnel of the owner or operator.

Specified carriers including Air Canada, CP Air, and Air India were required to provide a description of their security measures to the Canadian Minister of Transport.

An Order-in-Council on 29 September 1960 established that the RCMP was responsible for the direction and administration of police functions at major airports operated by Transport Canada. The duties of the Police and Security Detail at these designated airports include the following:

- carry out policing and security duties to guard against unauthorized entry, sabotage, theft, fire or damage;
- enforce federal legislation;
- respond to violations of the Criminal Code of Canada, Federal, Provincial, and Territorial statutes, and perform a holding action pending

arrival of the police department having primary criminal jurisdiction;
- man guard posts; and
- provide a police response in those areas of airports where pre-board screening takes place.

Section 5.1(9) of the Aeronautics Act states that "The Minister may designate as security officers for the purposes of this section any persons or classes of persons who, in his opinion, are qualified to be so designated." Pursuant to this section Transport Canada has established criteria for persons or classes of persons that are designated as security officers in a Schedule registered on 11 April 1984. The criteria also specify that a security guard company and its employees will meet Transport Canada requirements provided that the company:

- is under contract with a carrier to conduct passenger screening under the Aeronautics Act and Regulations;
- is licensed in the province or territory;
- complies with the security guard criteria as follows in that the guard must:
  - be 18 years or older,
  - be in good general health without physical defects or abnormalities which would interfere with the performance of duties,
  - be licensed as a security guard and in possession of the licence while on duty, and
  - meet the training standards of Transport Canada consisting of successfully completing the Transport Canada passenger inspection training program, attaining an average mark of 70 per cent, and undergoing refresher training within 12 months from previous training;
- uses a comprehensive training program which has been approved by Transport Canada and is capable of being monitored and evaluated;
- keeps records showing the date each employee received initial training and/or refresher training and the mark attained; and
- provides supervision to ensure that their employees maintain competency and act responsibly in the conduct of searching passengers and carry-on baggage being carried aboard aircraft.

2.6 Canadian Security Procedures

In accordance with the Canadian Aeronautics Act and pursuant regulations, air carriers are assigned the responsibility for security. Transport Canada provides the following security services for the air carriers using major Canadian airports, including the international airports in Vancouver, Toronto and Montreal:

- security and policing staff including RCMP airport detachments;
- specific airport security plans and procedures;
- secure facilities (e.g., secure areas, pass identification systems, etc.); and
- security equipment and facilities (e.g., X-ray detection units, walk-through metal detectors, hand-held metal detectors, explosive detection dogs).

As of 22 June 1985, the following general security measures were in place at Canadian airports:

- metal detection screening of passengers; and
- X-raying of carry-on baggage.

Checked baggage was not normally subject to any security screening. A few air carriers such as Air India had extra security measures in place because of an assessed higher threat level (see section 2.7 below).

On 23 June 1985, Transport Canada required additional security measures to be implemented by all Canadian and foreign air carriers for all international flights from Canada except those to the continental United States. These measures required:

- the physical inspection or X-ray inspection of all checked baggage;
- the full screening of all passengers and carry-on baggage; and
- a 24-hour hold on cargo except perishables received from a known shipper unless a physical search or X-ray inspection is completed.

Further, on 29 June 1985, Transport Canada directed that all baggage or cargo being interlined within Canada to an Air India flight was to be physically inspected or X-rayed at the point of first departure and that matching of passengers to tickets was to be verified prior to departure.

2.7 Air India Security Program in Canada

In accordance with the Foreign Aircraft Security Measures Regulations, Air India had provided the Minister of Transport with a copy of its security program. It included measures to:

- establish sterile areas;
- physically inspect all carry-on baggage by means of hand-held devices or X-ray equipment;
- control boarding passes;
- maintain aircraft security;
- ensure baggage and cargo security; and
- off-load baggage of passengers who fail to board flights.

Under these procedures established by Air India, passengers, carry-on baggage, and checked baggage destined for AI 181/182 on 22 June 1985 were subjected to extra security checks. A security officer from the Air India New York office arrived in Toronto on 22 June 1985 to oversee the security operation at Toronto and Montreal.

On 17 May 1985, the High Commission of India presented a diplomatic note to the Department of External Affairs regarding the threat to Indian diplomatic missions or Air India aircraft by extremist elements. Subsequently, in early June, Air India forwarded a request for "full and strict security coverage and any other appropriate security measures" to Transport Canada offices in Ottawa, Montreal and Toronto, and RCMP offices in Montreal and Toronto.

2.8 PD-4 Sniffer

On 18 January 1985, prior to the inaugural Air India flight out of Toronto on 19 January, a meeting on security for Air India flights (Toronto) was held with representatives from Transport Canada, RCMP and Air India. At this meeting, a PD-4 sniffer belonging to Air India was produced. It was explained that it would be used to screen checked baggage as the X-ray machine had not yet arrived. At that time, an RCMP member tested its effectiveness. The test revealed that it could not detect a small container of gunpowder until the head of the sniffer was moved to less than an inch from the gunpowder. Also, the next day the sniffer was tried on a piece of C4 plastic explosives and it did not function even when it came directly in contact with the explosive substance. It is not known if this was the same sniffer used on 22 June 1985.

2.9 Medical Evidence

Medical examination was conducted on the 131 bodies recovered after the accident. This comprises about 40 per cent of the 329 persons on board. It should be noted that assigned seating is based on preliminary information. Also, the exact position of passengers is not certain because it is not known if passengers changed their seats after lift-off. On the information available, the passengers were seated as follows:

Passengers:*

	Seats Available	Occupied	Bodies Identified
Zone A	16	1	0
Zone B	22	0	0
Upper Deck	18	7	0
Zone C	112	104 + 2	29
Zone D	86	84 + 1	38
Zone E	123	105 + 3	50
SUB-TOTAL	377	301 (+6 infants)	117
Crew:			
Flight Deck	3	3	0
Cabin	19	19	5
TOTAL	399	329	122

There were 30 children recovered and they showed less overall injury. The average severity of injury increases from Zone C to E and is significantly less in C than in Zones D and E.

Flail pattern injuries were exhibited by eight bodies. Five of these were in Zone E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evenly

*See Appendix C for interior seating arrangement.

distributed throughout the zones, but with a tendency to be seated at the

sides, particularly the right side (12 bodies).
Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 in Zone D, 11 in Zone E, 2 crew and 1 unknown), and 16 had little or no clothing.
Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).
There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).
There is a general absence of signs indicating the wearing of lap belts.
Pathological examination failed to reveal any injuries indicative of a fire or explosion.

2.10 Flight Recorders and Shannon Air Traffic Control (ATC) Tape Analyses

VT-EFO was equipped with a Fairchild A100 Cockpit Voice Recorder (CVR) and a Lockheed 209E Digital Flight Data Recorder (DFDR). These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the aft pressure bulkhead. The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor.
The Shannon Air Traffic Control Centre was in contact with VT-EFO and recorded radio communications with the aircraft. At the time of the accident, 5.4 seconds of noise was recorded, and the transponder signal seen on the radar scope was lost from the aircraft. This signal which displays aircraft altitude showed no deviation before disappearing from the radar scope.

2.10.1 Analysis by National Research Council, Canada

From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder. The initial waveform of the cockpit area microphone signal is not consistent with the sharp pressure rise expected with detonation of an explosive device close to the flight deck, but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, the possibility that it originated from such a device elsewhere in the aircraft cannot be excluded.

By correlating the oscillograph records of the CVR and the Shannon ATC VHF recording, it was estimated that the unusual sounds recorded on the ATC tape started 1.4 ± 0.5 seconds after the start of the sudden sound detected by the cockpit area microphone and lasted intermittently for 5.4 seconds. It was felt the closeness in time of the two noises indicated the 5.4 seconds recorded on the ATC tapes originated from AI 182. The ATC recording that followed the cockpit area microphone sounds appeared at first to contain a series of short intermittent sounds. Listening to the sounds, it also appeared that a human cry occurred near the end of the recording. Spectral analysis of these sounds and comparison with voice imitations revealed that the recorded sounds do not contain all the pitch harmonic frequencies normally associated with voice sounds. The origin of these sounds has not been determined.

An examination of the DFDR showed no abnormal variations before the accident. With the spare engine, this aircraft was restricted to altitudes below 35,200 feet and indicated airspeeds less than 290 knots. During the last 27 minutes of the flight, the computed airspeed did gradually increase to nine knots above this limit in the first part of this period and the power was readjusted several times. The speed fell below the 290 knot limit at about 07h:09m GMT as recorded by the DFDR; power was increased again at about 07h:10m causing the aircraft to accelerate to six knots above the limit by the time the accident occurred at 07h:13m:59s. The observed excursions outside the specified limits are not considered significant.

The aircraft was flown with 1.5-degree left-wing-down with 4.2 degrees clockwise control wheel as compared to the aircraft without the 5th engine installation. Also, 9.4 per cent of right rudder pedal was applied giving a 1.1-degree right deflection of the upper and lower rudders. Considering the carriage of the 5th engine on the left side, these figures are not considered abnormal.

When synchronized with the other recordings, it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR.

Irregular signals were observed over the last 0.27 inches of the DFDR tape. Laboratory tests indicated that the irregular signals most likely occurred as a result of the recorder being subjected to sharp angular accelerations about the lateral axis of the recorder, causing rapid changes in tape speed over the record head. This equates to an angular acceleration on the recorder about the aircraft's longitudinal axis in a left-wing-down sense. Therefore, these tests indicate that the digital recorder was subjected to a sharp jolt separate from any violent motion of the aircraft.

The other possibility for the irregular signals is that the Flight Data Acquisition Unit which generated the serial digital data signal and which is located in the electronics bay under the cabin floor forward of the cargo compartment could have suffered some damage or had an intermittent power supply that caused it to generate the irregular signals.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom

The AIB analysis was restricted to the CVR and the Shannon ATC tape. The correlation of the CVR and ATC tapes showed that the ATC recording started after the CVR had stopped recording and 1.1 ± 0.4 seconds from the start of the sudden sound. The total duration of the signal on the ATC tape was 5.4 seconds.

An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Evidence of the presence of audio warning signals buried amongst the noise was investigated with negative results. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.

The analysis of the ATC tape audio determined three or four words could be heard at the beginning of the transmission, but extensive filtering did not allow the sounds to be transcribed. Two bursts of tone occurred during the first second. The spectrum of the tone does not coincide with any B747 audio warning. The transmission is chopped until at about 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound is similar to that heard in other accidents where there has been a rapid increase in airspeed. Toward the end of the transmission a crying sound was heard; however, a study of the noise indicates a human cry would contain more harmonics. The origin of this sound was not determined. Knocking sounds were also heard during the transmission. These were initially thought to be due to hand-held microphone vibration, but this was discounted because of the frequency of the sounds. Almost identical sounds were heard on the DC-10 CVR after the explosive decompression had occurred. Their source was not identified. On the DC-10, the pressurization audio warning sounded 2.2 seconds after the decompression. No such warning was identified on the ATC tape.

*Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization. A loud noise is associated with this event but not necessarily an explosion.

Every aircraft provides a different signature when the press-to-transmit button is released. These signatures were compared with transients which occurred during the open microphone transmission. There is a close match with the previous AI 182 signatures. Therefore, it is almost certain that the ATC tape recording originated from AI 182.

The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182. It further states there is strong evidence to suggest a sudden explosive decompression of undetermined origin occurred. Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. However, the AIB report is of the opinion that the device would have to be small not to be detected as it is considered that a large high-explosive device could not fail to be detected on the CVR.

2.10.3 Analysis by Bhabha Atomic Research Centre (BARC), India

The BARC analysis was restricted to the CVR and the Shannon ATC tape.

Channel 3 of the recording which corresponded to the cockpit area microphone showed the first indication of a rising audio signal. The signal level rises from the ambient level in the cockpit by about 18.5 decibels in approximately 45 milliseconds. The signal starts falling and stabilizes at a level about 10 decibels higher than ambient for about 375 milliseconds. The total duration of the signal is about 460 milliseconds. The timings of the CVR and the Shannon ATC tape were correlated, and it was determined that the explosive sound on the CVR coincided with the beginning of the series of audio bursts on the ATC tape. The report concluded that the sounds recorded on the ATC tape emanated from AI 182 at the time of the occurrence.

The noise on the CVR was compared with an explosion which caused the crash of an Indian Airlines B737. In this occurrence, the explosive sound recorded on the cockpit area microphone showed a rise time of about 8 milliseconds. It was also determined that the explosion occurred 8 feet from the microphone. The report concluded that the rise time is a measure of the distance from the cockpit area microphone to the source of an explosion. Hence, the exact location in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the cockpit judging from the rise time of 45 milliseconds.

The report concluded that the series of audio bursts on the ATC tape were most probably generated by the break-up of AI 182 in mid-air.

2.11 Aircraft Structures Examination

The examination of aircraft structures consisted of the following areas: floating wreckage, wreckage mapping and surveying, wreckage distribution, photographic and video interpretation of wreckage, wreckage recovery and initial examination, and examination of recovered wreckage.

2.11.1 Floating Wreckage

During the search, aircraft wreckage was sited and recovered by several search vessels. The wreckage was transported to Cork, Ireland, where preliminary examination was conducted. This examination took place in June and July, 1985.

The wreckage consisted mainly of various leading edge skin panels of the left and right wings, left wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canoe fairing pieces, landing gear wheel well doors, pieces of elevator and aileron, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggage, suitcases, personal effects and a number of internal fittings. The floating wreckage constitutes about three to five percent of the aircraft structure.

The wreckage was then transported from Ireland to Bombay, India where it underwent further examination by the Floating Wreckage Structures Group which then produced a report which was submitted to the Indian Inquiry. The report concluded:

- There was no evidence of fire damage.
- There was no evidence of lightning strike damage.
- The cabin floor panels from the forward and rear sections of the aircraft separated from the support structure in an upward direction (floor to ceiling) pulling free from the attaching screws and, in some cases, breaking the vertical web of the seat track/floor beams.
- The position of the leading edge flap rotary actuator and the damage to the flap structure indicated that the leading edge flaps were in the retracted position.
- The six spoiler actuators found were in the retracted position. The lower surface of all the spoiler panels showed signs of spanwise skin

splits with the edges curled into the core of the honeycomb. The report concluded that this was possibly due to the loading of the spoilers by being deployed in flight at high speed, resulting in compression on the lower surfaces. This, in turn, caused splitting of the lower skin into the honeycomb.

- The right wing root leading edge, number 3 engine inboard fan cowling, the right inboard midflap inboard leading edge, and the right stabilizer root leading edge all exhibited damage possibly due to objects striking the right wing and stabilizer before water impact.

In addition to the above conclusions, the following significant information regarding the floating wreckage is noted in the report:

- The aircraft was carrying a -7Q engine at the 5th pod and a -7J 5th pod kit in the aft cargo compartment. In all there were 14 engine fan cowls (four in the aft cargo compartment). Out of these 14 fan cowls, nine, including six from the working engines and three from the aft cargo compartment, and two additional pieces of fan cowls were found. Five of the fan cowls from the working engines showed folding damage lines at about the three and nine o'clock positions. The number 3 engine inboard fan cowl had severe impact damage on its leading edge and had small outward puncture holes but no penetration through the outer skin in the lower centre region. The two fan cowls of the -7J 5th pod kit stowed in the aft cargo compartment showed severe damage. One piece was cut at one corner in an arc of about 20 inches diameter and its external skin was peeled back.
- The cockpit entry door and the side bulkhead panel were found relatively intact but had come out of their attachments.
- Twelve toilet doors out of 16 were found and were relatively intact but had come out of their attachments.
- Cabin interior panels and overhead bins of the main and upper decks which were recovered exhibited only minor damage.
- The wooden boxes which contained the fan blades of the 5th pod engine were loaded in container 24L in the forward cargo compartment and were found broken apart exhibiting no burn marks.
- One passenger oxygen bottle and one portable oxygen bottle were

recovered and showed no sign of damage.

Mr. V.J. Clancy, an aviation explosives expert representing Boeing Aircraft Corporation, prepared a preliminary report based on his examinations of certain items of recovered and floating wreckage. Mr. Clancy's report notes the following with respect to floating wreckage:

- A foam-backed floor panel which showed a small number of perforations was recovered. Mr. Clancy recommended that it should be X-rayed and a detailed examination completed.
- One of the lavatory doors had, into its inner surface, a number of fragments of glass mirror - presumably from breakage of a mirror normally fitted into the lavatory. Most of the fragments, buried edgeways, were oriented parallel to each other. The remainder were approximately at right angles to the others. Mr. Clancy concluded that it would be improbable that any reliance could be placed on the penetration by mirror fragments as being indicative of an explosion.
- Three steel oxygen cylinders which were stowed in the forward cargo compartment were recovered. One had been dented apparently by the impact of an object measuring about one to two centimetres. The depression had a maximum depth of about four millimetres.
- A few suitcases recovered among the floating wreckage were examined. Mr. Clancy felt that one might provide useful information. It was of red plastic material with a blue lining. Mr. Clancy reported that plastic material has been found to retain identifiable traces of explosive after long immersion in the sea. Also, the lining which was severely tattered resembled that of one found after an explosion in an aircraft in Angola.
- A wooden spares box was found on the foreshore of Wales. It was of the kind used on the aircraft. It was charred on one side and partially on the bottom. The depth of charring suggested that the burn time was three to four minutes. This box was normally stowed in the aft cargo compartment; however, on this flight it may have been stowed in the forward compartment.
- Two pieces of the cover of an overhead locker originating above either door 2R or 4R were also found on the foreshore. They were partially

damaged and blackened by fire. Mr. Clancy concluded that this indicated the presence of fire.

- Two pieces of U-section alloy channel partially filled with plastic foam were found on the foreshore. The alloy was of a kind not used in aircraft structure; however, it could have been from some fitting supplied by a sub-contractor. Also, since the pieces were found near an area where practice firings at targets are carried out off the west coast of the United Kingdom, it could have come from some other source. One piece of the alloy bore marks ("mooncraters") typical of an attack by very high velocity fragments such as produced by an explosion. X-rays showed the presence of a few small particles buried in the foam which Mr. Clancy recommended should be extracted and examined. He also felt that this provided the strongest single indication of an explosion and that it was essential to determine if these pieces came from the aircraft or any of the equipment or cargo aboard the aircraft.

The CASB in its examination of the floating wreckage noted the following:

- The fan cowls of the number 4 engine had a series of five marks in a vertical line across the centre of the Air India logo on the inboard facing side of the fan cowl. These marks had the characteristic airfoil shape of a turbine blade tip. It is possible that a portion of the turbine parted from the number 3 engine and struck the cowl of the number 4 engine.
- The upper deck storage cabinet which was located on the left side had unusual damage to its bottom. A large rounded dent in the bottom inboard edge of this stiff cabinet structure revealed smooth stretching without breakthrough. The damage did not seem to be achievable by inertia or impact forces as the cabinet except for the bottom was undamaged. The damage was considered by a CASB investigator to be compatible with the spherical front of an explosive shock wave generated below the cabin floor and inboard from the cabinet; however, it is not known if this damage could be caused by some other means.
- The right wing root fillet which faired the leading edge of the wing to the fuselage ahead of the front spar had a vertical dent similar to that which would have resulted had the fillet run into a soft cylindrical object

with significant relative velocity. The paint on the inboard chord appeared to be scorched brown in the centre areas of three honeycomb panels. It has been determined that sudden heat can turn these panels brown, but it is not known if other reasons for the discolouration exist. The fillet abutted the fuselage side at the aft end of the forward cargo compartment.

- There was blackened erosion damage to the bottoms of some seat cushions. The damage had an appearance similar to that which would have been caused by an explosive device. It is not known if marine life feeding on the cushions or some other cause could have produced the same effect.
- The charred wooden spares box contained some sand and small shellfish. The flesh from the shellfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

An electronic device was found among some floating wreckage and was forwarded to the Bhabha Atomic Research Centre for analysis. There was some concern that it could have been used to detonate an explosive device. The device was forwarded to the RCMP who in conjunction with the CASB determined it to be an item manufactured for use in radiosondes (weather balloons) and was not modified as a detonating device.

2.11.2 Wreckage Mapping and Surveying

The Canadian Coast Guard Ship (CCGS) John Cabot was given the task of mapping the wreckage on the ocean floor. On 19 July 1985, the Cabot with a SCARAB deep submersible on board departed Cork. On arrival at the site, and based on surface wreckage distribution and bottom side scan sonar plots, four transmitters were placed on the sea bed. These transmitters provided signals for the ALLNAV navigation system used to accurately plot the sea bed wreckage.

Based on all the data available, the SCARAB was launched on 24 July 1985 to begin the bottom search in position 51°01.9'N 12°41.0'W. During the mapping, stage areas were designated for search and each progressive area was determined based on the information gained during the search. The search was conducted using sonar and video. Wreckage found was recorded on video tape and on 35mm positive film.

The first object plotted on the sea bed was a torn suitcase located at lat 51°02.63'N, long 12°53.15'W and was the most westerly object located. This suitcase has not been recovered, nor has it been positively identified as having come from the accident aircraft.

As the search progressed eastward, the first positive identification of aircraft wreckage was made at lat 51°02.9'N, long 12°49.93'W. Slowly, over a period of about 90 days, a detailed bottom wreckage plot was developed.

While mapping was in progress, some of the wreckage was revisited to obtain additional data. During the transit through areas already searched, wreckage not previously plotted was found, and, in some areas, the density of wreckage physically precluded 100 per cent coverage. Components and major structural items were identified from all sections of the aircraft and when the mapping of the sea bed ended, most of the aircraft had been found and photographed. Although positive identification of each piece of wreckage could not be made, it was decided in late October 1985 that the search phase was essentially completed and wreckage recovery could begin. A bottom wreckage distribution plot is contained separately in an envelope as Appendix F.

2.11.3 Wreckage Distribution

The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling on the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled.

Although badly damaged, sections 41, 42 and 44*, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been plotted or photographed.

Sections 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the westernmost identified aircraft component located at lat 51°02.90'N and long 12°50.1'W. The wreckage extended in a line about 110 degrees True to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern.

A?? third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southeast orientation. One of the operating engines was displaced 0.5 nautical miles to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

*See Appendix D for location of aircraft sections and aircraft body stations (BS).

2.11.4 Photographic and Video Interpretation of Wreckage

2.11.4.1 Photographic Interpretation

All wreckage sighted was recorded on video tape and all major items were recorded on 35mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage patterns. For example, the sine wave bending of target 7* appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into account.

2.11.4.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

2.11.4.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gear were in the 'up' position at the time of impact.

2.11.4.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

*See Appendix E for location of targets on aircraft.

2.11.4.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

2.11.4.6 Section 42

Portions of section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers.

All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

2.11.4.7 Section 44

Section 44, containing the aircraft structure between body station (BS) 1000 and BS 1480 including that area where the fuselage and wings were mated was located in the same general area as the forward sections of the aircraft. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one-third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gear were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

2.11.4.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northernmost area of the wreckage pattern.

The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

2.11.4.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of BS 1480 and, for purposes of this Submission, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were identified (targets 35, 37, 73 and 296), and one portion of the bulkhead was never located. Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognizable as having come from a specific area of the aircraft.

Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from BS 1600 to BS 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

The tail cone and the auxiliary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure of air or water.

The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabilizer was missing and the auxiliary spar was exposed. There was localized damage to the right-hand root of the leading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

2.11.4.10 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from sections 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42, and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat-belts were not fastened.

2.11.5 Wreckage Recovery and Initial Examination

During the wreckage mapping, some small items were recovered, and an unsuccessful attempt was made to recover a portion of the forward cargo door. On completion of the sea bed survey, an offshore supply ship, Kreuztrum, chartered by the National Transportation Safety Board

(NTSB), joined John Cabot for a wreckage recovery operation. Prior to the commencement of the wreckage recovery, the structures group met at the Boeing facility in Seattle, USA and reviewed the video tapes and photographs of the wreckage. Based on their findings, a list of items was identified as being most desirable for recovery. The priority list was prepared by a group in Cork, Ireland, headed by Dr. V. Ramachandran. On 8 October 1985, the John Cabot sailed, and on 9 October 1985, the Kreuztrum sailed for the accident site. The following target numbers and items were recovered during the mapping and wreckage recovery stages of the investigation: 7, 8, 35, 47, 117, 193, 223, 245, 287, 296, 299, 362/396, and 399 (as the location on the aircraft of some of the targets was not known when Appendix E was created, some are not shown in the appendix). The first officer's seat, some suitcases and small debris were also recovered using a metal frame basket. Initial examination of the wreckage was carried out in Cork and then it was transported to Bombay for detailed examination.

2.11.6 Examination of Recovered Wreckage

Although all the recovered wreckage was examined, only those items exhibiting characteristics which provided some evidence as to what may have happened to the aircraft during its final moments of flight are discussed. CASB engineering personnel and other participants examined the recovered wreckage at Cork and Bombay. The observations made during their examinations are discussed below.

2.11.6.1 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from BS 1480 to 1860 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear, and the torn edge was buckled in waves, like the trace of a sine wave. On the right side, between the one-quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at BS 1480. The skin tear located at about BS 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distorted and

elongated.
The left and right trunnion vertical support fittings located at BS 1480 were examined optically using the stereomicroscope. Both trunnions were fractured through the three bolt holes. The right fracture characteristics were consistent with an overload mode of failure. Although most of the left fracture surface was also characterized by overload features, there were heavily corroded areas where the fracture mode could not be confirmed through optical examination. One lug fracture was sectioned from the left trunnion and prepared for scanning electron microscope (SEM) examination. After the corroded area was cleaned, the examination revealed some ductile characteristics on the fracture surface. There was no evidence of intergranular fracture observed to suggest a stress corrosion cracking mode of failure, nor was there any evidence of progressive failure observed. The corrosion appeared to have developed after the accident.
2.11.6.2 Target 8 - Lower Fuselage Skin Panel
This skin panel was located below the aft cargo area and extended from BS 1860 to 1960 and from stringer 46L to 46R. A small section from the aft end along the belly skin splice at stringer 46L was removed for examination. SEM examination revealed that the fracture was characterized by slightly elongated ductile dimples along its length, including areas adjacent to the edges of the rivet holes. On the aft edge of each rivet hole examined, a distinctive shear lip was observed. These features are consistent with an overload mode of failure along the skin splice with an apparent direction of failure from aft to forward.
2.11.6.3 Target 35 - Portion of Rear Pressure Bulkhead
Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 o'clock position. The piece from 12 to 1 o'clock had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 o'clock position, the outer edge showed sinusoidal buckling, and the edge sector at 9 o'clock was partially collapsed and its edge was turned under. Samples taken for optical stereomicroscope and SEM examination revealed that the fracture characteristics were consistent with an

overload mode of failure. The examination suggested a general direction of failure from the aft to the forward edge of the rear pressure bulkhead panel.

2.11.6.4 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occupied the 7 to 9 o'clock position. Optical and SEM examination were undertaken on this item.

The fracture along the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation. Representative fracture samples were cut from the left-hand and right-hand edges of the fracture surfaces. Optical and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

2.11.6.5 Target 47 - Aft Cargo Compartment

This portion of the aft cargo compartment roller floor was located between BS 1600 and BS 1760. Based on the direction of cleat rotation on the skin panel (target 7) and the crossbeam displacement on this structure, target 47 moved aft in relation to the lower skin panel when it was detached from the lower skin. No other significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

2.11.6.6 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between BS 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

2.11.6.7 Target 399 - Left-Hand Side Triple Seat with Tray Arms

It would appear that this section was from row 18, seats A, B and C, the first set of triple seats aft of door 2L. The notable damage to this unit was as follows: front leg aisle side buckled and crushed in place; front leg window side buckled and crushed in place; forward edge tube to seat broken and bent downwards at joint with fore and aft tube between window and centre seats; and fore and aft tube between centre and aisle seat broken at start of T-connection to rear edge of seat tube. The damage suggests that the failures resulted from vertical loading. All the life-jackets were in place.

2.11.6.8 Target 399 - Fuselage Side and 2R Entry Door

The fuselage segment was located between BS 780 and 940. This piece was badly damaged and buckled inwards along a line through the lower door hinge. There were 12 holes or damaged areas on the skin generally with petals bending outwards. The curl on a flap around a hole had one full turn. This curl was in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal. When this target was recovered from the sea, along with it came a few hundred tiny fragments and medium-sized pieces. One of the medium-sized pieces recovered with this target was a floor stantion about 35 inches long. It was confirmed that this stantion belonged to the right side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the stantion.

Scientists from the Bhabha Atomic Research Centre, the National Aeronautical Laboratory and the Explosives Research and Development Laboratory in India conducted a metallurgical examination of certain items of wreckage. Their report on target 399 concluded that:

- the curling of the metal on the floor channel was indicative of a shock wave effect;
- the large number of tiny fragments from the disintegration of nonbrittle aluminum was a characteristic indication of explosive forces; and

- the indications of punctures, outward petalling around holes, curling of metal lips, reverse slant fracture, formation of spikes at fracture edges and certain microstructural changes all were indicative of an explosion.

2.11.6.9 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segment was located between BS 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

2.11.6.10 Target 362/396 - Lower Skin Panel - Forward Cargo Area

This section of skin panel was located between BS 720 and 860 and is just below target 399. The skin was badly crumpled and torn and had several punctures. It was pulled free from a large mass of debris which included some mangled cargo floor beams and roller trays. Some of the punctures had a feathered or spiked profile, with spikes angled at approximately 45 degrees to the edge. Other puncture holes gave clear indication of being formed by underlying stiffeners at impact. Two of these holes contained pieces of web stiffener. Most of the punctures were the result of penetrations from inside.

In the preliminary report of Mr. V.J. Clancy, representing Boeing, the following observations regarding target 362/396 were made:

- There were about 20 holes in the lower skin panel clearly resulting from penetration from inside.
- In addition to the fact that perforation was from inside, there were certain features which suggested that they were made by high velocity fragments such as those produced by an explosion. Mr. Clancy's report describes these features as follows:
- the presence of toothed or spiked edges at some parts of the metal which has petalled out from the perforations;

(Tardif and Sterling, Canadian Aeronautics and Space Journal, 1969, 15, 1, 19-27, obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.)

- the presence of marked curling (in some cases of more than 360 degrees) of some of the petals;

(Tardif and Sterling stated that such curling was a feature of explosively produced fragments.)

- the virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal;
- the virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object, thereby suggesting that the production of at least many of the perforations were separate independent events; and
- the presence of one perforation (identified as number 14) resembling a "bullet hole" that was clearly punched out - a type of hole usually associated with a high velocity missile.
- There was evidence that the forward part of the skin panel had been folded back inward along the line of station 760 and then bent back again along a line slightly forward of this station.
- Such folding, perhaps violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces, thus producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.
- One hole (identified as number 13) was almost certainly caused by a slipping wire rope used as a sling.
- Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken of this area for further examination for evidence of fire or explosives.
- A large number (several hundred) of small fragments were recovered. These varied in size from an inch or less to a few inches. They included fragments broken out of sheet metal, and these were reported to be from the same area as T362.
- The production of a large number of small fragments is generally regarded as an indication of an explosion.
- One piece, which was isolated, was about an inch square of sheet alloy with characteristic spikes on one edge similar to those described by Tardif and Sterling.

The following is an excerpt from the report by Mr. V.J. Clancy wherein he gives his opinion and conclusions regarding target 362.

"Opinion
The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.
Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.
A more detailed study, metallurgical and fractographic, is required.
The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.
The single "bullet hole," No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.
If the forward part of this item was forcefully and rapidly folded back to impact on the other part, it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility.
The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.
The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."
Mr. Clancy concluded that:
"there is strong circumstantial evidence that an explosion occurred but neither individually nor collectively do the several pointers give the degree of confidence necessary for a firm and final conclusion, at this

time."
With respect to target 362/396, in his report Mr. Clancy recommended:
"that firing trials be carried out projecting various size missiles at targets similar to the material of T362 to obtain reference samples for laboratory comparison with the perforations in T362."
The Indian report, in addition to the observations made by Mr. Clancy, noted the following with respect to the metallurgical examination:

- The microstructure in the various areas examined on target 362/396 confirmed explosive loading in this part of the aircraft.
- The holes and other features observed in targets 362/396 and 399 must have been due to shock waves and penetration by fragments resulting from an explosion inside the forward cargo hold.
- The chemical nature of the explosive material was not identified. No part of an explosive device, its detonator or timing mechanism was recovered.

2.11.6.11 Examination of Wreckage in India with CASB Participation
The examination of the targets recovered did not reveal any pre-existing defect, premature cracking or pre-impact corrosion damage associated with any of the failures.

3.0 DISCUSSION

3.1 Initial Event

From the correlation of the recordings of the DFDR, CVR and Shannon ATC tape, the unusual sounds heard on the ATC tape started shortly after the flight recorders stopped recording. The conversations in the cockpit were normal, and there was no indication of an emergency situation prior to the loud noise heard on the CVR a fraction of a second before it stopped recording. The DFDR showed no abnormal variations in parameters recorded before it stopped functioning. The only unusual observation was the irregular signals recorded over the last 0.27 inches of the DFDR tape. Laboratory tests indicated the possibility that these signals resulted from the recorder being subjected to a sharp disturbance at the time it stopped recording. The other possibility for the irregular signals on the DFDR is that they were caused by a disturbance to the Flight Data Acquisition Unit in the main electronics bay. Since there was an almost simultaneous loss of the transponder signal, this indicates the possibility of an abrupt aircraft electrical failure. The medical evidence showed a general absence of signs indicating that seat-belts were fastened. From the video and photographic examination of the wreckage on the bottom, it was ascertained that the majority of seats located did not have the seat-belts fastened. The above evidence indicates that the initial occurrence was sudden and without warning. The abrupt cessation of the data recorder could be caused by airframe structural failure or the detonation of an explosive device as the initial event. The millisecond noise on a CVR as observed in this case is usually, as described in the available literature, the result of the shock wave from detonation of an explosive device. However, in this case, certain characteristics of the noise indicate the possibility that the noise was the result of an explosive decompression. There is some disagreement regarding the cause and location of the source of the noise heard on the CVR, that is, whether the noise resulted from an explosive device or an explosive decompression and whether the noise originated from the rear or closer to the front of the aircraft.

3.2 Passenger/Flight Deck Area

From the examination of the wreckage recovered and wreckage on the bottom, there is no indication that a fire or explosion emanated from the cabin or flight deck areas. The medical examination of the bodies also showed no fire or explosion type injuries. However, pieces of an overhead locker coming from above door 2R or 4R had been blackened by fire. There was blackened erosion damage to the bottoms of some seat cushions, showing damage possibly from an explosive device, and the upper deck storage cabinet had a large rounded dent in the bottom inboard edge which might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet. It should be noted that the pieces of the overhead locker were found on the Welsh shore some time after the accident, and it is not known if the pieces were subjected to a fire after the accident. Also, it is not known if the damage to the seat cushions and the upper deck storage cabinet could have been caused by other means. Nevertheless, the above evidence suggests that some areas of the passenger cabin may have been subjected to minor fire and explosive damage possibly emanating from below the cabin floor.

3.3 Aircraft Break-up Sequence

The medical evidence showed a proportion of the passengers with indications of hypoxia, decompression, flail injuries and loss of clothing. The incidence of hypoxia and decompression indicates that the aircraft experienced a decompression at a high altitude. The flail injuries and loss of clothing indicate a proportion of the passengers were ejected from the aircraft before water impact. The severity of injuries increased from Zones C to E and was significantly less in Zone C than in Zones D and E.

The wreckage of the forward portion of the aircraft up to and including the aircraft body wheel well area and the wings was lying about 0.8 miles north of the vertical and horizontal stabilizers. Hence, it is likely that the aft portion of the aircraft separated from the forward portion before striking the water. In addition, the wreckage found west of longitude 12°48' consisted of suitcases and aft cargo compartment lower skin panels. There was also a wide scatter of sections 46 and 48 in an east-west direction, whereas the wreckage of the forward portion was mainly localized within a relatively small area.

The higher severity of injuries in the aft end of the passenger cabin appears to coincide with the break-up of the aft end, sections 46 and 48 of the aircraft. The fact that items from the aft cargo compartment were found further west than the tail section indicates that the aft cargo compartment ruptured first during the break-up sequence of the aft end. The forward portion of the aircraft was highly localized, which indicates that it struck the water in one large mass.

3.4 Aircraft Structural Integrity

As described earlier, the sudden nature of the occurrence indicates the possibility of a massive airframe structural failure or the detonation of an explosive device.

3.4.1 Aircraft Break-up

The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer before water impact. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.

The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile to the west indicating that there was some break-up of the number 3 engine before water impact.

The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction. Also, passenger seats viewed and recovered exhibited that they had been subjected to an upward force from below. They showed that the seats to the rear in sections 46 and 48 had their back legs buckled, and the seats toward the front had both front and back legs buckled. This indicates the vertical force was greater at the front than the rear of the aircraft. It is possible that this vertical force on the floor was caused by the force of the water during impact, but the rear of the aircraft broke up before impact and therefore any vertical loading on the floor in this area is unlikely to have occurred at impact. Twenty-three passengers also showed evidence of vertical impact injuries. These could have been caused from a force from below during flight or at water impact. Sixteen of these passengers had little or no clothing indicating that some may have been ejected before water impact. Therefore, there is some indication that the upward force on the floor may have occurred in flight and was more severe toward the front.

3.4.2 Aft Pressure Bulkhead

The localized impact mark found on the leading edge of the right horizontal root leading edge is indicative of an object striking the stabilizer in flight before water impact. This suggests that the loss of the tail plane was not the first event. The horizontal and vertical stabilizers were found separated and each was intact and in good condition. Items from the aft cargo compartment were found further to the west of the tail plane. The absence of the type of damage to the tail plane as was found in the Japan Airlines (JAL) Boeing 747 accident where the aft pressure bulkhead failed and which took place shortly after this occurrence, and the rupture of the aft cargo compartment before the loss of the tail indicate that there was not an in-flight failure of the aft pressure bulkhead. In addition, examination of the recovered portions of the bulkhead shows evidence of overload failures from the rear to front only and no evidence of any pre-existing defect, premature cracking or pre-impact corrosion damage.

3.4.3 Target 7 - Lower Fuselage Skin Panel

Target 7 which extends from BS 1480 to 1860 shows a break at the joint at BS 1480. The forward keel joint splice plate is bent and the keel joint holes are distorted and elongated. Some of the fracture surface was heavily corroded. An in-flight failure in this area would cause a massive failure of the aircraft's structural integrity. Further examination showed the fractures to be overload, and there was no evidence of an intergranular type fracture to suggest a stress corrosion cracking mode of failure. The corrosion was concluded to be post-impact and, therefore, there is no evidence to suggest an in-flight failure in this area as the initial event.

3.4.4 Structural Failure

The examination of the floating and recovered wreckage and the analysis of the photos and videos of the wreckage on the bottom failed to indicate any evidence of a failure of the primary or secondary structure as a result of a pre-existing defect. The initial event has been established as sudden and without warning. The abrupt cessation of the flight recorders indicates the possibility of a massive and sudden failure of primary structure; however, there is evidence to suggest that there were ruptures in the forward and aft cargo compartments prior to any failure of the primary structure in flight. Therefore, available evidence tends to rule out a massive structural failure as the initial event.

3.4.5 Explosive Device

A violent explosion occurring within an aircraft in flight usually leads to a complicated break-up mode and sequence of failure. Fractures of metal caused by an explosion are normally different in character to those caused by overstressing or crash impact forces. Shattering of metal into very small and numerous fragments and minute deep penetration of a metal surface are not usually found in aircraft accident wreckage. The size and characteristics of these particles often accompanied by rolled edges, surface spalling, pitting or evidence of heat are indicative of an explosion.

Of the floating wreckage, there is little to indicate the possibility of an explosion:

- the lining in one suitcase was severely tattered;
- although the wooden spares box was burned, this could have happened after the occurrence;
- although pieces of an overhead locker were damaged by fire, it is not known if the burning happened at the time of the occurrence;
- although the pieces of U-section alloy clearly indicated evidence of an explosion, it is quite possible that these pieces were not associated with the aircraft;
- the bottoms of some seat cushions show indications of a possible explosion;
- the inside of the right wing root fillet appears to have been scorched; and
- the deformation of the floor of the upper deck storage cabinet might have been caused by an explosive shock wave generated below the

cabin floor and inboard from the cabinet.
It is not known if the suitcase came from the aft or forward cargo compartment, and the location of the seats from which the cushions came is also unknown.
The scorching of the right wing root fillet and the damage to the upper deck cabinet suggest, if there was an explosion, it emanated from the forward cargo compartment.
From the examination of the recovered wreckage, the following deductions can be made:
- Target 47, which is a portion of the aft cargo compartment roller floor, shows no indications characteristic of an explosion emanating from the aft cargo compartment.
- Target 362/396, which is a lower skin panel from the forward cargo compartment is badly crumpled and torn and has about 20 punctures resulting from penetration from inside. It appears that some folding occurred on water impact which brought stringers or stiffeners from the aircraft structure into forceful contact with the internal surface of the panel producing most of the penetrations. However, there are certain punctures which indicate no evidence of impact marks on the inside surface and show evidence of being produced by high velocity fragments. Part of the inner surface of the skin panel appeared to have been blackened by soot from a fire.
- Target 399, consisting of a piece of the skin and stringers on the right side in the area of the forward cargo compartment contained holes and several hundred metal fragments. The damage to the floor stantion and the presence of the fragments are consistent with an explosion.
The examination of the recovered wreckage contains no evidence of an explosion except for targets 362/396 and 399 which contain some evidence that an explosion emanated from the forward cargo compartment.
An explosion in the forward cargo compartment would explain the loss of the DFDR, CVR and transponder signal as the electronics bay is immediately ahead of the cargo compartment.

3.5 Security Aspects

There is a considerable amount of circumstantial and other evidence that an explosive device caused the occurrence. Therefore, it is reasonable to examine the security measures in place on 22 June 1985. The evidence indicates that if there was an explosion, it most likely occurred in the forward cargo hold, not the passenger and flight deck areas or exterior to the fuselage. Although an explosive device could have been placed in a cargo hold in a number of ways, the available evidence points to the events involving the checked baggage of M. and L. Singh in Vancouver. The investigation determined that a suitcase was interlined unaccompanied from Vancouver via CP Air Flight 060 to Toronto. In Toronto, there is nothing to suggest that the suitcase was not transferred to Terminal 2 and placed on board Air India Flight 181/182 in accordance with normal practice. The aircraft departed Toronto for Mirabel and London with the suitcase unaccompanied. Similarly, a suitcase was interlined unaccompanied on CP Air Flight 003 from Vancouver to Tokyo to be placed on Air India Flight 301 to Bangkok. The explosion of a bag from CP 003 at Narita Airport, Tokyo, took place 55 minutes before the AI 182 accident. Therefore, the nature of the link between the two occurrences raises the possibility that the suitcase which was unaccompanied on AI 182 contained an explosive device.

3.5.1 Canadian Security Situation

Canadian security arrangements in place prior to 23 June 1985 met or exceeded the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand luggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

In Canada, the Department of Transport (Transport Canada) is responsible for establishing overall security standards for airports and airlines, and for the provision of certain security equipment and facilities at airports. By regulation, air carriers are responsible for applying security standards for passengers, for baggage and cargo and for ensuring security within individual aircraft. The RCMP provides airport physical security and responds to criminal incidents.

Air carriers contract for or otherwise provide the personnel who operate the security check-points through which passengers and their carry-on baggage enter the secure area of the airport terminal. These personnel also operate security equipment for the screening of cargo, passengers and checked baggage. Usually, air carriers use the service of private security firms. Transport Canada has established certain standards required for licensed security guards, such as the successful completion of the Transport Canada passenger inspection training program and annual refresher training. As stated earlier, a significant number of the security guards did not meet the criteria with respect to the completion of the training program and refresher training. In addition, the criteria do not require training for the screening of cargo and checked baggage. ICAO Annex 17 recommends that contracting States establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage or cargo intended to be carried on board aircraft. For all Canadian airlines, Canadian regulations before 23 June 1985 required a system of identification that prevented baggage, goods and cargo from being placed on board an aircraft if it was not authorized to be placed on board by the airline operator. However, if someone were to purchase a ticket, check in baggage and not board the aircraft, the baggage would in all likelihood have been authorized by the airline to be placed on board the aircraft. Therefore, it was possible to interline baggage unaccompanied and this explains how a suitcase was interlined to AI 181/182 from CP 060. It is not the normal practice of airlines to interline baggage if there is not a confirmed reservation to the destination. In this case, the ticket agent allowed the suitcase to proceed; however, if there had been a confirmed reservation, the suitcase would have been interlined unaccompanied without question.

3.5.2 Air India Security

Air India, as required by Canadian regulation, had a security program. Because of the threat level assessed against the airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and received extra security from Transport Canada and the RCMP for the month of June 1985. For Air India Flight 181/182, Air India provided a security officer from its New York office to oversee the security arrangements at Toronto and Mirabel. The security program at each airport was under the overall supervision of the respective Air India station managers. In Toronto, it was not clear who, if anyone, was undertaking this function.

It is not known if the suitcase interlined from CP 060 was screened before or after the X-ray machine broke down in Toronto. Although baggage not examined by X-ray was screened by a PD-4 sniffer, there are indications that the sniffer could have been ineffective in detecting explosives, especially plastics. Rather than using the sniffer, it would have been more effective to open all bags and physically inspect them. Even though a number of security personnel were not adequately trained in the screening of passengers and baggage, it is not known whether more training would have prevented an explosive device from being placed on board.

Although airline procedures required baggage to be accompanied, the agents checking in passengers in Toronto used a passenger security numbering system but did not number checked-in baggage, and baggage was not correlated with passengers. Therefore, the interlined unaccompanied suitcase from CP 060 was not detected. At Mirabel, checked-in passengers and baggage were numbered so that the number of passengers checking in baggage could be correlated with the number of passengers boarding the aircraft. Had a passenger-baggage correlation been carried out in Toronto, the suitcase from CP 060 would have been detected. The airline procedures would have prevented the placement of the suitcase on the aircraft.

Once loaded on the aircraft, the suitcase would have been placed in container 11L and 12L (see Appendix B) if in the forward cargo compartment, in container 44L or 44R if in the aft cargo compartment, or in position 52 if in the bulk cargo compartment. It could not be determined in which cargo compartment the suitcase was loaded.

Therefore, although the procedures were in place to prevent an explosive device from being placed on board the aircraft in checked-in baggage, there was a breakdown in the X-ray machine used to screen baggage, and there are indications that the PD-4 sniffer was inadequate. Also, the security numbering system used in Toronto was ineffective in preventing unaccompanied interlined baggage from being placed on board the aircraft.

4.0 CONCLUSIONS

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion.

4.2 Other Findings

Even though they may not be causal or related to the accident, the following additional conclusions can be drawn from the investigation with respect to certain security arrangements and their application pertaining to this flight:

1. In compliance with the International Civil Aviation Organization Annex 17 to the Convention on International Civil Aviation, the Department of Transport of Canada has made regulations requiring foreign aircraft operators who land in Canada to establish, maintain, and carry out certain security measures at airports.
2. In accordance with these regulations, Air India submitted a security

program to the Minister of Transport which included security measures with respect to aircraft, cargo, baggage, and passengers.

3. On 22 June 1985, an unaccompanied suitcase was interlined from Vancouver to Toronto on CAP Flight 060 for transfer in Toronto to Air India Flight 181/182.

4. The baggage loaded in Toronto was screened through an X-ray machine process but, during the course of this procedure, the X-ray machine broke down.

5. After the X-ray machine breakdown, an explosives detector was used to screen the baggage; the baggage was not opened and physically examined.

6. The effectiveness of the explosives detector is in doubt.

7. It is not known whether the unaccompanied suitcase interlined from Vancouver was screened before or after the X-ray machine broke down.

8. The security numbering system used in Toronto did not prevent unaccompanied interlined baggage from being placed on board the aircraft.

9. The normal procedures for interlining baggage in Toronto indicate that the unaccompanied suitcase was loaded on Air India Flight 181/182.

Appendix A

PAGE

DR. V. RAMACHANDRAN MR. J. S. GHARIA
CAPT. J. S. DHILLON MR. J. K. MEHRA
CAPT. B. K. BHASIN
SECRETARY
MR. S. N. SHARMA
FEBRUARY 26, 1986

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INTRODUCTION

1.1.1 On the morning of 23rd June, 1985 Air India's Boeing 747 aircraft VT-EFO (Kanishka) was on a scheduled passager flight (AI-182) from Montreal and was proceeding to London enroute to Delhi and Bombay. It was being monitored at Shannon on the Radar Scope. At about 0714 GMT it suddenly disappeared from the Radar Scope and the aircraft, which has been flying at an altitude of approximately 31,000 feet, plunged into the Atlantic Ocean off the south-west coast of Ireland at position latitude 51° 3.6'N and Longitude 12° 49'W. This was one of the worst air disasters wherein all the 307 passengers plus 22 crew members perished.

1.1.2 The fact that emergency had arisen was first noticed by Shannon Upper Area Control (UAC) after the aircraft had disappeared from the Radar Scope. The control gave a number of calls to the aircraft but there was obviously no response. Thereafter various messages were transmitted and that is how the rest of the world came to know of the accident.

1.1.3 Shannon Control at 0730 hours advised the Marine Rescue Coordination Centre (MRCC) about the situation which appeared to have arisen. MRCC, in turn, explained the situation to Valencia Coast Station and requested for a Pan Broadcast. Thereafter ships started converging on the scene of the accident and they commenced search and rescue operations.

1.1.4 The aircraft in question - Kanishka, was named after the most powerful and famous king of the Kushanas who perhaps ruled in India from AD 78 to AD 103. Besides being a great conqueror, he was an ardent supporter and follower of Budhism - a religion which preaches non-violence. Emperor Kanishka, however, met a violent end. After 25 years of reign he was killed by some of his own subjects. His life was thus brought to an abrupt end.

1.1.5 It is indeed ironical that the Jumbo Jet which bore the name 'Kanishka' also met with a violent and a sudden end on that fateful morning of 23rd June, 1985.

INITIAL ACTION TAKEN BY THE GOVERNMENT OF INDIA

1.2.1 Initial intimation of the accident was received by Air India who, in turn, communicated the same to Mr. H.S. Khola, Director of Air Safety, Civil Aviation Department, New Delhi. The Accident Investigation Branch of United Kingdom also sent information to the Director General of Civil Aviation, New Delhi to the effect that the accident had taken place on international waters and as such it was India which was the authority to investigate the accident in accordance with the provisions of ICAO Annex 13.

1.2.2 Thereupon Order No. AV.15013/8/85-AS dated 23rd June, 1985 was issued by the Director General of Civil Aviation whereby Mr. H.S.Khola was appointed Inspector of Accidents for the purpose of carrying out the investigation into the aforesaid air accident. This appointment was made under Rule 71 of the Aircraft Rules, 1937.

1.2.3 While search and rescue operations were underway at the site of the accident, a team of officials headed by Dr.S.S. Sidhu, Secretary, Ministry of Tourism & Civil Aviation rushed from India to Cork. The said team was joined by Mr. Kiran Doshi, the Indian Ambassador to Ireland, and also by two officers of the Indian Navy who were attached to the Indian High Commission at London. Subsequently two Medical Experts from India also joined the said Team.

1.2.4 The Indian Team arrived at Cork, Ireland on 24th June, 1985. Representatives of the Governments of United States of America, Canada and United Kingdom also reached there that day. They were met by the representatives of the Government of Ireland.

1.2.5 The members of the Team saw the rescue and salvage operations being conducted. They also visited the Cork Regional Hospital and had discussions with Irish and other Authorities with a view to release the bodies of the victims which were being brought to Cork.

1.2.6 For facilitating the process of investigation the Inspector of Accidents after consulting the representatives of the aforesaid Governments formed the following groups:

a. Structures, Power Plant and Systems Group.

b. Operations Weather & ATS Group.

c. Medical and Human Factor Group.

d. Search & Rescue Group.

The aforesaid groups were required to collect evidence and to submit their respective reports to the Inspector of Accidents.

1.2.7 The bodies which were being recovered were brought to the Cork Regional Hospital for identification and post-mortem. At that time it was considered proper that apart from the two medical experts from India, Wing Commandor Dr.I.R. Hill, who is an expert in aviation pathology should also be called from United Kingdom.

1.2.8 It was also being speculated that the accident may have occurred due to an explosion on board the aircraft. In order to see whether there was any evidence of an explosion which could be gathered from the floating wreckage which was being salvaged, the Government of India requisitioned the services of Mr. Eric Newton, a Specialist in the detection of explosives sabotage in aircraft wreckage.

1.2.9 In order to coordinate and guide the operations of the various ships working at the crash site, a control centre was set up at Cork Airport on 30th June, 1985.

1.2.10 The control centre was manned by representatives of the Governments of Ireland, Canada and United States. The Indian Naval Officers from the High Commission at London were overall in-charge of this centre. After the flight recorders had been recovered the centre continued to function, but the representatives of the United States departed.

1.2.11 For retrieving the Cockpit Voice Recorder (CVR) and Digital

Flight Data Recorder (DFDR), a cable ship named Leon Thevenin was engaged which had on board Submersible Robot (Scarab) which was fitted with a Sonar receiver and TV Cameras. The aforesaid ship was engaged and after an intensive search CVR and the DFDR (more popularly known as 'the black boxes') were located and retrieved on 10th July and 11th July, 1985 respectively.

1.2.12 The Government of India, in exercise of the powers conferred by Rule 75 of the Aircraft Rules, 1937 vide Notification No. AV. 15013/10/85-A, dated 13th July, 1985, directed that a formal investigation of the accident be carried out. Mr Justice B.N. Kirpal, Judge of the Delhi High Court, was appointed as the Court to hold the said investiation. The Central Government also appointed Dr. V. Ramachandran of National Aeronautical Laboratory, Bangalore; Mr. J.S. Gharia of Explosive Research and Development Laboratory, Pune; Captian J.S. Dhillon, retired Director of Operations, Air India, Bombay; Mr. J.K. Mehra, retired Manager (Technical Training), Indian Airlines, Hyderabad and Captain B.K. Bhasin, Deputy Managing Director of Indian Airlines, New Delhi to act as Assessors of the said Investigation. The Court was required to make its report to the Central Government by 31st December, 1985, which date was later extended to 28th February, 1986.

1.2.13 Mr. S.N. Sharma, Director of Airworthiness, Civil Aviation Department, was appointed as Secretary to the Court vide Ministry of Tourism & Civil Aviation letter No. AV/15013/10/85-A, dated 22nd August, 1985. The appointment was to take effect from 13th July, 1985.

ACTION TAKEN BY IRELAND, INCLUDING THE CORK REGIONAL HOSPITAL

1.3.1 The accident had occurred on the Atlantic Ocean approximately 100 miles south-west of the coast of Ireland. It is the Air Traffic Control at Shannon, Ireland who first became aware of the tragic event.

1.3.2 On coming to know of the accident, various authorities in Ireland took immediate action. The Shannon ATC asked the Marine and Rescue Coordinating Centre there to take emergency action. Thereupon MRCC, Shannon asked Valantia Coast Radio Station (CRS) for a PAN broadcast requiring all the vessels in areas 51N/1250W to keep a look out for the wreckage of an aircraft. The PAN broadcast was repeated and all ships were directed to proceed to the site of accident which was determined as 5101.9N/1242.5 W.

1.3.3 Irish authorities also took great pains in rendering every possible assistance to the Indian and other authorities. Some of the wreckage which had floated in to the west coast of ireland was transported to Cork where a boat house had been hired by the Government of India. The wreckage which was placed in the said boat house was protected from any outside interference by the local Gardai (police).

1.3.4 Irish ships proceeded to the scene of accident and helped in search and rescue operations. The ATC at Shannon gave details about the accident, in so far as they were aware of it, and copies of the ATC tapes were supplied. Aer Lingus, national airline of Ireland, provided assistance by making available its local engineering facilities to the coordinating centre at Cork and also to the other authorities.

1.3.5 Cork is a city having a population of approximately 1,34,000. One of the hospitals which was opened in 1978 is the Cork Regional Hospital which had been set up to meet the needs of the people. This 600-bed hospital was designated for the purposes of the Major Accident Plan of the Southern Health Board and thus became the appropriate centre for the reception of the casualities of the Air India disaster. Since the hospital first opened, it had dealt with a number of major accidents involving road, rail and marine incidents. The Major Accident Plan of the Southern Health Board sets out formally, the strategy and procedure which the hopital is required to follow while deailing with major accidents.

1.3.6 On the morning of 23rd June, 1985 at approximately 11.20 A.M. the hospital was put on alert following the disappearance of the Air India Flight 182 off the south-west coast of Ireland. The first message which was communicated to the hospital indicated that it was unlikely that there would be any survivors. The key hospital personnel were alerted and a meeting was arranged in the hospital for the purposes of discussing and making arrangements for the receipt of the bodies on the basis of the information which was available at that time.

1.3.7 On being informed that there were no survivors in the accident and that the hospital should be prepared to receive a large number of bodies, then, in accordance with the Major Accident Plan, mortuary facilities were improvised by appropriating the gymnasium attached to the Deparatment of Rheumatology. Subsequently it became evident that additional mortuary and postmortem facilities would be needed. In order to decide where the second mortuary was to be located, the hospital had to take into cosideration the following factors:-

(a) The number and the condition of the bodies;

(b) The period during which the bodies would be retained;

(c) The hospital would be required to provide an on-going service for in-patients, out-patients and serious accident and emergency cases;

(d) To avoid unnecessary internal transport problems, the bodies should be near the Post-Mortem and Pathology Departments; and

(e) To facilitate traffic flow in the hospital curtilage and to to aviod unduc public access.

The hospital authorities accordingly located the second mortuary in a recreational room adjoining the gymnasium.

1.3.8 Two rooms were put at the disposal of the Garda (Police) authorities for use as Garda Control Rooms in the hospital. Telecommunications lines were set up immediately for their assistance as the Gardai was responsible for the forensic and identification procedures in regard to the bodies brought to the hospital.

1.3.9 A small Co-ordinating Group was set up consisting of the Chief Executive Officer of the Southern Health Board, Medical Co-ordinating Officer, Press Liaison Officer, a Senior Registrar who knew about Indian customs and traditions and a Hospital Administrator. This small Co-ordinating Group, whose membership never changed, worked together and were capable of assessing situations, making decisions, liaising with other agencies and services and undertaking with other agencies and services and undertaking responsibility for hospital press releases. Apart from individual contact between members, the Group had a standing arrangement to meet every morning and afternoon. In the late evening, the Group, met the Garda, Hospital Pathologists and key staff members for a general review of progress and to decide the tasks and objectives for the following day.

1.3.10 Within a few hours, the Co-ordinating Group realised that the hospital was a world focal point of the international media, and was required to:

a. Accommodate 131 bodies;

b. Provide pathological and Radiological services for each body;

c. Co-operate with the Garda in their forensic work;

d. Cater for relatives of the victims;

e. eet representatives of foreign Governments; and

f. Keep press agencies informed.

Thus began an operation which demanded a quick and dedicated response from all staff working in close cooperation with the Gardai. At the same time, the hospital was required to continue functioning in the delivery of normal in-patient and out-patient services. The Major Accident Plan, apart from alerting staff, provided the framework and basis for many decisions taken as events evolved. An additional advantage in the practical implementation of the Plan was the fact that the hospital had staff experienced in dealing with previous emergency situations and could marshal the extensive manpower resources available.

1.3.11 The hospital authorities also made the following arrangements:-

a. They briefed Government Ministers and Officials and other dignitaries who visited the hospital. They were taken round the hospital and were explained the arrangements which had been made.

b. Some of the services which were being provided at the hospital were either discontinued or postponed.

c. Bodies were received at the hospital and arrangements were made on their arrival to numerically label and certify as dead all the 131 bodies which were initially received. All the bodies, at that stage, had been individually placed in special purpose body bags. Initially, bodies were placed on tables, but, it was subsequently decided that it would be much easier for all concerned to place the wrapped bodies on polythene

covered floors.
d. Arrangements were made for carrying out of the post-mortem examinations. Three Pathologists from other city Hospitals were recruited to augment the existing staff. Dr. Harbison, State Pathologist, was in charge of this aspect of the operation. All the post mortem were completed by 27th June, 1985.
e. For the preservation of the bodies five refrigerated containers with a capacity to hold 140 bodies were hired. These containers were fitted with timber shelving.
f. Government Information Service was located in the Matron's Office.
g. The Army provided troops for the unloading of the bodies from the helicoplers at Cork Airport. They also supplied and erected two large tents for storing bodies after post mortem and embalming. Under Garda escort transport of all the bodies which were recovered was undertaken by the
Army and these arrangements were co-ordinated by Chief Ambulance Officer.
h. Embalming was carried out in the hospital and bodies were then coffined and the coffins with appropriate number plaques were subsequently laid out in the numerical order on the floor when all the post mortems had been completed.
I. All the embalmed bodies were x-rayed (whole body). The examination was completed on 28th June, 1985.
j. A provision was made for a 24 hour extended catering service to meet the needs of staff, Gardai, Army and other personnel involved including visiting relatives.
k. A simple plan was devised for dealing with the relatives. This was a sensitive task bearing in mind the varying religious beliefs, customs and cultures generally of the visiting relatives. Their main function was to provide moral and emotional support to the relatives.
l. As identification progressed, special arrangements were made to assist the relatives. They were met by teams of councellors from the Hospital as soon as they disembarked at Cork Airport and subsequently at the

Hospital. The relatives had the same Counsellor and Garda Officer throughout the identification procedure. An interesting development noted was that each family group of relatives, their Counsellor and Garda officers formed a single family unit transcending cultural barriers. On subsequent visits, families appeared lost if their own Counsellor was not immediately available to them. Usually, the Counsellor and the Garda officers accompanied the relatives, at their own request, for visual identification.

m. When plans were being formulated to receive the relatives, it had been hoped to discourage them from coming to the Hospital until such time as progress had been reported on the identification process. Practical experience subsequently proved this strategy to be inappropriate for a number of reasons. Apart from facilitating the collection from relatives of salient information on the victims, the most fundamental reason was the underestimation of the abiding wish of the relatives to be physically and psychologically as close as possible to their deceased dear ones. Moreover, it was the express wish of almost all relatives on arriving at Cork Airport to proceed directly to Cork Regional Hospital; there, they were given an informal talk by Air India and Garda representatives on the progress of the investigation and the methods of identification. Many of the relatives visited the hospital daily and remained there throughout each day.

n. Coach trips were arranged to Bantry Bay for the relatives; Bantry Bay is the nearest landmark from the site of the crash. Relatives visited the seaside to pay their last respects to the departed souls. These were solemn occasions when each relative prayed in his/her own way. Rose petals and wreaths were immersed in the sea in keeping with Indian traditions. The visit gave them mental satisfaction and in the early days following the crash, helped in diverting their attention while the investigative procedures were being completed.

o. A small number of visiting relatives had personal medical problems and they were treated at out-patient and in-patient levels at the Hospital.

p. Cork/Kerry Tourism Organisation helped to co-ordinate the accommodation of relatives between a number of hotels. Approximately seven hotels were used within a radius of twenty miles of the city for this purpose.

g. A number of press conferences were held. The Chief Executive Officer, directed that press photography and television filming be not allowed within the hospital in deference to the privacy of patients and in respect for the relatives wishes.

r. Responsibility for the identification of bodies rested with the Garda Authorities and the conditions under which bodies were released are summarised as follows :-

(I) Satisfactory identification

(ii) Consent of the Coroner

(iii) Proper authentification of the person claiming each body

All bodies arriving at Cork Regional Hospital had already been numerically labelled by the Garda Authorities. To prevent confusion, the bodies were then given identical numbers under the hospital major accident labelling system and this proved to be very helpful later during identification, investigations and recordings. A routine was established for examining and recording information about each body. Teams consisting of a doctor, nurse, clerical officer and Garda made the necessary examination, labelling and recording each body and such details as :-

a. Sex

b. Adult or child

c. Clothing

d. Jewellery and personal effects

e. Injuries

f. Obvious scars

Death was confimed in all cases. Each body was fingerprinted and photographed by Garda Technical Bureau Staff. Each body was subjected to autopsy, forensic and dental examination. All bodies were embalmed and following embalming, were photographed and x-rayed. This procedure was completed in respect of all the bodies by the evening

of the fifth day of the crash. The data from these investigations was collated on an Interpol form (pink) for each body. Similar ante-mortem information was obtained from the relatives about each victim on a separate Interpol form (yellow). When the information on the pink and yellow forms matched beyond doubt, a positive identification was made. It might be noted that the photographs originally taken by the Garda Technical Bureau Officers of each body were matched with photographs of the 131 embalmed bodies. When a positive identification was made, the relatives were shown photographs of the deceased. These photographs were available for inspection by Saturday, 29th June. As positive identification progressed,
personal effects were added to the identification process and finally, visual identification took place. For obvious forensic reasons, positive identification was necessarily slow and meticulous and, in fact, was made more difficult by reason of the fact that only 131 bodies out of the 329 passengers and crew were recovered. All 131 bodies were identified, the first positive identification was made on 27th June and the last on the 6th August. Each coffin had affixed to it a metal plaque clearly indicating the number assigned in the first instance to the body it contained. The bodies when identified were released by the Garda Authorities through the undertaker. The Coroner directed that a reasonable time would have to elapse before unidentified bodies could be disposed off an this was to be by way of burial. The final date for this purpose was fixed for 3rd August, 1985, but, this date was subsequently extended to 6th August, 1985, to coincide with the date of the Civic Commemoration Ceremony.
(s) Bodies of victims for identification were brought individually to separate viewing rooms, suitably decordated with flowers and with incense burning. Visual identification was performed in private by the relatives and moreover, it allowed them to pay their last respects in their own religious beliefs. An adjoining room was also made available where they could grieve in private. Subsequently, it was learnt that these arrangements were much appreciated by the relatives who articulated this appreciation by commenting that the arrangements provided were as

near as possible to the funeral rites observed in their domestic communities. The relatives were of the opinion that the special arrangements made conveyed a deep personal and individual response to the dignity of each victim which might otherwise be lost with such a large number of bodies.

(t) Procedures were laid down which were required to be followed and observed for the purposes of preventing infection.

(u) On 6th August, 1985 an interdenominational service was held in the morning. In the evening on that day a Civic Commemoration Ceremony was held which was attended by a large number of persons.

(v) A formal inquest was held by the Coroner in the Courthouse, Cork, which commenced on 17th September, 1985 and ended on 23rd September, 1985. The Coroner's Jury returned a verdict in accordance withmedical and pathological evidence.

ACTION TAKEN BY THE COURT

1.4.1 Despite the fact that Mr. H.S. Khola had been appointed as the Inspector of Accidents under Rule 71 of the Aircraft Rules, the Government thought it proper to appoint Mr.Justice B.N. Kirpal as the Court to investigate into the circumstances of the accident.

1.4.2 The appointment of the Court was made under Rule 75 of the Aircraft Rules, which is as follows :-

"75. Formal Investigation - Where it appears to the Central Government that it is expedient to hold a formal investigation of an accident it may, whether or not an investigation or an inquiry has been made under rule 71 or 74, by order direct a formal investigation to be held and with respect to any such formal investigation the following provisions shall apply namely

(1) The Central Government shall appoint a competent person (hereinafter referred to as "the Court"), to hold the investigation, and may appoint one or more persons possessing legel, aeronautical, engineering, or other special knowledge to act as assessors, it may also direct that the Court and the assessors shall receive such remuneration as it may determine.

(2) The Court shall hold the investigation in open court in such manner

and under such conditions as the Court may think fit most effectual for ascertining the causes and circumstances of the accident and for enabling the Court to make the report hereinafter mentioned.

(3) (i) The Court shall have, for the purpose of the investigation, all the powers of a Civil Court under the Code of Civil Procedure, 1908 and without prejudice to those powers the Court may :-

(a) enter and inspect, or authorise any person to enter and inspect, any place or building, the entry or inspection whereof appears to the court reguisite for the purpose of the investigation; and

(b) enforce the attendance of witness and compel the production of documents and material objects; and every person required by the Court to furnish any information shall be deemed to be legally bound to do so within the meaning of section 176 of the Indian Penal Code.

(ii) The assessors shall have the same powers of entry and inspection as the Court.

(4) The investigation shall be conducted in such manner that, if a charge is made or likely to be made against any person, that person shall have an opportunity of being present and of making any statement or giving any evidence and producing witness on his behalf.

(5)Every person attending as a witness before the Court shall be allowed such expenses as the Court may consider reasonable: Provided that, in the case of the owner or hirer of any aircraft concerned in the accident and of any person in his employment or of any other person concerned in the accident, any such expenses may be disallowed if the Court, in its discretion, so directs.

(6)The court shall make a report to the Central Government stating its findings as to the causes of the accident and the circumstances thereof and adding any observations and recommendations which the Court thinks fit to make with a view to the preservation of life and avoidance of similar accidents in future, including, a recommendation for the cancellation, suspension or endorsement of any licence or certificate issued under the rules.

(7)The assessors (if any) shall either sign the report, with or without reservations, or state in writing their dissent therefrom and their reasons for such dissent, and such reservations or dissent and reasons (if any) shall be forwarded to the Central Government with the report. The Central Government may cause any such report and reservation or dissent and reason (if any) to be made public, wholly or in part, in such manner as it thinks fit."

1.4.3 The Court, which is appointed under Rule 75, does not act as a 'Commission of Inquiry' which is usually appointed under the Commissions of Inquiry Act to inquire into any definite matters of public importance. The role of the Court, on its appointment under Rule 75 of the Aircraft Rules, is essentially that of an Investigator. It is for this reason that no procedure has been prescribed in the Rules which the Court is required to follow. While carrying out its functions, the Court is not only required to comply with the provisions of the Aircraft Act, and the Rules framed thereunder, but it must necessarily also keep in view the provisions of ICAO Annex. 13.

1.4.4. As an Investigator, investigating into an accident, the Court had to perform multi-farious duties and functions. Before referring to them, it would be pertinent to point out that whereas an Inspector of Accidents, who is appointed under Rule 71, would normally be belonging to the Civil Aviation Department and would have all the machinery available to him for conducting the investigation, the Court, when it is appointed to hold an investigation under Rule 75, lacks the basic infrastructure to conduct the investigation of such a magnitude. Assessors are appointed to assist the Court but the actual investigation work cannot be carried out by them. Despite these handicaps, the investigation continued smoothly primarily due to the fact that whenever directions were issued by the Court to any of the participants before it or to the Civil Aviation Department or any other Organisations, the directions of the Court were readily complied with. On a few occasions it also became necessary to require the Assessors to conduct the investigation, which they did with the help of other organisations.

1.4.5 As an Investigator, the first task which was undertaken was to see that the tapes from the Cockpit Voice Recorder, which had been salvaged, were recoverd from the recorders and subsequently analysed. Requisite directions were issued and the tapes were removed from their respective recorders on 16th July, 1985. This operation was carried out at the Air India workshop at Santacruz in the presence of the accredited representatives of Lockheed (manufactures of DFDR), Fairchild (manufacturers of CVR), Boeing Airplane Co., Canadian Air Safety Board (CASB), National Transportation Safety Board, USA (N.T.S.B), Air India and Government of India. The tapes so recovered were subsequently played and analysed.

1.4.6 On an appointment being made under Rule 75 the Court would become incharge of overall investigation of the accident. In that capacity, and in order to effectively discharge its functions, it became necessary for the Court to undertake the following tasks :-

(a) For getting first hand information, the Court had to personally inspect the wreckage which had been recovered and was housed in a boat yard in Cork. While in Cork opportunity was also taken to go to the Cork Regional Hospital and to have discussions with and be briefed by the hospital staff. A trip was also made to Shannon with a view to see and understand the working of the Secondary Radar System which was in use there. On this visit the original ATC tape, which contained communication betwen Kanishka and the ATC, was also heard.

As it was suspected that there may be a link between the blast which had taken place at Narita Airport on 23rd June, 1985 and the accident to Air India's flight 182, it was felt necessary to inspect the site of the bomb blast at Narita Airport.

On the aforesaid visit to Tokyo, the site where the blast had taken place was inspected which gave some, though very vague, idea of the detonating power of the blast. While in Tokyo meetings and discussions were also held with the police and Aviation Authorities. The Court also had the advantage of being able to meet members of the team investigating into the Japan Airlines Flight JL 123 accident which had occurred near Tokyo on 12th August, 1985. Similarities and dissimilarities between the two accidents were, to some extent, noticed and some information was exchanged.

Information was received, that some floating wreckage had been picked on the coast of England and it was possible that some of the places, which were so received, should be subjected to further detailed chemical and metallurgical examination. In order to decide this, it became necessary to visit RADRE, Kent, U.K. As a result of the inspection and the discussions there, it was decided by the Court that the pieces so recovered should be sent to BARC at Bombay for further analysis.

(b) Directions had to be given, from time to time, with regard to the mapping and salvaging of the wreckage which was being effected. It had to be decided as to how, and in what areas, the Scarab should continue to map the wreckage and take video films and still photographs. Based on the information received therefrom and after discussions with the experts, both Indian and foreign, a list was drawn up indicating the items which had to be salvaged. As the weather was likely to be unpredictable, with a possibility of its deteriorating rapidly, a priority list of items to be salvaged had also to be prepared, and this was done. In view of the fact that the Canadian ship John Cabot and the Scarab had a limited capacity, with regard to the size and weight of pieces which could be lifted from the bottom of the ocean, decision had also to be taken with regard to the deployment of another ship. As a consequence thereof a ship 'Kreuzturm' was also engaged in salvage operations.

(c) Directions had also to be given assigning work and duties to different teams of persons. As an Investigator, the Court was incharge of the entire work of investigation which was being carried out in different parts of the world. It not being possible for the Court itself to undertake all the tasks, decisions had to be taken as to how the investigating work was to progress and who would carry out the directions issued from time to time. For example, immediately after reaching Cork on 25th July, 1985 it was felt necessary that a team should be immediately sent to Canada in an effort to get relevant information from there in connection with the flight AI 182. Accordingly, a team of 3 persons headed by Mr. H.S. Khola was directed to proceed to Canada immediately. As a result of the efforts put in by this team, and with the considerable amount of cooperation, help and assistance rendered by the Canadian Authorities valuable information was received by the Court having direct bearing on the investigation. Yet another example in this regard was of requiring Dr. V. Ramachandran, one of the Assessors and an expert in Metallurgy, to be stationed on board the salvage ships during the recovery operations. The procedure which had to be followed by him was also determined. Information about the progress of the salvage operations was communicated on telephone to the Court at all times of day and night. On receipt of such information further instructions, when ever necessary, used to be issued.

(d) Discussions were held with the Indian experts in order to understand some of the complicated questions which had arisen during the investigation.

In an effort to be able to fully appreciate the effect of decompression, the Court visited the Institute of Aviation Medicine at Bangalore where explsoive decompression was simulated for the Court's benefit. Discussions were also held with other experts of aviation medicine who were also given copies of the post-mortem reports for their opinion. National Aeronautics Laboratory was also visited in Bangalore where meeting was held with experts in aerodynamics, structure and metallurgy. Visits to Bombay where more frequent and necessary so that the Court could get first hand information with regard to the work which was being done at BARC.

The investigation involved looking into matters concerning aviation, electronics, medicine etc. Not being familiar with these branches, the discussions which were held, were of immense help and assistance to the Court who had to understand all the evidence and information which it was gathering.

(e) The accident had attracted world wide attention. Right from the start of the investigation by the Court when the recorders were first opened in Bombay on 16th July, 1985 till the conclusion of the hearing, the Press and the TV were eager for information. It was felt that rather than the media resorting to speculation of getting wrong information, the Court itself or its representative should, as and when necessary, brief the media. In this connection interviews were given, both in India and abroad, which were broadcast over the television and printed in the Press. As a result of this, correct information was disseminated with regard to the progress of the investigation without disclosing the Court's opinion on the evidence which had been received.

(f) Finally, the Court had to conduct the formal investigation in Court. For this purpose it laid down the procedure which would be followed. Rule 75 of the Aircraft Rules required that the investigation would be in open court. It was, however, felt that in this particular case it would be advisable that some evidence should be obtained in Camera. The Court, accordingly, recommended that necessary amendment should be made in Rule 75 so that the Court was given the power to hold certain proceedings in camera when the circumstances so warranted. The suggestion of the Court was accepted and that resulted in Rule 75(2) being amended and, as a result thereof, the Court was given the power to hold proceedings in camera if the stipulated conditions existed.

COMMENCEMENT OF FORMAL INVESTIGATION

1.5.1 The object of setting up a court to investigate into an accident is primarily to find out the causes and circumstances of the accident and thereafter to make recommendations. Such an investigation is not in the nature of an adversary litigation between the participants before the Court. As such it should be the endeavour of all the participants to assist the Court in arriving at a correct conclusion.

1.5.2 Under Rule 75 of the Aircraft Rules, the procedure which has to be followed in the investigation of an accident is to be determined by the Court itself. While laying down the procedure which is required to be followed, the endeavour of the Court has necessarily to be to adopt such procedure which would help the court in being able to complete its task satisfactorily, and in the shortest possible time. Whenever an accident takes place, it is of utmost importance that the cause of the accident must be ascertained at the earliest so that if any remedial measures are to be taken then those steps should be taken without any undue delay.

1.5.3 In the present case, there were a number of factors which had to be kept in view while determining the procedure whichshould be followed. The accident had occurred over international waters and approximately at a distance of about 5000 miles from the place where the investigation was to be conducted, namely, New Delhi. The ill fated flight itself had commenced from Canada, and this meant that most of the evidence would only be available there. Matters were not simplified by the fact that the debris itself was lying at the bottom of the ocean, 2 miles under water. It became apparent, at the very beginning, that to recover the entire debris would be a superhuman task and it will not be possible to do so within the limited time span which was available.

1.5.4 It was thought that it would be of assistance if all the participants got together so as to determine what procedure should be followed. The procedure had to be such which would give an effective opportunity of hearing to all the participants, without in any way unduly prolonging the investigation.

1.5.5 The Court decided that, in order to obtain the views, it would be necessary and advisable to have a Pre-hearing Conference.

1.5.6 The first decision which had to be taken was as to who were to be given a participants status. Keeping inview the provisions of Annex 13, participants status was given to Governments of Ireland, Canada, USA and India. Similar status was also given to Boeing Airplane Co. and Air India. As there might have been some similarities or dissimilarities between the present accident and the accident of the Japan Airlines Boeing 747-SR and also because there may have been a possibility of the present accident being linked with the explosion which had taken, place at Narita Airport, Tokyo on 23rd June, 1985, an Observer's status was given to the Government of Japan.

1.5.7 Notices for holding of the Pre-hearing Conference on 16th September, 1985 were accordingly issued on 29th August, 1985. The agenda for the Conference was to be as follows :-

a. To make suggestions to the Court for its consideration, regarding the procedure to be followed in the conduct of the formal proceedings in the Court.

b. To draw up a tentative list of witness.

c. To draw up a tentative list of exhibits.

d. To determine the areas to be inquired into

e. To fix a date for the commencement of the public hearing.

f. Any other matter with the permission of the Court.

1.5.8 Except for the Government of Japan, all the other participants were represented at the said Pre-hearing Conference. After discussions had been held between the Court and the Participants, some decisions were arrived at regarding different items of the agenda.

1.5.9 Firstly the following points were framed, indicating the areas to be inquired into by the Court:

a. Whether the accident was caused by a structural failure?

b. Whether the accident was caused by some human effort?

c. Whether the accident was caused by some criminal act?

d. Whether the accident was caused by an external non-criminal act?

e. Based on the evidence on record, what steps should or can be taken so as to ensure greater air safety.

1.5.10 It was further decided that, as suggested by all the participants, at least critical portions of the wreckage should be recovered.

1.5.11 With regard to the recording of the evidence it was decided that evidence will, in the first instance, be taken by filling affidavits or by filling statements alongwith affidavits. Copies of the same were to be supplied to the other participants for their consideration. These affidavits were to be filed on or before 18th October, 1985 and a second Pre-hearing Conference was to take place on 30th October, 1985 at New Delhi when it was to be decided as to which of the persons should be called for cross-examination. It was determined that it is only thereafter that hearing would commence in open court.

1.5.12 A tentative list of witnesses was also drawn up and it was decided that on the next date names of more witnesses may be added and, furthermore, the participants would be free to file any affidavits which they deem fit including affidavits in rebuttal.

1.5.13 Another important decision which was taken at the Pre-hearing Confence was that a Structural Group was formed consisting of (1) Mr. H.S. Khola or his nominee (2) Representative of the Canadian Government (3) Representative of NTSB, USA (4) Representative of

Boeing Airplane Co., USA (5) Representative of Air India. This group was entrusted with the task of examining and analysing, initially in Seattle, USA, the video films and the still photographs of the wreckage. This group was also to indicate and decide the items of priorities of wreckage which had to be recovered. The report of this group was required to be submitted by 18th October, 1985. The report of the work done at Seattle was in fact submitted only on 25th October, 1985. This group was also given the liberty to associate any other experts or persons from Boeing or any other Authority. The group was also to inspect the floating wreckage which had already been salvaged and any further wreckage which would be salvaged.

1.5.14 Although the affidavits by way of evidence had to be filed by 18th October, 1985, it was only the Government of Ireland who filed an affidavit by at date. On behalf of the Government of India, an application was filed asking for more time. The reason stated was that the affidavit which had to be filed was to be of Mr. H.S. Khola but he was out of India as he was heading the structures group which was evaluating the video films and photographs at Seattle. The Court had no option but to grant further time to the Union of India to file its affidavits and this necessarily resulted in the adjournment of the Pre-hearing Conference which had been fixed for 30th October 1985.

1.5.15 As the salvage operations were reaching a critical point it became necessary for the Court to go to Cork on 27th October, 1985. Taking advantage of the presence of the Court in Cork, other participants also came there. Besides them, representatives of CP Air and Air Canada also arrived. At one of the informal meetings between the Court and the representatives of the participants, applications were filed by CP Air and the Air Canada, inter alia, praying that they should be permitted to participate in the investigation. It might be mentioned here that CP Air had interlined one of the passangers from Vancouver to AI-182, while Air Canada was the handling agents in Canada of Air India. After hearing the participants it was decided that participant status should also be given to these two viz., CP Air and Air Canada.

1.5.16 The participant had all filed their affidavits by way of submissions. The Court indicated that formal hearings would be held for the purpose of cross-examining some of the witnesses about three weeks after the receipt of all the reports of the various groups. While in Cork, in the first week of November, 1985 some of the salvaged pieces of the wreckage were brought there. After they were inspected by all the participants and their advisers, who were present in Cork, it was decided by the Court that further detailed metallurgical and other examination of those pieces would be done at BARC, Bombay. In order that there should be no undue delay the Court decided that a Group be constituted consisting of expert representatives of all the participants and also the nominees

of the Court. This group was asked to carry out metallurgical and other examination of some of the critical pieces salvaged and give its report to the Court. The group consituted as a 'Committee of Experts' was as under :-

a. Mr. A.J.W. Melson, Canadian Aviation Safety Board, Canada.
b. Mr. R.K. Phillips, Canadian Pacific Air, Canada.
c. Mr. T. Swift, Federal Aviation, Administration, USA.
d. Mr. R.Q. Taylor, Boeing Commercial Airplane Co., USA.
e. Mr. J.P. Tryzl, Boeing Commercial Airplane Co., USA.
f. Mr. J.F. Wildey II, National Transportation Safety Board USA.
g. Mr. S.N. Seshadri, Bhabha Atomic Research Centre, India (Coordinator).

1.5.17 The parties were informed in Cork that the report of Mr. H.S. Khola, Inspector of Accidents, would be available by about 8th November, 1985. It was then decided that the statements of the first batch of witnesses should be recorded from 20th November, 1985. It was also agreed that if some of the reports of the experts were not received, further examination of the witness may have to postponed.

1.5.18 After receipt of the report from Mr. Khola. on the 8th November, 1985, a notice of the holding of the Public Hearing was issued to all the participants. This notice indicated that the hearing would commence on 20th November, 1985. In the meantime, a Public Notice was also published in the daily "Times of India" in Delhi and

Bombay editions on 21st October, 1985 in which it was stated as follows :-

NOTICE AIR INDIA KANISHKA ACCIDFNT INVESTIGATION

The Government of India, vide Notification dated 13th July, 1985, appointed Hon'ble Mr. Justice B.N. Kirpal as a Court to investigate into the accident to Air India's Boeing 747 aircraft VT-EFO (KANISHKA) near the Irish Coast on 23rd June, 1985, when the aircraft was engaged on a scheduled passenger flight from Montreal to Bombay via London and New Delhi.

Any person having direct knowledge, who may desire to make representation concerning the circumstances or causes of the accident, may do so in writing in the form of an affidavit duly attested by an Oath Commissioner or a Notary Public and address the same to the undersigned so as to reach him within 15 days of the publication of this Notice.

S.N. SHARMA SECRETARY COURT OF INVESTIGATION COURT NO.10,DELHI HIGH COURT SHERSHAH ROAD NEW DELHI - 110 003

Pursuant to the aforesaid public notice no affidavit was received from any one.

1.5.19 The public hearing commenced on 20th November, 1985 and the first session concluded on 28th November, 1985. During this period statements of Mr. H.S. Khola, Wing Commander Dr. I.R. Hill and Sgt. Atkinson of R.C.M.P., Canada were recorded.

1.5.20 Till that date, report on the examination of the salvaged pieces had not been received. It was anticipated that the report would be available by mid December, 1985. In order to give the parties sufficient time to study the reports of all the experts it was decided that further evidence would be recorded from 22nd January, 1986.

1.5.21 After the reports were received from BARC; AIB; Farnborrough; NTSB; USA; and Mr. Bernard Caiger of CASB, Canada and the copies of the same had also been received by all the participants, recording of evidence commenced from 22nd January, 1986 and concluded on 30th January, 1986. In all statements of 13 witnesses were recorded.

1.5.22 At this stage it will be pertinent to make a few observations with regard to the procedure which was laid down for recording of evidence etc. As already indicated, most of the evidence was such which was not available in India. As a Court investigating the accident under the provisions of Aircraft Rules, it had no jurisdication to compel attendance of any witness from abroad. The Court also had no jurisdication, either under the Rules or under the provisions of Annex 13, to require any witness to be examined in a country other than the one in which the Court is holding the investigation. The Court was informed that, if called upon, some of the persons who were outside India may not be inclined to testify before the Court.

1.5.23 Faced with the aforesaid difficulty it became necessary, therefore, to evolve a procedure which would enable the Court to get the requisite information. As long as the Court was satisfied that the information which was being received was one which had been truthfully given by a person, it was immaterial as to the manner in which the information was received. It is for this reason that it was decided that evidence will, in the first instance, be given by way of affidavits. It was also provided that the statements could also be filed along with affidavits. This latter course was permitted so as to enable some of the statements, which had been recorded by members of the Royal Canadian Mounted Police, to be placed before the Court. These statements, of course, had to be accompanied, as they were, with the affidavits of the persons who had recorded the statements.

1.5.24 At one stage, by a formal application in writing, Air India had protested against this procedure being followed. By order dated 22nd November, 1985, an objection by Air India to the filing of the statements accompanied by affidavits, was dealt with by the Court in the following words :-

"With regard to the affidavits which have been filed by the Government of Canada, I would only like to observe in the Pre-hearing Conference on 16th September, 1985, it was decided that "Evidence will, in the first instance, 1985 be taken by filing affidavits or by filling of Statements along with affidavits." It was understood that if it is not possible to file affidavits of the persons who are in a position to give information then affidavits may be filed of other persons who may have recorded the statements of the persons who are in a position to give information. This is not an adversary litigation where one of the parties may lose because of lack of proof. One of the objects of setting up a Court to investigate into an accident is to find out the causes of the accident and to make recommendations. It is necessary for this purpose to get information which may be relevant. It is true that strictly speaking the statements which are annexed to the affidavits may not be admissible as evidence in a Court of Law when there is a litigation between the parties but considering limitations which we have, namely, where a Court like the present has no jurisdication to enforce the attendance of any witness who is outside this country and furthermore, the Court has no jurisdication to compel any one to give information, the procedure which was adopted was thought to be the most practical one for obtaining information in connection with the accident. Under the circumstances, the affidavits which have been filed along with the statements which have been annexed thereto which give information with regard to the accident, have to be taken on record."

1.5.25 Another advantage of following the aforesaid procedure was that the time which would have been taken in Court in examining of the witnesses was considerably reduced. After the participants had filed affidavits, the same were to be secrutinised and it was then to be decided as to which of the deponents or persons should be called for examination in Court. Effectiveness of this procedure which was adopted is apparent from the fact that though affidavits by way of evidence were filed in Court, ultimately only 13 witnesses had to be examined in Court and sitings were held in Court only on 14 days.

1.5.26 Written arguments were filed on the forenoon of the 4th February, 1986 and oral arguments were heard in the afternoon of that day. No written arguments or oral submissions were made by the Government of Ireland, CP Air or Boeing Company.

1.5.27 Mr. I.G. Whitehall, councel for the Government of Canada took exception to some of the submissions which were contained in the written submissions filed by Air India. Mr. Whitehall contended that the Court had opined that it will not go into the question of responsibility of the unfortunate accident and therefore, there was no; justification for Air India to include in its written submissions numberous passages which tended to fix responsibilities.

1.5.28 By the order dated 4th February, 1986, it was made clear that it was not the intention of the investigation to apportion blame if any lapse had been committed and, therefore, the Court would ignore any written submissions which tended to apportion blame or responsibility for any lapse of any participants. It might here be mentioned that such a question had earlier arisen while the statement of Sgt. Atkinson was being recorded. The Court had then held that it will not go into the question as to who was responsible for the accident. It was in view of this order that no evidence was led by any of the parties on the question as to who may have been responsible for any possible lapse which could have led to this accident.

2.1 Flight Preparation

2.1.1. Air India Boeing 747 aircraft VT-EFO 'Kanishka' was operating flight AI-181 (Bombay-Delhi-Frankfurt-Toronto-Montreal) on 22nd June, 1985. From Montreal it becomes AI-182 from Mirabel to Heathrow Airport, London enroute to Delhi and Bombay. The aircraft arrived at Toronto from Frankfurt at 1830 Z and was parked at gate No. 107 Terminal 2 at L.N. Pearson International Airport. In accordance with the Canadian regulations, all the passengers and their baggage were off loaded to complete the customs and immigration checks. Transit cards were handed out to 68 transit passengers destined to Montreal who disembarked at Toronto for customs and immigration checks.

2.1.2. The flight from Toronto to Montreal was made up of the following:-

(I) Passengers originating at Toronto and their baggage.

(ii) Transit passengers, and their baggage, continuing their flight to Montreal.

(iii) Two diplomatic bags from Indian Consulate General, Vancouver via Air Canada Cargo Flight, and some Air India Mail.

(iv) Fifth Pod engine and its associated parts.

(v) Interline passengers and their baggage from connecting flights as detailed below:-

a) Air Canada flight AC-102
from Sasktoon - 2 Passengers

b) Air Canada flight AC-106
from Edmonton - 4 Passengers

c) Air Canada flight AC-170
from Winnipeg - 1 Passenger

d) Air Canada flight AC-170
from Winnipeg - 4 Passengers

e) Air Canada flight AC-136
from Vancouver - 10 Passengers

2.1.3. One passenger by name 'M. Singh', checked in at Vancouver on Canadian Pacific flight CP-060 (Vancouver-Toronto) of 22nd June 1985, and got his one piece of baggage interlined to Air India flight AI-181 even though he had no confirmed reservation on AI-181. This passenger, however, did not board the flight CP-060 at Vancouver and also did not check-in for Air India flight AI-181/182 at Toronto.

2.1.4 The checking-in of passengers for Air India flight AI-181/182 at Toronto began at 1830 Z. The checking-in of the passengers was carried out by Air Canada personnel who are the handling agents for Air India, and was supervised by Air India personnel. The Air Canada personnel indicated the computer sequeritial numbers (security numbers) on the passenger boarding card stubs. At about 1930 Z announcement was made for the primary security check of passengers and their hand baggage. The passengers passed through the Door Frame Metal Detector and their hand baggage was checked through X-Ray machine. The passengers were also subjected to physical security check with the help of Hand Held Metal Detectors. The transit passengers to Montreal and their hand baggage were also subjected to these security checks, while their checked in baggage, after clearance by the Canadian Customers authorities was placed by the passengers themselves on the conveyor belt while they were still in sterile area. In this way there was personal identification by the passengers of all checked in baggage, except the baggage which had been interlined to this flight.

2.1.5 The flight was closed for check-in at about 2150 Z. There were 10 'NO SHOWS' and 4 'GO SHOWS'. The security checked passengers remained in the holding area gate No. 107 till boarding was announced at about 2210 Z. At the boarding gate secondary security check of the passengers and their hand baggages was carried out. The passengers were frisked with the help of Hand Held Metal Detectors and their hand baggages were opened and physically checked.

2.1.6 The security numbers on the stubs were circled on the pre-numbered Security Control Sheet to ensure that all the checked-in passengers have boarded the aircraft. Passenger boarding was completed by 2300 Z. Traffic/Sales representative of Air India verified the Security Control Sheet with the number of stubs collected and the number of passengers checked-in.

He found that all the 202 passengers, who had checked-in, had boarded the aircraft.

2.1.7 As stated earlier, 68 transit passengers had disembarked at Toronto for completing the customs and immigration checks. However, only 65 of these passengers re-boarded the aircraft as per transit cards collected at the boarding gate. It is in evidence that almost every flight of Air India to Canada, two or three transit passengers do not re-board the flight at Toronto. Some Toronto passengers travelling to India buy their tickets "Montreal-India-Montreal" instead of "Toronto-India-Toronto", for which the fare is higher, and they travel by bus to Montreal to catch the Air India flight to India. On their return journey, when they get down at Toronto for customs and immigration checks, they simply do not re-board the flight even though their reservations are upto Montrteal. These passengers sometimes inform Air India personnel at Toronto about their not re-boarding the aircraft. On 22nd June, 1985, however, no such passenger informed Air India personnel.

2.1.8 There was a crew change at Toronto. The flight and cabin crew members who took over the flight AI-181/182 had been laid over in

Toronto for the week prior to the accident flight and were scheduled to take the flight upto London where they were to be relieved by another set of crew. Capt H.S.Narendra was the Commander of the flight, with Capt S.S.Bhinder as co-pilot and Mr.D.D.Dumasia as the Flight Engineer. In addition there were 19 cabin crew members. All the crew members reported together at the airport at 2130 Z. As per the practice existing at that time, the flight crew and cabin crew members were not subjected to frisking checks and their hand baggage were also not security checked. Their checked-in baggage was, howevewr, security checked along with the other checked-in baggage of passengers.

2.1.9 The interline baggage was brought to the international baggage make-up area by the Air Canada staff but, as mentioned earlier, it was not personally identified and matched with the passengers.

2.1.10 The checked-in baggage of the originating passengetrs and crew members of AI-181/182 was sent on a conveyer belt to the baggage make-up area. All the checked-in baggage along with the interline baggage was required to be security checked on the X-ray machine which was located in the baggage make-up area at the end of international belt No.4.

2.1.11 It has been reported that the X-ray machine worked intermittently for some period and at about 2045Z it broke down and there was no picture on the screen. The Machine could not be repaired on that day as it was a week-end and no technician could be contacted. Air India's Security Officer then advised that the rest of the baggage be checked with a PD-4 explosive detector provided by him. He also demonstrated the use of the PD-4 detec- tor to the concerned personnel. It has been reported that about 60 to 70 baggages were checked and cleared by the PD-4 detector.

2.1.12 The security checked baggage was loaded in the containers by the Air Canada personnel. The loading of the baggage in containers was over by about 2230 Z. The ramp personnel of Air Canada carried the container and loaded them in the aircraft.

2.1.13 From March, 1985, after the introduction of Air India flight AI-181 through Toronto, diplomatic bags from Indian Consulate General at Vancouver were being sent to India by Air India flight from Toronto. Accordingly, two diplomatic bags, duly sealed and escorted, were delivered to Air Canada office at Vancouver on 21st June and they arrived at Toronto by Air Canada flight AC-580. One of the bags Sl.No. 49 contained 13 empty large diplomatic bags while the other bag Sl.No. 50 contained diplomatic mail. The total weight of the bags was 13.8 Kgs.

2.1.14 In addition to the above, a few envelopes containing some flight documents addressed to Accounts Office, Air India, Bombay, and one envelope addressed to Commercial Headquarters, Air India, Bombay from Air India Town Office in Toronto, were collected by Messrs Mega International.

2.1.15 The aircraft was refueled by CAFAS with 14,602 litres of fuel.

2.1.16 On 8th June No. 1 engine of Air India Boeing 747 aircraft VT-EGC had failed during take off. The failed engine was to be ferried to Bombay on flight AI-181/182 of 22nd June.

2.1.17 The failed engine and the associated parts were placed in Air Canada Engineering Hangar at Toronto airport since June 8,when the aircraft was brought to the engineering hangar for engine replacement. Air India had requested Air Canada on 15th June for preparing the failed engine for installation as fifth pod mounting of the aircraft on 22nd June.

2.1.18 On 15th June Air India deputed one of their foremen to Toronto to bring back the failed engine. From 17th to 21st June, Air Canada technicians prepared the failed engine for installation as fifth pod. This preparation involved removal of cowlings, fan blades, locking of compressor rotors etc. Air Canada Engineering/Maintence personnel loaded the aircraft/engine parts on 4 pallets and one container. These pallets and container were then delivered at 0100 Z on 22nd June by Air Canada personnel to Messrs Mega International cargo warehouse at Toronto Airport within restricted airport area. (Messrs Mega International Cargo Warehouse at Toronto Airport within restricted airport area. (Messrs Mega International is the cargo handling agent of Air India at Toronto). The fifth pod engine was transported by Air

Canada directly from their premises to the 'Kanishka' aircraft for mounting it on the fifth pod.

2.1.19 Installation of the engine on the fifth pod began immediately on arrival of flight AI-181 at Toronto on 22nd June and the work was completed by 1930 Z. One of the mechanics of Air Canada installed the Mach Air Speed Warning Switch in the Main Equipment Centre as part of the fifth pod engine installation.

2.1.20 The pre-loaded four pallets and one container were brought to the aircraft by M/s Mega International personnel from their warehouse in the afternoon of 22nd June for loading them into the aircraft cargo compartment at positions assigned by the Air Canada load agent. Difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fitting from the aft cargo compartment door cut-out. After removal of the fittings, the cowl could be loaded. All the removed fittings were then reinstalled.

2.1.21. On account of the delay in loading the cowls, departure of the flight was delayed by one hour and twentyfive minutes.

2.1.22 Maintenance Manager of Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft and no snag was observed by him. The commander duly accepted the aircraft.

2.1.23 Senior Flight Despatcher, Air India, Toronto did the flight despatch of AI-181/182 for sectors Toronto-Montreal-London. He briefed the flight crew members about flight plan, weather, Air Traffic Control and fuel requirements. The flight plans for the sectors Toronto-Montreal-London were duly accepted and signed by the Commander.

2.2 Progress of the Flight

2.2.1. The Aircraft took off from Toronto Runway 24L at 0016 Z on 23rd June, 1985. The Maintenance Manager, Security Officer and Passenger Service Supervisor of Air India travelled on board the aircraft for their duties at Montreal. In all there were 270 passengers on board in addition to 22 crew members.

2.2.2. The route from Toironto to Montreal was V-98/JHL-594/MSS/V 203/FRANX at flight level 290. The flight was uneventful and the aircraft landed at Montreal at 0110 Z. No snag was reported by the flight crew. The aircraft was parked at Cluster 1 Bay No.114.

2.2.3 Sixtyfive passengers destined to Montreal along with the three Air India personnel mentioned above deplaned at Montreal. The remaining 202 passengers, who had joined the flight at Toronto, remained on board the aircraft as transit passengers were not allowed to disembark at Montreal.

2.2.4 Baggage handlers off loaded three containers of baggage, one valuable container and four cargo containers from the aircraft.

2.2.5 Transit Check 'C' of the aircraft was carried out at Montreal. The Flight Engineer also carried out his pre-flight inspection and found that rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to an Air Canada Technician who flaired the handle and applied the high speed tape. There was no other snag observed during the inspection. The personnel of CAFAS refueled the aircraft with 96,000 litres of fuel. Total fuel on board at the time of take off from Montreal was 104,000 Kgs. which was adequate for 8 hours 40 minutes of flying. The commander accepted the aircraft and signed the 'Certificate of Acceptance' of the aircraft.

2.2.6 At approximately 2130 Z Air Canada personnel opened the passenger check-in counter for flight AI-182 (The flight AI-181 terminates at Montreal and the flight from Montreal to London-Delhi-Bombay is designated as AI-182). The checked-in baggage was sent to the baggage make-up
area. Between 2300-2350 Z, a suspect suitcase was identified as the X-Ray showed what appeared to be some wires next to the suitcase opening. The suitcase was placed on the floor next to the X-Ray machine. Subsequently two more suspect suitcases were located. These suitcases were also placed next to the X-Ray machine to await the arrival of the Air India Security Officer who was to arrive on Air India flight AI-181 from Toronto. The remainder of the checked-in baggage, which cleared the security check, was loaded in containers by Air Canada personnel for loading on board the aircraft.

2.2.7 Two diplomatic pouches from the Indian High Commission, Ottawa were brought to Mirabel. After the flight arrived, one of the pouches of Category 'A' weighing 1 Kg. was given to the Flight Purser. The other Category 'B' pouch weighing 9 Kgs. was placed in an valuable container 14R.

2.2.8 No other cargo was accepted for this flight except a small package (weighing less than 1 Kg) containing medicines for cancer treatment of a patient in New Delhi. This parcel was received at 1530 Z on 21st June and was loaded in container 14R by Messrs Mega International on 22nd June, more than 24 hours after its receipt.

2.2.9 Five baggage containers, one valuables container and two empty containers were loaded in the aircraft.

2.2.10 The checked-in passengers with their hand baggage went to the departure sterile area. At the entrance to the departure sterile area security staff used X-Ray units and metal detectors to check passengers and their hand baggages.

2.2.11. At approximately 0100 Z, 23rd June, after the primary security check was completed, the passengers proceeded to boarding gate No.80. At this lcoation the secondary security check was done on passengers using hand held metal detectors. Hand baggages were also subjected to further physical and visual check by them.

2.2.12. A total of 105 passengers boarded the flight AI-182 at Mirabel Airport. It was determined that all the passengers who had checked-in, boarded the aircraft. There was no interline passenger. At Montreal there were five 'NO SHOWS' and two 'GO SHOWS'. In all 307 passengers were on board the aircraft. The flight plan and the load and trim sheet, however, indicated 303 passengers as four of the 6 infants were not included in the passenger list.

2.2.13. The seating distribution of the passengers was as given below:-

Zone/Class Total number of Seats Occupied seats Zone 'A' - First Class 16 1 Zone 'B'- Club Class 22 - Upper deck - Club class 18 7 Zone 'C' - Economy Class 112 104+ 2 Zone 'D' - Economy Class 86 84+ 1 Zone 'E' - Economy Class 123 105+ 3 377 301+ 6

(Infants)
2.2.14 The seating distribution of the 19 cabin crew members was as follows:-
Two at door L1 and two at door R1
Two at door L2 and two at door R2
Two at door L3 and one at door R3
Two at door L4 and one at door R4
One at door L5 and one at door R5
One in crew rest area, Zone 'A'
One in jump seat upper deck
One crew rest area upper deck.

2.2.15 The three suspected suit cases were not loaded on the aircraft and were detained in the baggage make-up room. After the names of the passengers to whom the suit cases had belonged had been identified the same were transferred to the decompression chamber of E1 A1 Airline where they were examined, with the aid of a Police Explosive Dog, with negative results. The suit cases were kept overnight in the said chamber and when they were opened it was found that they contained no explosive items.

2.2.16. No unclaimed baggage pertaining to the Air India flight was recovered either at Toronto or at Mirabel or Dorval Airport in Montreal.

2.2.17. The flight plan for the sector Montreal to London was filed on telephone by the Air India Flight despatch from Toronto to Dorval ATC Centre. He requested for route SHERBROOKE-COLOR-NAT XRAYBUNTY-MERLY-EXMOR-IBLEY-SAMTN-HAZEL-OCKHAM-LONDON at flight level 290 upto COLOR and flight level 330 thereafter. The reporting points on Track XRAY on that day were COLOR, 47N/50W, 49N/40W, 50N/30W, 51N/20W, 51N/15W, 51N/08W and BUNTY.

2.2.18 The aircraft took off from Montreal at 0218 Z. Its estimated time of arrival at London was 0833 Z. The CVR and the ATC tapes show that the flight was normal and quite uneventful. Suddenly at about 0714 Z, when the flight was being monitored by the Air Traffic Controller at Shannon, with the help of secondary surveillance radar, the aircraft disappeared from the radar scope. Subsequently, the ATC at Shannon got the know that the aircraft had met with an accident and its wreckage was sighted about 110 miles west south-west of Cork, Ireland.

PERSONNEL INFORMATION

2.3.1 Pilot-in-Command (Capt. H.S. Narendra)

2.3.1.1 Cap.t H.S. Narendra (age 561/2 years, date of birth 25th November, 1928) joined Air India on 1st October, 1956. He held ALTP Licence No. 247 valid upto 29th October, 1985 and FRTO No. 478 valid upto 23rd October, 1985. He was released as a Co-pilot on Boeing 707 aircraft on 21st July, 1960 and as a Commander on Boeing 707 aircraft on 17th September, 1964.

2.3.1.2 For conversion as Pilot-in-Command on Boeing 747 aircraft, Capt. Narendra had undergone ground training at Boeing Airplane Company, USA and simulator and aircraft flying training at Bombay in 1972. He completed his route checks for Pilot-in-Command endorsement between December, 72 and January, 73. He became a Commander on Boeing 747 aircraft on 14th February, 1973.

2.3.1.3 Details of Capt. Narendra's flying experience and licence renewal checks are as given below:

a. Total flying experience : 20, 379:15 hours

b. Flying experience on B-747 as

(i) Pilot-in-Command : 6,364.50 hours

(ii) Co-pilot : 123:45 hours

c. Day flying experience
on B-747 aircraft : 3,980:00 hours

d. Night flying experience
on B-747 aircraft : 2,508:35 hours

e. Flying experience during

(i) last 6 months : 301:45 hours

(ii) last 3 months : 159:40 hours

(iii) last 30 days : 68:45 hours

(iv) last 7 days : 9:00 hours

He had last flown as Pilot-in-Command on flight AI 181 (Frank- furt to Toronto) on 15th June, 1985.

f. Date of last licence
renewal and IR check : 8 May, 1985
g. Date of last route check : 24 March, 1985
h. Date of last medical
examination at CME,
Delhi : 29 April, 1985
i. Date of last simulator
refresher course : 19 December, 1984
j. Date of ground technical
refresher course : 6/7 May, 1985
k. Date of last flight
safety refresher course : 25 July, 1984
l. Rest period before
operating the accident
flight : 1 week

2.3.1.4 Records indicate that on 29th June, 1966, Captain Narendra was declared medically unfit for 2 months to reduce his weight by 10 Lbs. In February, 1973 he was advised to wear corrective by-focal glasses while flying. In May, 1975 he was again declared medically unfit for 3 months.

2.3.1.5 Capt. Narendra was earlier involved in the following two incidents:

(a) On 25th August, 1984, while operating flight AI-1100 from London to Delhi, there was a deviation of the aircraft by about 170 nautical miles from the track over Rahimyar Khan in Pakistan. He was given necessary INS refresher and Route checks with particular emphasis on cross checking procedure.

(b) On 6th December, 1984, while operating flight AI-124 Delhi-Bombay, the aircraft was observed approaching runway 32 at Bombay Airport when runway in use was 27. Captain Narendra was given simulator training for a series of approaches and landings and visual circuits from right hand and left hands seats for approaches and landings on runway 27 at Bombay Airport.

2.3.1.6 Captain Narendra was not involved in any accident previously.

2.3.2 Co-pilot (Capt. S.S. Bhinder)

2.3.2.1 Capt. S.S. Bhinder (age 411/2 years, date of birth 30th November, 1943) joined Air India on 12th October, 1977. He held ALTP Licence
No. 940 valid upto 25th July, 1985 and FRTO Licence No. 2290 valid upto 2nd February, 1986.

2.3.2.2 Capt. Bhinder was released as a Co-pilot on Boeing 707 aircraft on 18th November, 1978 and as a Co-pilot on Boeing 747 aircraft on 17th May, 1980.

2.3.2.3 Details of his flying experience and licence renewal checks are as given below:

a. Total flying experience : 7,489:00 hours

b. Experience on B-747
aircraft as Co-pilot : 2,469:30 hours

c. Day flying experience
on B-747 aircraft : 1,426:15 hours

d. Night flying experience
on B-747 aircraft : 1,043:15 hours

e. Flying experience during

(i) last 6 months : 157:45 hours

(ii) last 3 months : 65:00 hours

(iii) last 30 days : 20:15 hours

(iv) last 7 days : 9:00 hours

He had last flown as Co-pilot on flight AI-181 (Frankfurt to Toronto) on 15th June, 1985).

f. Date of last licence
renewal check : 25th March, 1985

g. Date of last IR check : 23rd November, 1984

h. Date of last route check : 9 April, 1985

i. Date of last medical
examination at CME
Delhi : 14 January, 1985

j. Date of last simulator

refresher course : 16 July, 1984
k. Date of last ground technical
refresher course : 8/9 October, 1984
l. Date of last flight
safety refresher course : 3 December, 1984
m. Rest period before operating
the accident flight : 1 week.

2.3.2.4 Records indicate that Capt. Bhinder was not involved in any accident earlier.

2.3.3 Flight Engineer (Mr. D.D. Dumasia)

2.3.3.1 Flight Engineer Mr. D.D. Dumasia (age 57 1/2 years, date of birth 10th October, 1927) joined Air India on 27th December 1954. He held flight Engineer's Licence No. 37 valid upto 6th December, 1985. Mr. Dumasia was released as a Flight Engineer on Boeing 707 airecaft on 16th December, 1963 and on Boeing 747 aircraft on 6th February, 1974. He had a total flying experience of 14,885 hours out of which 5,512:35 hours were on Boeing 747 aircraft.

2.3.3.2 Last medical examination of Mr. Dumasia was completed on 1st October, 1984 at CME Delhi. He had completed simulator refresher course on 14th February, 1985, ground technical refresher course on 14/15th January, 1985 and flight safety refresher course on 13th August, 1984.

2.3.4 Cabin Crew

2.3.4.1 A total of 19 cabin crew members were on duty on Flight AI-181/182 on 23rd June, 1985. Their brief details are as given below:

Sl.No. Names Designation Flight Safety course completed on 1. Mr. S.L. Lazar Inflight Supervisor 1/2 April, 1985 2. Mr. K.M. Thakur Flight Purser 18 February, 1985 3. Mr. Inder Thakur Flight Purser 9/10 May, 1984 4. Mr. Shukla Flight Purser 23 January, 1985 5. Mr. S.P. Singh Flight Purser 15 January, 1985 6. Mr. N. Vaid Asst. Flight Purser 2/3 May, 1985 7. Mr. B.K. Sena Asst. Flight Purser 3 December, 1984 8. Mr. N. Kashipri Asst. Flight Purser 12/13 Sept., 1984 9. Mr. J.S. Dinshaw Asst. Flight Purser 17/18 Dec., 1984 10. Mr. K.K. Seth Asst.

Flight Purser 11/12 February, 1985
11. Miss Raghavan Airhostess 13 July, 1984 12. Miss S. Ghatge Airhostess 10/11 April, 1985 13. Miss R. Bhasin Airhostess 11/12 February, 1985 14. Miss L. Kaj Airhostess 17/18 April, 1985 15. Miss P. Dinshaw Airhostess 17/18 Dec., 1984 16. Miss S. Lasarado Airhostess 15/16 April, 1985 17. Miss E.S. Rodricks Airhostess 10/11 June, 1985 18. Miss S. Gaonkar Airhostess 3/4 April, 1985 19. Miss R.R. Phansekar Airhostess 29/30 April, 1985 AIRCRAFT INFORMATION

2.4.1 General

2.4.1.1. Boeing 747-237B 'Kanishka' aircraft VT-EFO was manufactured by Messrs Boeing Company under Sl.No. 21473. The aircraft was acquired by Air India on 19th June, 1978. Initially, it came with the expert Certificate of Airworthiness No. E-161805. Subsequently, the Certificate of Airworthiness No. 1708 was issued by the Director General of Civil Aviation, India on 5th July, 1978. The C of A was renewed periodically and was valid upto 29th June, 1985. From the beginning of June, 1985, C of A renewal work of the aircraft was in progress. The aircraft had the Certificate of Registration No. 2179 issued by the DGCA on 5th May, 1978. The commercial flight of 'Kanishka' aircraft started on 7th July, 1978.

2.4.1.2 The aircraft was maintained by Air India following the approved maintenance schedules. It had logged 23634:49 hours and had completed 7525 cycles till the time of accident.

2.4.1.3 The aircraft was fitted with four P & W JT9D-7J engines having thrust rating of 48650 pounds. The hours and cycles logged by the engines since new till the time of accident are as given below:

Engine No.1 : P662927-7J - 29,663:26 Hrs (9422 cycles)
Engine No.2 : P695610-7J - 20,810:28 Hrs (6031 cycles)
Engine No.3 : P695602-7J - 21,992:31 Hrs (6564 cycles)
Engine No.4 : P662926-7J - 32,332:15 Hrs (11295 cycles)

2.4.1.4 All the DGCA mandatory modifications and inspections applicable to the subject aircraft had been compiled with. No major component installed on this aircraft and its engines had exceeded the stipulated life period.

2.4.1.5 The last quarter Periodic Check of the aircraft was carried out on 24th May, 1985, at 23274:53 hours and 7439 cycles. Subsequent to this check, two Check 'B' schedules were carried out. The last Check 'B' was carried out on 17th June, 1985, at 23564:14 hours and 7510 cycles and was valid for 200 flying hours.

2.4.1.6 The aircraft had flown 359:56 hours and 86 cycles since last quarter Periodic Check and 70:35 hours and 15 cycles since last Check 'B' till the time of accident.

2.4.1.7 The last Flight Release Certificate was issued on 24th May, 1985 on completion of quarter Periodic Check and was valid for 1100 hours or 150 days elapsed time whichever occurred first. After the last departure from Bombay on 21st June, 1985, the aircraft had flown for 22:34 hours till the time of crash.

2.4.1.8 Mr. Rajendra, Maintenanace Manager, Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft at Toronto on 22nd June, 1985 and no snag was observed by him. No snag was reported by the flight crew during the flight from Toronto to Montreal. Transit Check 'C' of the aircraft for the flight AI-182 was carried out at Montreal by Mr. Rajendra and three Air Canada technicians. The flight engineer also carried out his pre-flight inspection and found that the rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to Mr. P. Bayle, Air Canada technician who faired the handle and applied high speed tape. No other snag was observed during the inspection.

2.4.2 Previous Incidents and Snags

2.4.2.1 A maintenance Group was formed with representatives from Air India and Airworthiness Directorate with Mr. R.K. Paul, Senior Air Safety Officer as the Group Leader to scrutinise the maintenance documents and various defects experienced on this aircraft. The report submitted by the Group (Attachment 'B') indicates that the aircraft was involved in six incidents since the last C of A renewal, details of which are given below

(I) On 13th July, 1984 at Dubai -- flight AI-868 The aircraft returned

after aborting take off due to no rise in the EPR and N1 on No.1 engine (Sl.No. 695612). The engine front and rear were checked and found OK. Slight wetness was noticed in the bleed outlets. No external oil leak was noticed. Oil quantity was topped up. The chip detectors and oil filter were found OK. EVC Ph filter was found
OK. EVC linkage wes exercised. The engine was run up and its operation was found satisfactory. The snag was suspected to be due to lack of pressurising air at low N1.

(ii) On 18th July, 1984 at Delhi -- flight AI-105 The right hand side fuselage skin between stations 480 and 500 in line with lower portion of forward cargo door cut-out was damaged by high lift. The same was repaired at Delhi. Permanent repair was carried out at Bombay. The repairs were accomplished using guidelines given in the Boeing Structural Repair Manual.

(iii) On 12th August, 1984, at Rome -- flight AI-135 The aircraft landed with No. 2 engine (Sl.No. 662826) shut down in flight due to oil pressure and oil quantity droping. On motoring the engine, oil leak was observed from metal line between F C O C and L O P switch at the switch end. The line was found cracked which was welded and refitted. The line was subsequently replaced at Bombay.

(iv) On 24th October, 1984, at London -- flight AI-104 There was total loss of No.1 hydraulic system fluid. The fluid leak was traced to inlet pressure adapter of flap control module in the left hand body gear wheel well. Two of the four bolts holding the adaptor on the flap control module had sheared. The hydraulic pump, seal, back-up ring and case drain filter were replaced. The flap control module was replaced when the aircraft arrived at Bombay.

(v) On 14th February, 1985, at Delhi -- flight AI-164 On arrival the leading edge honey comb of the left hand aft trailing edge flap was found damaged about 18 inches in length due foreign object damage. Necessary repair was carried out at Delhi. The aft flap was replaced at Bombay.

(vi) On 28th May, 1985, at Dubai -- flight AI-103 On arrival, the left hand wing to fuselage botton fairing forward rubber seal with strip was found turn off. Temporary repair was carried out at Dubai. Permanent repair was carried out subsequently at Bombay.

2.4.2.2 The flight snags recorded in the flight report books of the aircraft during the 4 1/2 month period prior to the accident were scrutinised by the Maintenance Group and the only significant repetitive defect observed was "R2 door not going to manual". On ground checks by the aircraft maintenance engineers, the operation of the selector was, however, found normal.

2.4.2.3 Prior to operating the accident flight, the aircraft arrived at Toronto from Frankfurt. Capt. R.K. Spencer was the commander of the flight. The flight crew had reported the following three snags:

(I) HF system No. 2 had a lot of distortion

(ii) E P R L indicator unserviceable in 'Go around' mode

(iii) Hydraulic system No.1 pressure indication unserviceable (This snag was carried forward from Delhi).

2.4.2.4 The Auxiliary Power Unit (APU) was unserviceable ex-Bombay and had been released under M E L.

2.4.2.5 For rectification of the above stated snag No.1, Shri Rajendra, Air India's Maintenance Engineer at Totonto checked the connections of the transreceiver and reracked the unit. No snag was reported on this system on Toronto-Montreal sector.

2.4.2.6 Snag No. 2 was carried forward.

2.4.2.7 Regarding the third snag, Mr. Rajendra has stated that the indicator showed 4000 P S I pressure even with no pump running. He therefore, interchanged No.1 and No.3 indicators. The snag, however, persisted. He then replaced transmitter No.1 with a spare transmitter from the aircraft SE box and the snag was rectified. No rectification work was however, recorded by the AME in the Flight Report Book. No snag was reported on this system on Toronto-Montreal sector.

2.4.3 Installation of 5th Pod Engine

2.4.3.1 On 8th June, 1985, No.1 engine of Air India Boeing 747 aircraft VT-EGC operating flight AI-181 failed during take off at Toronto. The aircraft returned and the engine was replaced by a loaned engine from Air Canada. The removed engine was a P & W JT9D-7Q type (Sl. No.

P702353-7Q).

2.4.3.2 Air India had planned to bring back the failed engine of VT-EGC aircraft to Bombay, as fifth pod on their flight AI-181/182 of 22/23 June, 1985 and had sent an Engineer along with the necessary kit to Toronto on 15th June, 1985. The engine borrowed from Air Canada on 8th June, 1985, was flown back to Toronto as a fifth pod engine on flight AI-181 of 22nd June, to return it to Air Canada.

2.4.3.3 Shri C.D. Kolhe, Controller of Airworthiness, Bombay examined the aspects relating to installation of the 5th Pod engine, loading of its components and certification of the related work. Shri Kolhe's report indicates that the failed engine and the associated parts were kept in the Air Canada engineering hanger at Toronto airport since June 8 when the aircraft was brought to the hanger for engine replacement. Air India requested Air Canada on 15th June, 1985, for prepairing the failed engine for installation as fifth pod engine on 22nd June. Accordingly, Air Canada's technicians undertook the preparatory work of removing the cowlings, fan blades, panels, locking of compressor, turbine rotors etc. on 17th June, 1985, and completed the work on 21st June, 1985. The fan blades (46 in number) from the failed engine were placed in 12 wooden shipping boxes provided by Air India. These boxes were then loaded in a container. The other components of the failed engine were loaded on 4 pallets.

2.4.3.4 Installation of the fith pod engine was carried out by Air Canada technicians and the individual items on the task card were certified by the individuals who had carried out the work.

2.4.3.5 Some difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fittings from the aft cargo compartment door cut-out. After removal of the fittings, the pallet could be loaded. All the removed fittings were then re-installed. Removal and installation of the fittings was certified by Mr. Rajendra.

2.4.3.6 A question arose whether removal of the door stop fittings could have caused some difficulty in flight. From the video films of the werckage it was found that the complete aft cargo door was intact and in its position except that it had come adrift slightly. The door was found latched at the bottom. The door was found lying along with the wreckage of the aft portion of the aircraft. This indicates that the door remained in position and did not cause any problem in flight. In the front cargo compartment, there were 16 containers out of which four were empty. Five containers had baggage of Delhi bound passengers. Container at Position 13L had baggage of the first class and London passengers and container at position 13R had crew baggage. The entire baggage of passengers ex-Montreal was loaded in containers at positions 12R, 21R, 22R, 23R and 24R in the front cargo compartment. Container at position 24L contained fan blades in wooden boxes and the other components of the pod engine. Valuable container was at position 14R.

2.4.3.7 In the aft cargo compartment, there were four pallets containing parts of the fifth pod engine and two containers at positions 44L and 44R containing baggage of Delhi bound passengers. The bulk cargo compartment contained passenger baggage bound for Delhi and Bombay. All the baggage and engine parts in the aft and bulk cargo compartments were loaded at Toronto.

2.4.3.8 The total weight of the fifth pod engine and its items was about 9000 kgs. As a result of carriage of the fifth pod engine, the payload of the flight was considerably reduced on London-Delhi sector.

2.4.3.9 At the time of take off from Montreal the aircraft had 104,000 kgs of fuel on board which was adequate for 08:40 hours of flying as against sector flying time of 06:15 hours. The flight plan fuel was calculated taking Paris as the alternate airport for London.

2.4.3.10 The load and trim sheet from the sector Montreal London was prepared and was duly counter-signed by the commander. The take off weight of the aircraft was 317,877 kgs which was within the maximum take off weight limit of 334,500 kgs. The estimated landing weight of the aircraft was 237,177 kgs which was also within the maximum landing weight limit of 256,279 kgs. The centre of gravity of the aircraft was at 21.3 percent of MAC at take off and the estimated C G position at the time of landing at London was 25.8 percent of MAC which was within the limits.

2.4.3.11 The load and trim sheet and the flight plan of the aircraft indicated that there was 301+2 passengers on board the aircraft whereas there were actually 301+6 passengers on board. The error occured because four of the six infants were not taken into account.

2.4.4 Corrosion Control Measures

2.4.4.1 Boeing Company have recommended various measure to control corrosion on Boeing 747 aircraft through different documents such as Maintenance Planning Data Document, Corrosion Prevention Manual and Service Bulletins. Compliance of these measures on Air India fleet is accomplished as follows:

(I) Support structure under galleys and lavatories

Boeing Company have recommended repeat inspections of under galley/ toilet structure at intervals of 12000 hours. However, in order to detect corrosion at an early stage, these inspections are carried out by Air India at intervals not exceeding 9000 hours.

(ii) Fuselage Lower Bilge Area:

Boeing Company have recommended modifications to provide improved drainage systems by incorporation of various Service Bulletins. All the relevant modification have been completed by Air India on the affected aircraft. In addition to completion of these modifications, repeat inspection of lower bilge area is being carried out to meet the requirements of Boeing Service Bulletins.

(iii) Canted Pressure Deck:

In order to prevent water accomulation and consequent corrosion in the area, Boeing Company have issued SBs 51-2015, 51-2026 and 51-2032. Air India have incorporated Service Bulletins 51-2015, and 51-2032 on all their affected airplanes SB 51-2026 is being complied progressively.

(iv) Cargo Compartments:

Inspection of all the cargo compartment interior structures for corrosion and cracks is being accomplished periodically by Air India after removal of linings and insulation blankets.

(v) Aft Pressure Bulkhead:

During every equalised Periodic Check routine, the aft surface of aft pressure bulkhead is being visually inspected for corrosion condition and security of attachements. The forward surface of the pressure bulkhead, which is covered by aft toilets, is inspected after removal of toilets at intervals not exceeding 9000 hours although the recommended interval by Boeing Company is 12000 hours.

2.4.4.2 Air India has stated that in addition to the above specific measures, aircraft structure particularly the areas below toilets, galleys, cargo compartments, outflow valve area etc. which are prone to corrosion, are inspected for corrosion, cleaned and protected during every equalised Periodic Check. Air India have further stated that no serious corrosion problem has been experienced by them so far on their fleet.

2.4.5 Supplemental Structural Inspection Programme

2.4.5.1 In the case of airplanes which have completed 10,000 flight cycles as on June 30, 1983, Federal Aviation Administration (FAA) U S A and Boeing Company had recommended additional structural inspections known as Supplemental Structural Inspection Programme. In the Air India fleet, the first three 747 aircraft, namely, VT-EBE, VT-EBN and VT-EBO fell in this category and are known as 'Candidate Airplanes'. The subject aircraft (VT-EFO) had completed only 7525 flight cycles at the time of the accident on 23rd June, 1985, and therefore, the Supplemental Structural Inspection Programme was not applicable to this aircraft.

2.4.6 Special Corrosion Inspection of B-747 Aircraft Fleet of Air India

2.4.6.1 In order to examine whether corrosion to the aircraft structure of Kanishka aircraft could have contributed to the accident, a group was constituted by Mr. H.S. Khola, Inspector of Accidents to carry out special corrosion Inspection of all the Boeing 747 aircraft of Air India.

The group consisted of the following members:

(a) Senior Air Safety Officer of the D.G.C.A.

(b) Senior Airworthiness Officer of the D.G.C.A.

(c) Air India's Representative.

2.4.6.2 The inspection was carried out in the following areas:

(a) Below toilets and galleys

(b) Forward and aft cargo compartments belly areas - internally and externally

(c) The forward and aft pressure bulkheads

(d) Canted pressure web area from inside the passenger cabin.

(e) Area around outflow valves

(f) MEC area inside and outside.

2.4.6.3 The inspection reports submitted by the Group show that no corrosion was noticed on the significant primary structural members of the aircraft. Surface corrosion was, however, noticed on some of the members below the toilets and galleys. The corrosion observed during the inspection was of minor nature which is normally expected on such inspection schedule. The Kanishka aircraft was subjected to Periodic Check on 24th May, 1985 at 23,274.53 hours/7,439 cycles and no significant corrosion was observed. Among the Nine 747 aircraft inspected for corrosion, 5 aircraft had logged hours more than the Kanishka aircraft. Three of the aircraft had actually logged nearly double the flying hours. Taking into consideration that the corrosion prevention measures recommended by the Boeing Company were followed by Air India and that even the high life aircraft (45,000 hours approximately) subjected to corrosion inspection at the time when Periodic Check was due i.e. 1100 hours since previous check, had no significant corrosion, it is considered unlikely that Kanishka aircraft, which had logged only 23,275 hours since new and 360 hours since last Periodic Check, had corrosion which could have contributed to the accident.

METEOROLOGICAL INFORMATION

2.5.1 A report on the Meteorological conditions prevailing en-route near the location where the aircraft crashed was provided by the Meteorological Service, Department of Communications, Dublin, Ireland. This report covers a period of one to two hours before and after the time of accident (0714 Z).

2.5.2 From the report it is seen that the surface Synoptic Situation in the vicinity of 51°N, 12.50°W at 0715 Z on 23rd June was as given below:

Surface wind : 250/15 knots

Surface visibility : 10 Kms (occasionally 4 kms in drizzle)

Surface temperature : 13°C

Cloud conditions : Cloud cover in the area was estimated to have been layered upto about FL 100 with a base of 600 feet. There is no evidence of cumulonimbus or thunderstorm activity.

Freezing Level : 700 feet.

2.5.3 With regard to Upper Air situation the report indicates that a mainly West or West North West airflow covered the area of FL 310 The Jet stream was centred at about 48°N. The estimated wind and temperature at FL 310 were 270/65 knots and -47°C. As per the report, at FL 310, 51°N 12.50°W and at 0715 Z any significant clear air turbulence was not expected.

2.5.4 Sunlight condition was prevailing at the time of accident. There were no sigmets valid for the area at that time.

AIDS TO NAVIGATION

2.6.1 The aircraft was equipped with Inertial Navigation System (INS) and was cruising normally at its assigned flight level 310 on track X-ray over Atlantic. It was under the control of Shannon Upper Area Control and was being monitored on the Secondary Surveillance Radar (SSR) located at Mount Gabreal. Till the time of accident, the aircraft was beyond the range of Shannon primary radar.

2.6.2 The aircraft entered Shannon airspace at the correct position and level and remained on the assigned track and flight level till it disappeared from the radar screen.

2.6.3. There is no evidence to indicate that AI-182 experienced any navigational problem during the flight.

COMMUNICATIONS

2.7.1 Two-way communication between the ill-fated aircraft and the ATS units of Canada and Ireland was maintained during the flight from Montreal till the time of crash. The communications were recorded on the ATC tapes. Transcripts of the relevant tapes were provided by the Canadian Aviation Safety Board and the Director of Air Traffic Services, Ireland.

2.7.2 From the Transcript of the conversations, it is observed that two-way communication between AI-182 and the various ATS units was normal. The last R/T contact with the aircraft was at 0709:58 Z when AI-182 informed Shannon UAC that it was squawking 2005. The tape transcript also shows that the aircraft did not transmit any information regarding the emergency on frequency 131.15 MHz on which it was last working with Shannon UAC or on distress frequency 121.5 MHz. Indecipheiable noise was, however, found recorded on the Shannon ATC tape just at the time of crash i.e. 0714:01 Z. Thereafter, repeated calls were made by Shannon UAC to AI-182, but there was no response.

SEARCH AND RESCUE

2.8.1 The report of the Search and Rescue Group gives the details of the Search and Rescue operations. From the report it is seen that at 0730 Z, Shannon UAC informed Marine Rescue Co-ordination centre (MRCC) shannon that AI-182, a Boeing 747 aircraft enroute Montreal-London had disappeared from the Secondary Surveillance Radar (SSR) at 0713 Z in position 51N/120W. Shannon UAC requested MRCC Shannon to take emergency section. At 0740 Z MRCC Shannon telephonically explained the situation to Valantia Coast Radio Station (CRS) and requested a PAN Broadcast urgently and to ask any vessels in area to keep sharp lookout and report to Valantia Radio. At 0746 Z Valantia Radio transmitted to all stations PAN message and above advice to ships. The transmission was repeated.

2.8.2 At 0750 Z, an Irish Naval Vessel AISLING reported on R/T to Valantia Radio that it was 54 miles from site of accident and was proceeding to the site. Valantia Radio passed on this information by Telex to MRCC Shannon. Between 0740/ 0750 Z MRCC briefed the Irish Naval Service (INS) Haulbowline, MRCC Swansea, RCC Plymouth and Irish Army Air Corps (IAAC) on the situation. At 0754 Z MRCC relayed a distress message to Shannon Aeradio via the Aeronautical Fixed Telecommunication Network (AFTN)

2.8.3 At 0803 Z Valantia Radio again transmitted the PAN message and the advice to ships. At 0840 Z Cargo vessel M W Laurentian Forest/ HBWP (Registered in PANAMA and owned by Federal Commerce of Montreal, Canada) at position 51.09N/12.18W reported that it was 22 miles away from distress area and was proceeding there. Laurantian enquired if there were other ships in the area and was informed about position of Aisling. At 0813 Z Valantia Radio informed MRCC Shannon by telex about Laurentain Forest.

2.8.4 Between 0815/0820 Z, MRCC Shannon updated RCC plymouth and they advised that a Nimrod Rescue Aircraft would depart shortly for the area and that SEA KING helicopters were already enroute the Cork Airport initially. Edinburgh RCC advised MRCC Shannon that a Nimrod Rescue Aircraft was also being prepared at Kinloss. At 0820 Shannon Aeradio informed Valantia Radio that there was message from Shanwick Oceanic Control that aircraft were picking up ELT signal in position 51N/15W and 51N/08W and the actual position was beleived to be 51W/1250W. At 0833 Z, Valentia Radio sent message giving the above information and requesting ships in the area to report to Valentia Radio.

2.8.5 At 0842 Z, Ali Baba informed Valentia Radio that it was at position 5125.5N/0825.4W and was listening on 121.5 MHz. At 0850 Z Western Arctic informed Valentia Radio its position 5207N/1151W and that it would proceed in about 20 minutes after bringing in cable. At 0857 Z, High Seas Driller informed Valentia Radio that Vessel Kongstain could be released, ETA 51/2 to 6 hours and they would standby. At 0858 Z, Valentia Radio informed MRCC Shannon about reports from Ali Baba Western Arctic and High Seas Driller.

2.8.6 At 0905 Z, Laurentian forest reported to Valdentia Radio that it was 5 miles from SOS position 51N/12.5 W and it had not sighted anything. Between 0905/0908 Z, three more vessels viz. Atlantic Concern, MV Norman Amstel and MV Tasman reported their positions to Valentia Radio. At 0908 Z, Swansea advised MRCC Shannon that four Seaking helicopters and two Nimrod Aircraft were enroute.

2.8.7 At 0913 Z, Laurentin Forest reported to Valentia Radio that they had sighted what looked like 2 rafts about 2 miles away. At 0914 Valentia Radio informed MRCC Shannon about the report from Laurentian Forest.

2.8.8 At 0918 Z, Laurentian Forest reported to Valentia Radio that it had sighted wreckage in water at position 5101.9N/1242.5W and the liferafts were not inflated. Valentia Radio passed the message to MRCC Shannon at 0920 and also sent transmission about wreckage sighting. Lifeboats Valentia and Baltimore reported to Valentia Radio that they were proceeding to the position of wreckage.

2.8.9 At 0937 Z, Laurentian Forest reported that it had sighted 3 bodies in water. Valentia Radio informed the same to MRCC Shannon at 0940 Z. At 0945 Z, MRCC Shannon and MRCC Swansea decided that for security and operational reasons Cork Airport would be the primary operational base and ATC Cork were informed of this decision.

2.8.10 At 0953 Z, S MYROLI informed Valentia Radio that it was 80 miles north of position and had a group of 10 to 20 French vessesls and desired to know if they should proceed to site. After consulting Laurentian Forest, S MYROLI was advised that it was not necessary. Valentia Radio kept on giving Mayday relay frequently.

2.8.11 At 1045 Z, a prohibited flying area was established with a radius of 40 N Miles from the datum point from sea level to 5000 feet. Falmouth Coast Guard reqested Valentia Radio the position of all ships in the distress area and those proceeding so that each vessel could be designated to search a particular area.

2.8.12 At 1126 Z, Laurentian Forest reported Valentia Radio that it had located numerous bodies in water and Seaking helicopter was hovering there. Valantia Radio Transmitted this information to all stations.

2.8.13 At 1133 Z, Valentia Radio informed Coast Guard Falmouth the position and ETA of various ships and also of the Lifeabouts Valentia and Beltimore. At 1150 Z, RRC Plymouth requested MRCC Shannon that "Le Aisling" assume duty as "On Scene Commander Surface Unit". At 1204 Z, information was received by Valentia Radio that 8 Spannish Trawlers were proceeding to distress position of AI-182 and their ETAs were between 1630/2000 Z. At 1246 Z, Star Orion informed Valentia

Radio that it would be able to refuel any vessel in medium or small quantities at the accident site. Valentia Radio informed MRCC Shannon and Falmouth about the Spanish Vessels and Star Orion.

2.8.14 Falmouth requested Valentia Radio at 1303 to advise Laurentian Forest to inform Aisling that 8 Spanish trawlers would arrive in search area between 1600 Z and 2000 Z and Aisling should deploy trawlers in conjunction with lifeboats to recover bodies as it would be easier to recover than from large vessels. Valentia Radio sent the above message.

2.8.15 Laurentian Forest informed Valentia Radio at 1307 Z that 10 bodies were on Aisling, 4 on Helo, and they had some alongside and had launched lifeboats to pick them up. Valentia Radio informed the same to MRCC Shannon and Falmouth. At 1338Z, MRCC Shannon requested Valentia Radio to include the following in their broadcast:

"Vessels within 100 N Miles of datum 5101.9N/1242.5W are requested to proceed to search area and contact Aisling/EIYP. Any vessels recovering bodies or wreckage are requested to retain them on board and inform MRCC Falmouth of total number of bodies recovered."

2.8.16 Valentia Radio transmitted the above message at 1340 Z to all stations and also informed MRCC Shannon. At 1503 Z Aisling informed Valentia Radio that they had recovered 56 bodies. MRCC Shannon requested Valentia Radio to advise Aisling that if they could locate "Black Box", they should drop buoy. Valentia Radio advised Aisling accordingly. At 1530 Z, on advice from MRCC Shannon, Valentia Radio asked Baltimore, Courtmaesherry and Ballycotton lifeboats to return to base. At 1633 Aisling requested Valentia Radio to inform Falmouth that they were unable to transfer bodies to Valentia Lifeboat as latter was returning to base owing to fuel shortage. At 1659, Laurentia Forest informed Valentia Radio that 66 bodies had been picked up by then. Aisling advised Valentia Radio that Valentia lifeboat was returning with four bodies.

2.8.17 At 1721 Z Falmouth requested Valentia Radio to relay following to all surface units at scene:

1. One mimrod remaining on scene overnight.

2. All other air units will be recalled at 2200 Z. One Helo remains at 15 minutes notice at Cork
3. Air Search recommences at 240400 Z.
4. All Civil surface units will be released by 2200 and may proceed on passage. Bodies should be landed at Irish Post for transfer to receiving station at Cork Airport.
5. Warship Challenger, Emer and Aisling acknowledge".

2.8.18 At 1723 Z Aisling informed Valentia Radio that they saw 3 Spanish vessels approaching and they were using Ch.16 which Aisling was using for co-ordination with RESCUE 52 and requested that Spanish Vessels be asked to stay outside 5 miles radius. Spanish Agent was told about Aisling request.

2.8.19. Valentia lifeboat informed Valentia Radio that they were heading for home (Valientia) at reduced spead of 11 knots and they had five bodies on board. At 1822 Z, Aisling requested Valentia Radio information on 'Black Box' that might help its location. Aisling was advised of ELT signal on 121.5 MHz. At 1840 Z Cork ATC Advised MRCC Shannon that a total of 64 bodies were in Cork.

2.8.20 At 1920 Z, MRCC Shannon downgraded the 'MAYDAY' Broadcast to 'PAN' (Urgency) Broadcast, Aisling informed Valentia Radio that 79 bodies had been recovered. At 1958 Z Laurentian Forest informed Valentia Radio that they were proceeding to Dublin. Valentia Radio thanked them for assistance.

2.8.21 At 2000 Z, MRCC Swansea advised MRCC Shannon that main air search would cease at 2200 Z and would recommence at 240400 Z. The overnight search would continue with one Nimrod providing air cover for the surface search by three warships. Vessels transiting the area were requested to keep a sharp look out and to report to HMS Challenger.

2.8.22 By 0300 Z on 24th June, four Seaking helicopters had deported from Cork to resume the airborne search. At that time the search area covered a six nautical mile radius of position 5059.2 N/1225.3W and the vessels Le Emer and HMS Challenger were requested to search this area. HMS Challenger was the coordinator of the surface search and

Nimrod Rescue 02 was on-Scene-Commander.
2.8.23 At 0450 Z Rescue 02 reported sighting of wreckage in position 5101 M/1245 W. Between 0505 and 0543, three USAF Chinook helicopters departed from Cork Airport to join the search. At 0556, MRCC
Swansea confirmed that there were 329 people on board the aircraft (Earlier reportes had idicated 325 people on board).
2.8.24 A continuous search was maintained throughtout the day (24th June) but only one further body and numerous pieces of wreckage were recovered. An extensive surface search was also maintained throughout the day and instructions were passed by MRCC Shannon to Valentia Radio requestiong all shipping to recover any wreckage or bodies sighted.
2.8.25 At 0900 Z, Capt. G Mc. Stay of Department of Communications advised MRCC Shannon that Aisling was bound for Cork, ETA 1300 Z and he (Capt. Mc Stay) was assuming responsibility for collection of wreckage. MRCC were also advised by Mr. Gregory of Britoil that their two vessels 'Constine' and 'Star Orion' were enroute to Foynes having picked up quantities of wreckage.
2.8.26 At 1740 Z, SRCC Plymouth advised Shannon that the Search will terminate at 242200 Z, at 1800 Z Falmouth MRCC advised MRCC Shannon to direct the Portisheal and Valentia Radios to concel Urgency Broadcast from 242000 and to release HMS Challenger and Le Aisling from the search at 242000 hours. All the aircraft were released at 24000. It was also decided that Le Emer would remain at the area. At 242003 Z, a message was transmitted to all stations on R/T and W/T that air and sea search was being terminated at 242000 Z and all the participant were thanked for their assistance.
INJURIES TO PERSONS
3.1.1 Post mortem examination was carried out by Irish Authorities at Cork. At that time Wing Commandor Dr. LR. Hill was also present. Subsequently Air Vice Marshall Kunzru also reached Cork. Both of them were members of the Medical Group which had been constituted by Mr. H.S. Khola.

3.1.2 By then 131 bodies had been recovered. None of the bodies of the flying crew were revocered. The bodies which were recovered represented 39.8 per cent of the victims. The exact seating position of passengers is not certain, because it is known if the passengers had changed their seats after the take off of the aircraft from Montreal. On the information which is available, the passengers were supposed to have been as follows:-

Passengers: Seats Occupied Bodies Available identified Zone A 16 1 0 Zone B 22 0 0 Upper Deck 18 7 0 Zone D 112 104 + 2 29 Zone D 86 84 + 1 38 Zone E 123 105 + 3 50 Sub-Total 377 301 +(6 infants) 117 Crew: Flight Deck 3 3 0 Cabin 19 19 5 Total 399 329 122

3.1.3 The Post-mortem reports were examined by Wing Commander Dr. Hill. He submitted two reports being Exhibits H-1 and H-2. He was also examined in Court as Witness No. 2. Dr. Hill who had developed a system which would indicate the severity of the accident and the injuries suffered. He used a scale from 0 to 4, with naught being no injury and 4 being a fatal lesion. Though there is some amount of subjectivity involved in the system, nevertheless categorising the injuries according to the sacle does give an overall picture of what had happened to the victims. After adding up all the injury scale for a particular body, Dr. Hill in his Report Exhibit H-1 divided the injuries as under:-

No. of victims Mild injury (0-49) total 34.4% 45% Moderate injury (50-99) 38.9% 51% Severe Injury (100-149) 25.2% 33% Catestrophic Injury (150 +) 1.5% 2 Total 100.1% 131 3.1.4 A further break up showing the overall injury score of the recovered victims is as follows:

Minor Moderate Severe Zone No. % % No. % % No. % % Total C 8 6.1 17.8 9 6.9 17.7 4 3.1 11.4 21 D 9 6.9 20 15 11.5 29.4 9 6.9 25.7 33 E 15 11.5 33.3 15 11.5 29.4 14 10.7 40 44 Unknown 13 9.9 28.9 12 9.2 23.5 8 6.1 22.9 33 Total 145 34.4 100 51 39.1 100% 35 26.8 100% 131 3.1.5 The reports submitted by Dr.Hill further indicted as follows

(a) There were 30 children recovered and they showed less overall injury. The average severity of injury increases from zone C to E and is significantly less in C than in Zones D and E.

(b) Flail pattern injuries were exhibited by eight bodies, five of these were in Zones E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

(c) There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evently distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

(d) Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 Zone D, 11 inZone E, 2 crew and 1 unknown), and 16 had little or no clothing.

(e) Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

(f) There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

(g) There is a general absence of signs indicating the wearing of lap belts.

(h) Pathological examination failed to reveal any injuries indicative of a fire or explosion.

3.1.6 In his testimony in Court, Wing Commander Dr. I.R. Hill further stated that the significance of flail injuries being suffered by some of the passengers was that it indicated that the aircraft had broken in mid-air at an altitude and that the victims had come out of the aeroplane at an altitude. He further explained that if an explosion had occurred in the cargo hold, it was possible that the bodies may not show any sign of explosion. It may here be mentioned that the forensic examination of the bodies do not disclose any evidence of an explosion. Furthermore, the seating pattern also shows that none of the bodies from Zone A or B was recovered, in fact as per the seating plan Zone B was supposed to have been unoccupied. This Zone is directly above the forward cargo compartment.

3.1.7 Dr. Hill further stated that the pattern of the accident as suggested by the injuries indicated that it was a complex affair and there were at least two phases of injuries, one in the air and the other at water impact. In answer to a specific question that if there was an explosive device in the cargo hold then could the passengers who were seated have suffered such injuries, the answer of Dr. Hill was that "it is possible". According to him, the pattern of injuries indicated that if there was an explosion in the aircraft it was more likely that the explosion had occurred in the rear cargo compartment than in the front cargo compartment. This conclusion was apparently based on the fact that, according to him, in zone E of the aircraft there were larger vertical load type injuries. Dr. Hill was also asked if he had to make any suggestions which would minimise injuries to passangers in the event of an accident. In answer, the witness made his suggestion in the following words "There are very complicated things one would have to do such as rearward facing seats; having safety belts which incorporated restraint for the upper part of the body; increasing the space between aircraft seats; incorporating shocks absorbing system within the seat and using materials which do not break easily like plastic. We would also need fuel systems which would not immediately set on fire and furnishing which would be resistant to burining, and also passengers should not carry into the aeroplanes large amount of hand bags which only get in way in the event of evacuation, and I personally feel that the carriage of large amount of alchohol both in the passengers and in the aeroplane is a hazard to flight and safety. Finally the passengers should take heed of the flight safety instructions given to them by the crew of the aeroplane".

3.1.8 Air Vice Marshal Kunzru, witness No. 10 in his report dated 14th November, 1985, Ex.A-48, gave his comments not only on the post-mortem reports but also on the statement of Wing Commander Dr. I.R. Hill. With regard to the post-mortem examination, the comment of AVM Kunzru was as follows:

"All victims have been stated in the PM reports to have died of Multiple injuries. However two of the dead, one infant and one child, are reported to have dies of Asphyxia. There is no doubt about the asphyxial death of the infant. In the case of the other child (Body No. 93) there could be doubt because the findings could also be caused due to the child undergoing tumbling or spinning with the anchor point at the ankles. Three other victims undoubtedly died of drowning. There was no evidence of significant Lap-belt injuries.

Considering rupture of the ear-drum, without injury to skull, as a criterion to indicate rapid decompression, two cases may be considered to fall in this category.

Histological examination has been carried out only in 57 bodies out of 131. Lung examination on almost all of them showed decelerative changes. Six bodies (Nos. 6,22,70,103,121 and 131) showed presence of Bone Marrow Embolism in Lung Sections. Though not of much significance in this accident, this finding does indicate survicval after a bony injury for an undefined period of time No evidence of fire burns or explosive material, other than Kerosene burns on some bodies, which I had myself seen at Cork, could be found. Kerosene burns in such acidents is a fairly common findings and is of no significance".

AVM Kunzru generally agreed with the crash injury analysis on the victims which had been furnished by Wing Commander Dr. Hill. He, however, gave the following comments with regard to hypoxia, decompression and decelerative changes:

"Hypoxia : The main Post Mortem findings in hypoxia is generalised congestion if the hypoxia is of the type described as "hypoxic hypoxia". In other causes of hypoxia of more severe degree such as "histotoxic hypoxia", "asphyxia" or "drowning" additional histological findings such as petechial haemorrhages and generalised congestion, and lung findings such as haemorrhage and extrusion of alvoolar phagocytos are seen.

Decompression : The term used by Dr. Hill is "Decompression". It is presumed that he means "Rapid/Explosive Decompression" which occurs within one Sec. and not "decompression sickness" which takes a minimum of 5 to 7 mnts to occur even at 31,000 ft. altitude and which in this case can positively be ruled out.
The Post-Mortem and histological signs of rapid Decompressions are :-
(a) Possibility of rupture of Ear drums without any injury to the skull.
*(b) Patchy Lung Haemorrhages
*(c) Emphysomatus changes
*(These occur more commonly in those cases where the individual was in the phase of breathing-in at the time of decompression.
3.1.9 If it is assumed that the aircraft suddenly broke up in Mid-Air at an altitude of 31,000 ft. the bodies will be at once exposed to hypoxia and rapid decompression and as a consequence will suffer body changes as mentioned above. As the aircraft/occupants start descending, they will be exposed to increasing amounts of Oxygen and as soon as ;they come down below 15,000 ft. and then below 10,000 ft. the effect of hypoxia rapidly diminishes. Finally, the aircraft/individuals come down and hit the ground/water with a very heavy impact, thus submitting the individuals to extremely severe G-loads of decelarative type.
Decelerative Changes : Decelerative impact brings about well established changes in the lungs besides many other associated injuries. It is relevant to note the decelerative lung changes which are :-
(a) Patchy haemorrhages in Lung.
(b) Marked Emphysomatus Changes.
(c) Extrusion of alvoolar Phagocytes
(d) Desqummation of bronchcolar epitherium.
"Comparative study of the PM/histological findings of hypoxia, Decompression and Decelerative Lung injuries reveal that they are more or less similar. Decelerative injury being the most severe of the three and last to occur tends to so modify the Post-Mortem and Histological findings that it becomes extremely difficult and some times impossible to isolate one from the other."
3.1.10 AVM Kunzru was, therefore, of the opinion that in this

accident evidence of hypoxia/decompression (except in 2 cases) had not been confirmed or established.

3.1.11 The difference of opinion between Wing Commander Dr. hill and AVM Kunzru, with regard to evidence of hypoxia and decompression, is of no significance in the present case. What is important to note, however, is that they have agreed that the injury pattern does indicate break up of the aircraft in mid-air and that the occupants of Zone E had suffered the greatest amount of injuries as compared to the occupants of the other zones.

MAPPING, WRECKAGE DISTRIBUTION AND SALVAGE

3.2.1 Introduction

3.2.1.1 Oceanographic charts indicated that the depth of sea in the crash area was about 6700 feet and the site appeared to be a flat sea bed, without any valleys or hills. The immediate necessity after rescuing/searching crash victims, was to locate and recover the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR). The operation was unique of its kind and had never been undertaken earlier in the world at this depth of the sea. It required an equipment which could home on the transmitted signals from the underwater locater acoustic beacons fitted on DFDR/ CVR, identify the units, clear them from attachments/wreckages, grab them and bring them to the surface.

3.2.1.2 The pressure exerted by the water at 6700 feet below mean sea level is extremely high and the temperature is very low. No light penetrates to that depth and it is pitch dark. Scarab I fitted on French Ship "Leon Thevenin" which had undertaken the challenging job of locating DFDR and CVR, and recovering the same, was not designed to operate at 6700 feet depth. Its maximum design operating depth was only 6000 feet. However, it was decided to exceed the design operating depth for this emergency operation.

3.2.1.3 By using the preliminary information of probable area of location OF CVR and DFDR as indicated by ship 'Gardline Locator', the Scarab I was Lowered in the sea to locate and recover these units which it accomplished on 10.7.85 and 11.7.85 respectively.

3.2.1.4 Prior to recovery of DFDR/CVR by the ship 'Leon Thevenin', sufficient spade work was done by the ship 'Gardline Locator' (A ship provided by Accident Investigation Branch, U.K.) and 'Le Aoife' (an Irish Naval Ship). The survey of the crash area, carried out with the help of side-scan sonars fitted on these ships, had indicated a general distribution of the wreckage and a rough idea about the sizes of the parts. Each part of the wreckage was called a target. The method used for survey was triangulation with multiple passes through the crash site.

3.2.1.5 Next phase was the task of :

(a) Locating hundreds of pieces of wreckage by the combined use of sonar and video monitors.

(b) Video and still photography of the pieces of wreckage.

(c) Plotting the distribution of the wreckage.

All this was to be carried out under the directions of the Court.

3.2.2 Scarab

3.2.2.1 The means (vehicles/equipment) proposed to be used in the locating, mapping and video photography of the wreckage were the CCGS John Cabot and SCARAB II.

3.2.2.2 The John Cabot is an ice breaker of the Canadian Coast Guard. Since utilisation as an ice breaker is seasonal, the John Cabot is also equipped for submarine cable laying. In order to enlarge its capabilities in this regard, the John Cabot is equipped to have on its deck the Scarab and to operate it. Thus the John Cabot can be used for repair of submarine cables. The John Cabot has complete facilities for operation, maintenance and repair of the Scarab. This includes a Control Hut, a Test Room, Workshop, Stores etc. The John Cabot has considerable experience in work on deep sea bed.

3.2.2.3 The SCARAB II is a submersible craft assisting repair and burial of cables. As will be clear from the following details, the Scarab is not ipso facto a submarine. It is a total system for carrying out its complex functions.

3.2.2.4 The SCARAB II is a state-of-the-art system designed and built for tethered unmanned work at ocean depths of upto 6000 feet. Scarab's standard equipment are :

Two rugged manipulators.

A complete optical suite.
Six thrusters of 5 hp each.
CTFM Sonar.
Navigation System.

3.2.2.5 The manipulators have a choice of grippers/claws/cutters etc. of any required description and size. The Scarab has three TV cameras mounted on separate pan/tilt mechanism to allow real time observation and video tape documentation. A 35 mm still camera was also installed and used in the present work. There was a choice of quartz-iodide flood lights to provide illumination.

3.2.2.6 The location and control of the Scarab is accomplished through a phased array navigation system.

3.2.2.7 The Scarab was equipped with a 360° high resolution Sonar with a range of 1000 meters. The Sonar was also capable of interrogating and detecting 37 KHz and 27 KHz pingers. It can function independently of the ship's facilities and is equipped with power generators and semiautomatic handling equipment.

3.2.2.8 The John Cabot can salvage items, but it is not a salvage ship as it does not have the specialised high capacity cranes, derricks etc. required for salvage of large objects. Further, it does not have deck space for keeping large salvaged items like the wings, fuselage or tail surfaces of an aircraft as large as a 747. The John Cabot was, therefore, adequate and fully satisfactory for the work envisaged in this phase of the programme, as salvage of large items was not planned in this phase. The task was, as mentioned earlier, locating, mapping and photography of the hundreds of pieces of wreckage. (The salvage work was part of the next phase of the programme).

3.2.3 Control and Monitoring of Operations

3.2.3.1 It was realised that the operation proposed would pose problems of control, monitoring and logistics.

3.2.3.2 Consider : A ship operating on the high seas in international waters on the task of locating, mapping and video photographing the hundreds of pieces of wreckage. The state of art system for Sonar location and photography (Scarab) used by the ship for handling this task. The group located on shore in charge of the operations. Finally, the Court in Delhi was in overall charge of the operatins.

3.2.3.3 It was realised that a proper line of control and communication was essential if the operations were to be smooth and successful.

3.2.3.4 Therefore it was decided that the following would be the chain of command :

Court Investigating the Accident
(Mr. Justice B.N. Kripal)

Control Centre at Cork
(Court's representative)

CCGS John Cabot
(Commanding Officer)

Scarab
(Project Manager)

3.2.3.5 Because of the multiplicity of agencies involved in the operations, the need was felt for a proper delineation of power at all levels. It was, therefore, decided that :

a. Overall responsibility for the operations would rest with the Indian authority viz. the Court. This would cover the identification and definition of assignment of the overall tasks, laying down of the priorities, overall control of the coverage of the operation and, finally, the time schedule for the operation.

b. Decisions taken at the Control Centre, flowing from the above, were to be taken solely by the Court's representative. The experts from CASB, NTSB and Boeing were free to give their views and recommendations, but the final decisions were to be left to the Court's representative. Examples of such matters are : Track of the survey, areas to be covered by John Cabot, assignment of priorities for specific tasks, amount of time to be devoted to any piece of wreckage, whether any item of wreckage is to be picked up, etc.

c. Operation Control of John Cabot would be in the hands of the Canadian Coast Guard Officer in the Control Centre, who would co-ordinate with the Commanding Officer of John Cabot.

This would cover decision on feasibility or otherwise of operations under adverse weather conditions, manner of covering the area, method of retrieving any wreckage, etc.

d. Decisions relating to the Scarab (i.e. whether the weather was suitable for Scarab operations, whether the size, weight etc. of an item would permit its being picked up by Scarab, etc.) would be left to the Scarab Project Manager on Board John Cabot.

3.2.3.6 It might appear at first sight that in the above system excessive power was delegated at certain levels to the detriment of overall control. Any such impression would not be correct. In actual fact, because of proper delegation of responsibility and power at different levels, the operations were carried out with extraordinary efficiency, smoothness and coordination, In this connection, it is relevant to point out that the operations were not a uni-disciplinary one. The operation (aircraft accident investigation) was totally dependent on experts from other disciplines, like naval (coast guard) operations, deep sea photograph, salvage from sea bed etc. It was therefore, decided that for smooth and efficient operations, adequate power and responsibility should be delegated at all levels, particularly to specialists engaged in the different areas of work as above.

3.2.3.7 It was also considered that adequate communication was a sine qua non for smooth operation. Therefore, the following communication facilities were established :

Control Centre at Cork Airport

Telex

Telephones (2)

3.2.3.8 The ship John Cabot had both telex and telephone facility. These links were through satellite (IN MARSAT). The Control Centre was in continuous communication contact with John Cabot through telex and telephones. In order to establish a reliable and satisfactory line of communication it was decided that instructions or communication from Control Centre to the Indian experts on John Cabot would follow the path as under :

Control Centre

Court's representative --- Canadian Coast Guard Officer

John Cabot

Indian experts --- Commanding Officer

3.2.3.9 It was felt that this would eliminate any possibility of inconsistent or contradictory orders/messages going to John Cabot.

3.2.3.10 With a view to have an ordered system of communications between the control centre and John Cabot (which is essential for proper control and monitoring of the operations), it was decided that John Cabot would sent to the Control Centre daily Situation Reports (SITREPS) at specified times viz. 0800 hrs, 1200 hrs, 1600 hrs and 2000 hrs. This however did not preclude the despatch of telexes by both Control Centre and John Cabot at any other time.

3.2.3.11 In order to inform all agencies of the above system of Control and Communication a number of meetings were held. These were on 12.8.85 and 3.9.85 on board John Cabot and on a number of occasions at the Control Centre. The purpose of these meetings was not only to inform all concerned about the specific task, the programme and the line of control and communication but also to sort out differences and to understand the technical and operational difficulties faced by the personnel on the spot and to find a way out.

3.2.4 Daily Monitoring of Progress

3.2.4.1 It may be relevant to point out here that search, location and video photography work was to be carried out round the clock. Thus a considerable volume of data would be coming into Control Centre. This required regular, almost hourly, monitoring, study and analysis for (a) proper understanding of the data collected and (b) advising John Cabot of any changes in its programme, such as additional photography on an item etc. For this purpose (i) SITREPS were filed in the Control Centre (ii) all data (description, latitude and longitude) obtained on every target was tabulated and the cumulative list updated daily.

3.2.4.2 The location of the targets was plotted on charts every 4 hours. This was in addition to the plotting of targets carried out on John Cabot.

3.2.4.3 Every day (including holidays and week ends) all the officers posted at Control Centre assembled at about 0900 hrs. They studied the SITREPS received at 0800 hrs and any other telexes received from John Cabot in the night. The lists of targets were updated and the new targets plotted on the charts. John Cabot generally also sent brief remarks such as description, nature of failure/damage, dimensions etc. Discussions were held on the significance of the targets and their implications. Instructions if any to be telexed to John Cabot were also discussed. Similarly SITREPS received at 1200 hrs and 1600 hrs were studied.

3.2.5 Monitoring at Cork

3.2.5.1 The Scarab provided video tapes and still photographs. In the initial stages (upto 9.8.1985) the John Cabot was operating in peripheral areas and therefore few targets were found. Hence the output of videotapes was small. In fact upto 9.8.85, only about 10 targets were found and only 3 video tapes were used up. But later, when John Cabot came close to and into the crucial areas, video tapes were recorded at a fast rate. Further, still photography facility on the Scrab was activated at about this time. Therefore, arrangements were made periodically to obtain the video tapes and films from John Cabot. Video tapes and still photographs (these required to be processed) were transported from John Cabot to Cork Control Centre.

3.2.5.2 About 50 video tapes and nearly 3000 still photographs (positives and transparencies) provided the visual information on the targets.

Arrangements had to be made at Cork for such viewing and study of the video tapes and still photographs. Video equipment (TV monitor plus VCR) suitable for viewing the video tapes had to be arranged.

3.2.5.3 The still photography used special professional quality colour film (35 mm), each roll having 800 frames. The film was diapositive. These had to be developed and transparencies obtained from them. Thereafter negatives and prints had to be made. Special equipment for viewing the transparencies had to be provided for continuous work. The video tapes, transparencies and prints provided the principal means of monitoring of the results of the operation.

3.2.6 Operations

3.2.6.1 The Charts prepared by 'Gardline Locator' were on a different type of grid system, and had to be translated into LAT-LONG system, for use by John Cabot. For the convenience of search/mapping operation the search area was divided into 4 blocks viz. Block 1, Block 2, Block 3 and Block 4.

3.2.6.2 The navigation system used by John Cabot is PULSE-8 system. This system needs the transponders to be placed on the sea bed. These transponders help in getting the correct fix of a target and in obtaining relative positions of the targets on the sea bed which is highly useful for revisit for the purpose of rephotography or recovery. Initially 4 transponders were placed, and subsequently the number was increased as the search operation was continued. The strategic locations for placing the transponders was decided by considering :

(a) frequencies of relative transponders,

(b) distances required between relative transponders,

(c) wreckage distribution suggested by side scan sonar plots of Eithena and Garline Locator, and

(d) size of search area.

These transponders were calibrated to match the navigation system of the ship.

3.2.6.3 In order to obtain the maximum information from search, it was decided that the Scarab search paths should be as follows :

(a) Normally the search paths should be east to west, or west to east within the individual blocks.

(b) The pattern of search should be a parallel search method.

(c) Distances between the parallel paths to be 1,200 feet (i.e. 2 cable widths), for effective use of sonar fitted on the Scarab.

(d) If Scarab deviates from its planned path for photography or recovery, it should return to its planned path for further search.

(e) In each block, the search was to be made, at least 1/2 mile (North or South) beyond the last target sighted, so as to ensure no target is missed out from the given block.

3.2.6.4 However, when there was a need to modify the search pattern, due to wreckage distribution in particular areas, the following changes were made:

(a) Expanding box type search pattern was used in Block 1.

(b) Some North to South and South to North passes were made in Block 3.

(c) In Block 3 northern end, the distances between the search passes was reduced to 600 feet i.e. 1 cable width.

However, these deviations were made basically to improve the reliability of search in specific areas, as demanded by peculiar distribution of aircraft wreckage.

3.2.6.5 To facilitate identification of the wreckage located by Scarab it was necessary to position aircraft maintenance personnel on board the ship. As the aircraft structure was badly torn, mutilated and distorted, serious difficulty was anticipated in identification of small pieces of structure. It was therefore essential that these maintenance personnel were provided with aircraft photographs, manufacturing drawings, parts catalogue, wiring diagram manuals and maintenance manuals. Since carriage of such voluminous literature was not praticable, 3M micro film reader printer machines with micro film cassettes of the above literature were produced and installed on the ship. In case of difficulty of locating any particular information, the engineers were advised to contact Cork Search Centre by telex or telephone who, in turn, could seek the desired information from the manufacturers.

3.2.7 Wreckage Distribution

3.2.7.1 The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling at the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled. Although badly damaged, sections 41, 42 and 44, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been mapped or photographed. Section 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the western most identified aircraft component located at lat 51°02.90'N and long 12°50.1'N. The wreckage extended in a line about 110 degrees to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern. A third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southwest orientation. One of the operating engines was displaced 0.5 nautical mile to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components

and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

3.2.7.2 Details of the various targets which were identified by the Structures Group is contained in Appendix 1 of this Report.

3.2.8 The Break up Pattern

3.2.8.1 The forward fuselage section of the aircraft was found inverted and badly broken into many pieces, the major pieces being :

(I) Section of fuselage right side below cockpit windows containing part of the name 'Kanishka' (in Hindi) and 3 passenger windows (Target No. 192)

(ii) Portion of upper skin between B S 360 and B S 520 below window belt right side, up and over crown. This portion includes the crew door and last letter of the "Air India" (in Hindi) logo (Target No. 192).

(iii) Section of fuselage between B S 510 to B S 700, including the passenger window belt right side, up and over crown to include upper deck windows left side (Target No. 218).

(iv) Section of fuselage between B S 720 to B S 840 including left side passenger window belt, up and over crown to right side passenger window belt. Forward and upper edges of L H No.2 door cutout can be seen (Target No. 193).

(v) Large section of fuselage between B S 1000 to B S 1460 including left side passenger window belt, up and over crown to right side passenger window belt. This section was found lying on its right side (Target No. 137).

(vi) The lower portion of the fuselage skin/frame between the nose and B S 1000 was damaged past recognition except for a small portion with the forwarded cargo door (Target No.204) and another portion containing the aft access door cutout at B S 810 (Target No. 362).

3.2.8.2 The aft fuselage was found in the following major pieces :

(I) Section of RH fuselage skin between B S 1640 and B S 1940 below the window belt up to the crown (Target No. 321).

(ii) The RH fuselage bottom skin between B S 1820 (forward edge of C2 door) and B S 2060 and between two stringers above the door cutout to just below stringer 46 lap joint (Target No. 40).

(iii) The lower fuselage skin with stringers between B S 1480 and B S 1846 about 100 inches wide approximately (Target No. 7).

(iv) The LH fuselage skin panel between B S 1740 and B S 1880 about 110 inches wide (Target No. 11).

(v) The LH fuselage skin between B S 1460 and B S 1800 width 80 inches including No. 4L door and passenger windows (Target No. 28).

(vi) The RH fuselage skin between B S 1660 and B S 1920, from below window belt up to the crown including the 4R door cutout (Target No. 321).

(vii) A fuselage lower skin panel (containing out flow valve) between B S 2120 and B S 2240 and 120 inches wide (Target No. 320).

(viii) A fuselage LH skin panel (containing 5 windows with "T -" part of registration) between B S 1980and B S 2080 between stringers 19L and 24L (Target No. 369 and 26).

(ix) A fuselage LH skin panel between B S 1460 and B S 1800 with 8 stringers below the bottom of the door and 3 stringers above the top of the door (Target No. 28).

3.2.8.3 The tail portion of the fuselage was found in the following pieces:

(I) The lower fuselage skin between B S 2412 and B S 2598 about 20 stringers wide (Target No. 371).

(ii) The vertical fin with rudders attached was lying on the ground by itself with a portion of B S 2517 frame. This includes a small portion of the aft pressure bulkhead (Target No.37).

(iii) The horizontal tail with elevators attached was lying on ocean floor with the jack screw and drive motor attached (Target No. 31).

(iv) The fuselage tail cone aft of B S 2669 was found basically intact and lying separately (Target No. 27).

3.2.9 Extent of Damage

Photographic and Video Interpretation of Wreckage

Photographic Interpretation

3.2.9.1 All wreckage sighted was recorded on video tapes and all major items were recorded on 35 mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage pattern. For example, the sine wave bending of target 7 appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into acount.

3.2.9.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

3.2.9.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gears were in the 'up' position at the time of impact.

3.2.9.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

3.2.9.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

3.2.9.6 Section 42

Portions of Section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers. All cargo doors were found intact and attached to the fuselage structure, except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different from that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back on to the sea bed. An attempt to relocate the door was unsuccessful.

3.2.9.7 Section 44

Section 44 containing the aircraft structure between B S 1000 and B S 1480 including that area where the fuselage and wings were mated was located and identified. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gears were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

3.2.9.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northern most area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

3.2.9.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of B S 1480 and, for purposes of this report, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

3.2.9.10 The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were positively identified (targets 35, 37, 73 and 296). Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognisable as having come from a specific area of the aircraft.

3.2.9.11 Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from B S 1600 to B S 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

3.2.9.12 The tail cone and the auxillary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

3.2.9.13 A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure.

3.2.9.14 The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

3.2.9.15 The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates° to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabiliser was missing and the auxilliary spar was exposed. There was localized damage to the right-hand root of the loading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

3.2.9.16 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from section 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42 and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat belts were not fastened.

3.2.10 Salvage Operations

3.2.10.1 During recovery operation the video tapes as well as photographs of the wreckage to be recovered, were supplied to the personnel on board the ship for facilitating identification and recovery of correct targets.

3.2.10.2 Whenever any component/part of the aircraft wreckage was salvaged it was essential to immediately subject the same to inspection and to identify the damage sustained during recovery operation. In order to oversee this critical operation, the Court deputed one of its Assessors, Dr. V. Ramachandran, to be on board the ships. Under his supervision, the components/parts were thoroughly washed with fresh water, dried and treated with corrosion inhibiting compounds. A detailed inspection was thereafter carried out, observations recorded and the targets were appropriately labelled and their numbers were painted thereon. A laboratory microscope was taken on board by Dr Ramachandran. With that, fragments of significance were segregated for further investigation. Indeed some of these fragments did give important clues.

3.2.10.3 All the investigating personnel on board the ship were provided with leather gloves, fisherman's shoes, raincoat, life floating suits, writing and labelling material, camera with coloured films, etc. Sufficient number of "body bags" were positioned on each ship to cater for the eventuality of recovery of bodies with the wreckage. This precaution helped when a body did come along with wreckage on 25.10.1985.

3.2.10.4 The ship John Cabot completed the operation of locating, mapping and photography of the wreckage and returned to Cork on 1.10.85 at 2020 hours. The next phase of operation was to recover the significant wreckage parts which would be useful for deciding the cause of the crash.

3.2.10.5 Subsequent to the accident to Japan Airlines Boeing 747 aircraft, suspected to have been caused by failure of the repair to the rear pressure bulkhead, NTSB and FAA decided to fund the U.S. Navy for a two week operation over the seas for recovery of significant pieces of wreckage. For this purpose, U.S. Navy appointed Commander J.R. Buckingham, a deep sea salvage expert, to head the recovery operation. An offshore supply vessel M.V. Kreuzturm, of Canada was hired by U.S. Navy to recover the wreckage with the help of Scarab on John Cabot. One nylon lift line together with winch and ram were installed on the ship prior to its sailing to Cork where it arrived on 4th October, 1985. One crane was installed on the ship Kreuzturm in Cork.

3.2.10.6 One inch dia Kevlar lines coated with black plastic for abrasion resistance and braided with Dacron lining were used by John Cabot as primary lift lines.

3.2.10.7 The structure group after studying the photographic data, had formulated a list of 32 targets for recovery on 3.10.85. A systemwise priority list proposed by the Court of Inquiry was received through Dr V. Ramachandran on 4.10.85. Using these two lists, and taking into account the operating restrictions imposed by two ship operation, a final list of targets was prepared for recovery by the ships, assigning a priority number to each target. However, as the recovery operation progressed, changes in priority list were made to achieve optimum utilisation of the ships.

3.2.10.8 A meeting was held at 1400 hrs. on 4.10.85 on board CCGS John Cabot to establish/clarify the priorities for the wreckage recovery operation and coordination between John Cabot, Kreuzturm and Cork Search Centre. All the personnel involved in the recovery operation were shown the slides and photographs of the targets which were chosen for recovery on priority basis. The method and procedure of the recovery operation was discussed in detail and finalised. Another meeting was convened on 6.10.85

to clarify the doubts and to present the picture albums containing various photographs of targets to be recovered. The mode of attaching grippers/grabbers to the targets at strong points was clarified. A serialised list of priorities was prepared based on the mode of operation indicated by the the crew of John Cabot and Kreuzturm. Dr Ramachandran was given the authority to make on-the-spot decisions during the salvage operations.

3.2.10.9 A detail log of the activities of the ships John Cabot and Kreuzturm which started the recovery operation of 10.10.85, reveals the following :

(a) The Scarab working independently recovered the following

(1) Basket at target 192 containing copilot's chair, 2 suitcases and radar antenna (12.10.85)

(2) Target 8 - Lower fuselage skin of aft cargo compartment. (11.10.85).

(3) Target 245 - Forward belly skin just aft of radome (16.10.85).

(4) Target 350 - Economy class seats and carpet (23.10.85).

(5) Target 296 - Piece of aft pressure bulkhead.

(b) The Scarab after attaching the grippers, bridal cable and lift line to the targets buoyed off the same to Kreuzturm which recovered the following targets :

(1) Target 362/396 - Forward cargo fuselage skin from station 700 to 840 and STR 41L to 43R. (16.10.85).
(2) Target 193 - Fueselage skin from station 720 to 860 and passenger door 2L (17.10.85)
(3) Target 223 - Nose landing gear pressure deck web and stiffeners, container pieces (staion 260-340)(19.10.85).
(4) Target 181 - Wing skin with forward cargo compartment SLIPPED OFF WITH GRIPPERS (21.10.85) AND WAS LOST.
(5) Target 399/358 - Fuselage skin from station 780 to 940 and STR 7R to 35R with 2R door (25.10.85). A body entrapped in target 399/358 was recovered. Another body which came upto surface with the wreckage fell off into sea and was lost while hauling the wreckage on board. The recovered body was identified as of Dr. Mathew Alexander, a Canadian passenger and was brought to Cork by Fisherman's vessel "Orion" at 0130 hrs. on 28.10.85 and was sent for Post Mortem etc.
(6) Target 7 - Aft cargo compartment fuselage skin from station 1480 to 1860 (26.10.85).
(7) Target 47/50 - Aft cargo floor structure with roller tracks, frames, latch etc. from station 1600 to 1760 (27.10.85).
(8) Target 117 - Three rows of coach class seats with passenger cabin floor boards, broken floor beam (28.10.85).
(9) Target 35 - Aft Pressure Bulkhead piece (30.10.85).

3.2.10.10 The Scarab experienced malfunctions with its arms, Sonar equipment, multiplex system, junction box, microprocessor unit, etc. off and on during the above period of operation. Fouling of lift line with umbilical cord was also experienced in the early stages of operation. Since the assigned recovery by Kreuzturm was over by 30.10.85, and as the Scarab became unserviceable due to breakdown of its power suppluy, the OSV MV Kreuzturm was directed to return to Cork to off-load the recovered wreckage and its operation was terminated, (Indian Government had funded the cost of operation of M.V. Kreuzturm from 21.10.85 onwards).

3.2.10.11 Since the Scrab continued to remain unserviceable, the ship

John Cabot was called back to Cork. It anchored in Cork at 1100 hrs. on 5.11.85. All the wreckage on board the ship was transported to the boat yard, in the afternoon.

3.2.10.12 After detailed macro photography of the recovered wreckage, the experts group mentioned in section 1.5.16 prepared a detailed factual report after carefully inspecting each of the targets recovered. It was decided to send the wreckage to Bombay for which necessary crates were then prepared and the large pieces of wreckage were cut along the lines indicated by the experts group to facilitate their packing.

3.2.10.13 RCMP investigators carried out a close visual and microscopic examination of the fragments recovered with the wreckage, suitcases, seats and cushions, etc. For further laboratory analysis. Dr A.D. Beveridge collected a few samples.

3.2.10.14 The Scarab appeared to be serviceable on 19.11.85 and the ship John Cabot sailed for completion of recovery of left over targets, on 20.11.85. However, the serviceability of Scarab proved elusive, it became inoperable on 21.11.85 and the ship returned to Cork at 1700 hrs on 25.11.85.

3.2.10.15 Efforts were made to repair Scarab so that the ship John Cabot could sail again in order to salvage as many pieces as possible. It was fortunate that the weather had not deteriorated. Some of the important but small pieces which had to be recovered had been placed in a basket at the bottom of the ocean. The ship sailed out again after Scarab had been repared. The basket was sought to be lifted, but, unfortunately, when it reached near the surface of the sea it overturned and the contents of the basket spilled and were never traced again.

3.2.10.16 At this juncture it was decided that the salvage operations should be terminated. The ship returned and sailed for home in the first week of December 1985.

3.2.11 Examination of Wreckage

3.2.11.1 Floating Wreckage

Soon after the accident, a number of light weight parts of the aircraft were found floating over a wide area at the crash site. These were picked up by the ships engaged in rescue operations and were brought to Cork where they were kept in the boat yard. The floating wreckage recovery continued for four days i.e. upto 26th June.

3.2.11.2 Some of the wreckage items were subsequently washed to the west coast of Ireland. These were picked up by the Irish Police and were brought to Cork. Some wreckage items were taken by a ship to Halifax, Canada. These were flown to Cork by the Canadian Aviation Safety Board. With the assitance of Air India engineers, the wreckage items were identified, labelled, photographed and laid out in the boat yard hangar for examination.

3.2.11.3 The wreckage was initially examined at Cork by the Structures, Power Plant and Systems Group. It was subsequently transported to Bombay for further examination. A few wreckage items which were taken by the Spanish trawlers to Madrid were also transported to Bombay. Some wreckage items had washed to the west coast of England. These were collected by the Accident Investigation Branch of UK and were transported to Cork and then to Bombay.

3.2.11.4 The floating wreckage recovered constituted approximately 3 to 5 per cent of the aircraft structure. The major items of the wreckage recovered were :

Various leading edge skin panels of LH nd RH wing, LH wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canon fairings aft end pieces, landing gear wheel wall doors, pieces of elevator and aileron, toilet doors, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggages, suitcases etc. and three empty oxygen bottles.

3.2.11.5 The Structures Group which had been constituted by the Court examined the floating wreckage and submitted its report. From the report the following significant information about the damage to major items of the floating wreckage is noted :

(I) VT-EFO aircraft was carrying a -7Q engine on 5th pod and a -7Q 5th pod kit in the aft cargo compartment. It had therefore, in all 14 engine fan cowls (eight working engine fan cowls plus two 5th pod engine fan cowls plus two -7T engine kit fan cowls in the aft cargo compartment plus two -7Q engine fan cowls in the aft cargo compartment). Out of these 14 fan cowls, 9 cowls (6 of working engines plus 2 of -7J kit plus one of 7Q kit) and two additional pieces of fan cowls were found. Five of the fan cowls of working engines show folding damage lines at approximately 3 O'Clock and 9 O'Clock positions. The number 3 engine inboard fan cowl has severe impact damage on its leading edge and has small inward to outward puncture holes (not penetrating through outer skin) in the lower centre region. The two fan cowls of -7J 5th pod kit stowed in the aft cargo compartment exhibit severe damage. One of these cowls is broken in two pieces. One of the pieces is cut at one corner in an arc of about 20 inches diameter and its external skin is pealed back. The external surfaces of all the three pieces have considereable scratches, tears and holes from outside to inside. None of the punctures penetrates the inner skin. Some punctures are also present from inside to outside but none of these penetrates the outer skin.

(ii) Out of the 12 spoilers, seven (number 2, 3, 5, 7, 8, 9 and 12) have been retrieved. Of these, six have their actuators attached to them in fully retracted position. Six spoilers have splits in their lower skin with split edges curled into the cores of honeycomb. Number 8 spoiler (located just inboard of number 3 engine) has a concentrated local impact damage on front spar and trailing edge beam from forward to aft and up direction over a span of 2 feet starting from outboard of spoiler actuator.

(iii) The left hand wing tip assembly with a part of H F Antenna was retrieved. No burning/discolouration marks around lightning arrester of H F system were noticed. The rib inboard of the lightning arrester was found intact. There were no burn marks anywhere on the panel.

(iv) The right hand wing leading edge top panel inboard of number 3 engine with a position of kruger flap frame along with bull nose attached was recovered. The bull nose was found crushed from top in the area just below the stay rod and the lower surface of stay rod has scratch marks from front to rear.

(v) The right hand wing root leading edge (inboard of W S 268.81) shows an impact damage at the leading edge. Bottom skin and internal structure are torn away. The leading edge skin is caved in over a span of about 3 feet and shows signs of heavy body impact in air. The impact damage shows signs of downward and backward movement of the impacting body.

(vi) A 3' x 2' piece of right hand inboard trailing edge fore flap with accordian seal was recovered. The inboard 8" portion of leading edge was found damaged by impact of an object going from lower forward to upper aft.

(vii) All the floor panels recovered from upper deck and main cabin indicate that these were detached from their attachments in an upward direction from all sides.

(viii) One main deck blow out door located between B S 2040 and 2140 left hand side was available. Out of its four metal clips, one clip was broken off with 2 nylon rivet heads sheared.

(ix) The cockpit entry door and the side bulkhead panel were found fairly intact but had come out of their attachment.

(x) Twelve toilet doors, out of a total of 16, were available and were found fairly intact, but had come out of their attachments.

(xi) The available cabin interior panels and overhead bins of the main deck and upper deck have only minor damage.

(xii) The woodent boxes which contained the fan blades of 5th pod engine and were loaded in container at position 24L in the forward cargo compartment were found broken apart with no burn marks.

3.2.11.6 Wreckage Salvaged from Sea

The wreckage salvaged from the sea was visually examined at Cork by the Committee of Experts as mentioned in section 1.5.16 and the observations thereon recorded. Subsequently detailed metallurgical examination was carried out at the Bhabha Atomic Research Centre, Bombay by

Dr. M.K. Asundi and Dr. G.E. Prasad of B.A.R.C., Mr. S. Radhakrishnan and Dr. R.V. Krishnan of National Aeronautical Laboratory and Mr. B.K. Athawale of the Explosives Research and

Development Laboratory, under the guidance of Dr. V. Ramachandran. During this examination, representatives of CASB, CP Air and Boeing were present in the first week. These represntatives left Bombay while the metallurgical examination was being carried out. The metallurgical examination was continued and the aforesaid group submitted the metallurgical report to the Court in December, 1985.

3.2.11.7 Although all the recovered wreckage was examined, only those items exhibiting characteristics which provide some evidence as to what may have happened to the aircraft during its final moments of flight are discussed herein below :

3.2.11.8 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from B S 1480 to 1850 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear and the torn edge was buckled in waves, like the trace of a sine wave. One the right side, between the one quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at B S 1480. The skin tear located at about B S 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distored and elongated.

3.2.11.9 This panel was examined by the committee of experts at BARC and according to their report the keel beam trunnion fitting beneath the outer chord of the station 1480 bulkhead had fractured at the aft set of bolt holes. The fracture surface of the right side of the trunnion fitting was clean. As per the report, it was typical of overload failure in tension. The fracture surface of the left side of the trunnion fitting was covered with corrosion products, especially, at one corner, due to sea water. After cleaning this area by the recommended techniques, scanning electron microscopy revealed morphology of overload fracture consisting of dimples. Away from this corner also the fracture was similar as being due to overload. There was no evidence of there having been any fatigue failure.

3.2.11.10 At B.A.R.C., a sample was cut from the corroded corner of the failed left side trunnion fitting and metallographic examination was carried out on the same. The said examination showed on a face perpendicular to the corroded fracture surface, pits due to corrosion by sea water. The basic microstructure was however free from intergranular cracking. It was thus concluded by the experts that the material in the region corroded by sea water had not suffered stress corrosion cracking which generally manifests as intergranular cracking.

3.2.11.11 A piece of the trunnion fitting was cut and the hardness and electrical conductivity values were measured by the said experts. As per their report, the electrical conductivity values were within the specified limits.

3.2.11.12 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from B S 1860 to 1960 and from stringer 46L to 46R. The forward end of target 8 matched with the aft end of Target 7. A region of fracture along the rivet holes near stringer 46L was marked for SEM examination. SEM examination after cleaning revealed that the fracture was characterised by dimples along its length, including areas adjacent to the edges of the rivet holes. These features are consistent with an overload mode of failure.

3.2.11.13 According to the metallurgical report, there was no evidence of fatigue failure on this target.

3.2.11.14 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 O'Clock position, the piece from 12 to 1 O'Clock position had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 O'Clock position the outer edge showed sinusoidal buckling, and the edge sector at 9 O'Clock position was partially collapsed and its edge was turned under. Samples taken for optical stereo microscope and SEM examination revealed that the fracture characteristics were consistent with an ovrload mode of failure.

3.2.11.15 According to the metallurgical report, there was no evidence of fatigue or any other mode of failure.

3.2.11.16 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occuped the 7 to 9 O'Clock position. Optical and SEM examination were undertaken on this item.

3.2.11.17 The fracture alont the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

3.2.11.18 Representative fracture samples were cut from the left-hand side and circumferential fracture edges of the fracture surfaces. Optial and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

3.2.11.19 Target 47 - Aft Cargo Floor Structure

This portion of the aft cargo compartment was located between B S 1600 and B S 1760. No significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

3.2.11.20 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between B S 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

3.2.11.21 In the metallurgical report it is stated that on an examination of this target it was also found that on the underside of this floor near the forward end, a number of dents and impact marks were observed. This region appeared to have suffered shrapnel penetration. This area was radiographed but no metallic fragment was detected.

3.2.11.22 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segement was located between B S 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

3.2.11.23 Target 399 - Fuselage around 2R Door

This target is shown in Fig. 399-1. A detailed description is given below :

TARGET 399 Fuselage Station 780 to 940 in the longitudinal direction and stringer 7R down
to stringer 35R circumferentially.

This piece contained five window frames, one in the 2R passenger entry door. Three of the window frames, including the door window frame, still contained window panes. Little overall deformation was found in the stringers and skin above the door. The structure did contain a significant amount of damage and fractures in the skin and stringers beneath the window level. In the area beneath the level of the windows, the original convex outward shape of the surface had been deformed into an inward concave shape. Further inward concavity was found in the skin between many of the stringers below stringer 28R. The skin at the forward edge of the piece was folded outward and back between stringers 25R and 30R. Over most of the remaining edges of the piece a relatively small amount of overall deformation was noted in the skin adjacent to the edge separations. Twelve holes or damage areas were numbered and are further described.

No.1 : Hole, 5 inches by 9 inches with two large flaps and one smaller curl, all folded outward. Reversing slant fractures, small area missing.

No.2 : Hole, 2 inches by 3/4 inch, one flap folded outward, reversing slant fractures, one curled sliver, no missing metal.

No.3 : Triangular shaped hole about 2 inches on each side. One flap, folding inward, with one area with a serrated edge. No missing metal, extensive cracking away from corners of the hole, reversing slant fracture.

No.4 : Tear area, 8 inches overall, with deformation inward in the centre of the area. Reversing slant fracture.

No.5 : Fracture area with two legs measuring 14 inches and about 24 inches. Small triangular shaped piece missing from a position slightly above stringer 27R. Inward fold noted near the joint of the legs. An area of 45° scuff marks extend onto this fold.

No.6 : Hole about 2.5 inches by 3 inches with a flap folded outward, reversing slant fracture. Approximately half the metal from the hole is missing.

No.7 : Hole about 3 inches by 1 inch, all metal from the hole is missing. Fracture edges are deformed outward.

No.8 : Forward edge of the skin is deformed into an "S" shaped flap. Three inward curls noted on an edge.

No.9 : Inwardly deformed flap of metal between stringers 11R and 12R at a frame splice separation. No evidence of an impact on the outside surface.

No.10 : Door lower sill fractured and deformed downward at the aft edge of the door.

No.11 : Frame 860 missing above stringer 14R. Upper auxilliary frame of the door has its inner chord and web missing at station 860. A 10 inch piece of stringer 12R is missing aft of station 860.

No.12 : Attached piece of floor panel (beneath door) has one half of a seat track attached. The floor panel is perforated and the lower surface skin is torn.

3.2.11.24 Much of the damage on this target was on the skin and stringers beneath the window level, i.e., on the starboard side of the front cargo hold. The inside and outside surface of the skin in this region are shown in Fig. 399-2 and 399-3 respectively. There were 12 holes or damaged areas on the skin as described above, generally with petals bending outwards. The curl on a flap around hole no.1 shown in Figh 399-4 has one full turn.

This curl is in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.

3.2.11.25 When this target was recovered from the sea, along with it came a large number, a few hundreds, of tiny fragments and medium size pieces, All of the fragmets were recovered from the area below the passenger entry door 2R. One of the medium size pieces recovered with this target was a floor stantion, about 35 inches long, shown in Fig. 399-5. It is a square tube. It had the mark station 880 painted on its inner face, i.e. facing the centre line of the cargo hold. The part number printed on this station is 69B06115 12 and the assembly number is ASSY 65B06115-942 E3664 1/31/78*. It was confirmed that this stantion belongs to the starboard side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the station. Fig. 399-6 is a print from the radiograph of this station. The inward curling can be seen clearly in this figure. Curling of the metal in this manner is a shock wave effect.

3.2.11.26 A piece near the fracture edge of this stantion was cut, and examined metallographically. Fig. 399-7 and 399-8 show the microstructure of this piece. Twins are seen in the grains close to the fracture edge. The normal microstructure of the stantion material is free from twins as shown in Fig. 399-9.

3.2.11.27 Fig. 399-10 shows a collection of small fragments recovered along with target 399. There were some curved fragments with small radius of curvature (A). Reverse slant fracture (B) was noticed in some of the skin pieces. A piece 3/4" x 1/2" and 3/16" thick was found to have three blunt spikes at the edge (C). This piece was metallographicaly polished on the longitudinal edge. The microstructre of the piece is shown in Fig. 399-11. It may be seen that the grains in this fragment also contain a large number of twins.

3.2.11.28 Target 362/396 Forward Cargo Skin

This piece indluded the station 815 electronic access door, portions of seven longitudinal stringers to the left of bottom centre and five longitudinal stringers to the right of bottom centre. The original shape of the piece (convex in the circumferential direction) had been deformed to a concave inward overall shape. Multiple separations were found in the skin as well as in the underlying stringers. Further inward

concavity was found in the skin between most of the stringers.
3.2.11.29 The two sides of this piece are shown in Fig. 362-1 and 362-2. This piece has 25 holes or damaged areas in most of which there are multiple petals curling outwards. These holes are numbered 1 to 3, 4a, 4b, 4c and 5 to 23. These are described below. Unless otherwise noted, holes did not have any material missing :

No.1 : Hole with a large flap of skin, reversing slant fracture.
No.2 : Hole with multiple curls, reverse slant fracture.
No.3 : Hole with multiple flaps and curls, reversing slant fracture, one area of spikes (ragged sawtooth)
No.4A : One large flap, reverse slant fracture, one area of spikes.
No.4B : Hole with two flaps.
No.4C : Hole with two flaps, one area of spikes
No.5 : HOle with two flaps.
No.6 : Braching tear from the left side of the piece, reversing slant fracture.
No.7 : Hole, with one flap, one curl and one area of spikes.
No.8 : Very large tear from the left side of the piece with multiple flaps and curls, reversing slant fracture and at least two areas of spikes.
No.9 : Hole with multiple flaps, one curl.
No. 10 : 2.5 inch tear
No.11 : One flap
No. 12 : Grip hole, plus a curl with spikes on both sides of the curl.
No.13 : "U" shaped notch with gouge marks in the inboard/outboard direction. Three curls are nearby with one are of spikes. Gouges found on a nearby stringer and on a nearby flap.
No. 14 : Nearly circular hole, 0.3 inch to 0.4 inch in diameter. Small metal lipping on outside surface of the skin. Most of the metal from the hole is missing.
No. 15 : Hole in the skin beneath the first stringer to the left of centre bottom. Small piece missing.
No. 16 : Hole in the stringer above hole No. 15. Most of the metal from this hole is missing.
No. 17 : Hole through the second stringer to the left of centre bottom,

0.4 inch in diameter. The hole encompassed a rivet which attached the stringer to the outer skin. Small pieces of metal missing.

No. 18 : Hole at the aft end of the piece between the third and fourth stringers to the left of centre bottom. The hole consisted of a circular portion (0.4 inch diameter), plus a folded lip extending away from the hole. The metal from the circular area was missing.

No. 19 : Hole with metal folded from the outside to the inside, about 0.6 inch by 1.5 inch. Flap adjacent to the hole contained a heavy gouge mark on the outside surface of the skin.

No. 20 : Hole containing a piece of extruded angle.

No. 21 : Hole containing a piece of extruded angle.

No. 22 : Hole with one flap.

No. 23 : Hole about 0.3 inch in diameter, with tears away from the hole. Small piece missing.

3.2.11.30 Fig. 362-3 to 362-7 show a few of these holes. There were also cracks or tears around some of the holes. The curls around some of the holes had nearly one full turn. In the large tear between body stations 700 and 740 and stringers between 41L and 45L, there were many pronounced curls as shown in Fig. 362-8. On the edges of the petals around several holes, reverse slant fracture was seen at a number of places. This slant fracture is at an angle of about 45° to the skin surface, the fracture continuing in the same general direction but with the slope of the slant fracture reversing frequently.

3.2.11.31 Sharp spikes were observed at the edges of the holes or at the edges of the petals around the holes No. 3, 4A, 4C, 7, 8 (at two locations), 12, 13 and 16. Some of the spikes are shown in Fig. 362-9 to 362-12. One of the holes, No. 14, on the skin was nearly elliptical with metal completely missing, as shown in Fig. 362-13. On the inside surface of the skin, paint surrounding this hole was missing. Hole No. 16 was through the hat section stringer, as shown in Fig. 362-14. In this, most of the metal was missing. On the inside of the hat section, the fracture edge of this hole had spikes, as shown in Fig. 362-15. Hole No. 17 was through the stringer and the skin, as shown in 362-16.

3.2.11.32 Through holes No. 20 and 21, extruded angles were found stuck inside, as shown in Fig. 362-17 and 362-18 respectively. In the petal around hole No. 20, there was an impact mark by hit from the angle as seen in Fig. 362-19 photographed after removing the angle. Such a mark was not present in the petals around other holes.

3.2.11.33 On the skin adjacent to hole No. 13 gouge marks were noticed, Fig. 362-20. These marks were on the inside surface of the skin. To check whether these could be due to rubbing by the bridal cable of Scarab during the recovery operations, a sample of bridal cable was obtained from "John Cabot" and gouge marks were produced by pressing this cable against an aluminium sheet. The gouge marks thus produced, as shown in Fig. 362-21, appear to be different from those observed near hole No. 13.

3.2.11.34 A piece surrounding hole No. 14 was cut out and examined in a Jeol 840 scanning electron microscope at the Naval Chemical and Metallurgical Laboratory, Bombay. Fig. 362-22 and 362-23 are the scanning electron micrographs showing the inside surface and outside surface of the skin around this hole. Flow of metal from inside to outside can be seen from these figures. Energy dispersive x-ray analysis was carried out on the edges of this hole. Only the elements present in this alloy and sea water residue were detected.

3.2.11.35 A portion of the skin containing part of hole No. 14 was cut, polished on the thickness side of the skin and examined in a metallurgical microscope. Fig. 362-24 shows the microstructure of this region. The flow of metal along the edge of the hole can be seen from the shape of the deformed grains near the hole. This can be compared with the bulk of the grains shown in Fig. 362-25, away from the hole. In addition, in Fig. 362-24, a series of twin bands can be seen in some of the grains near the hole. Fig. 362-26 shows these bands at a higher magnification. Normal deformation rates at various temperatures do not produce such twinning in aluminium or its alloys. It may be noted that this microstructural feature is absent in the microstructure of the skin, away from hole No. 14, Fig. 362-25.

3.2.11.36 Metallography was also carried out on a petal around hole

No.7 and on a curl with spikes around hole No. 12. The microstructures indicate twins, however they could not be recorded due to their poor contrast.

3.2.11.37 Small pieces containing the spikes around holes No. 12 and 16 were cut and energy dispersive x-ray chemical analysis on the region of spikes in both was carried out in the Jeol 840 SEM. Only elements present in the alloys and sea water residue were detected.

3.2.11.38 A number of small fragments were found along with the forward cargo skin in target 362. Amongst them was a piece from the web of a roller tray. This has pronounced curling of the edges towards the drive wheel, Fig. 362-27.

3.2.11.39 Another small fragment was found from the above target. This piece, identified as specimen No. 12 in box No. 1, target 362, has a number of spikes along the edge. A scanning electron micrograph of the spikes is shown in Fig. 362-28. The sides of the spikes on SEM examination revealed elongated dimples as shown in Fig. 362-29, characteristic of shear mode of fracture. Metallography was carried out on the thickness side of this specimen. Fig. 362-30 and 362-31 show the microstructure near the apex of the spike and at the root of the spike respectively. Extensive twinning can be seen in these regions of the spikes.

3.2.11.40 Another fragment recovered with target 362 and identified as specimen No. 8 in box No. 1, also showed extensive twinning. The microstructure is recorded in Fig. 362-32.

3.2.11.41 Reference has also to be made to two other reports concerning wreckage.

3.2.11.42 The floating wreckage recovered was initially examined at Cork. On 25th June, Mr. Eric Newton a retired investigator of AIB, UK, was requested to examine the floating wreckage recovered and other materials with specific reference to the possibility of explosive sabotage having taken place. Mr. Newton examined the floating wreckage, passenger clothings and the other materials recovered from the crash victims The findings of Mr. Newton on the material available at that time are summarised below:

a. Taking the scatter of the wreckage and bodies into consideration and the condition of the limited wreckage recovered indicates that the aircraft had broken up in flight before impact with the sea.
b. Detailed examination of the structural wreckage recovered did not reveal any evidence of collision with another aircraft. Nothing was found suggestive of an external missile attack.
c. There was no evidence of fire internal or external.
d. There was no evidence of lightning strike.
e. Examination of all available structural parts recovered, did not reveal any evidence of significant corrosion, metal fatigue or other material defects. All fractures and failures were consistent with overstressing material and crash impact forces
f. Examination of clothing from the bodies did not show any explosive fractures or any signs of burning. The seat cushions and head cushions also did not show any explosive characteristics.
g. The damage to the suitcases (14 large and 29 small) which were examined was due to impact crash forces. The presence of 14 large suitcases could, however, indicate that one of the baggage containers had been broken to permit these suitcases to escape.
h. A number of lavatory doors and structure also did not show any damage consistent with explosion. The flight deck door showed no explosion damage inside or outside.
i The circumstatnial evidence strongly suggests a sudden and unexpected disaster occurred in flight.
j. There was no significant fire or explosion in the flight deck, first and tourist passenger cabin including several lavatories and the rear bulk cargo hold.

3.2.11.43 The other report dated 30th November, 1985 is of Mr. V.J. Clancy. Mr. Clancey had examined the wreckage and had also taken part, though only for a few days, in the metallurgical examination which was being conducted at BARC, Bombay.

3.2.11.44 Mr. Clancey examined practically all the items of wreckage which had been brought to BARC and in his report he has dealt with all of them. His report contained a description of the recovered items and also his comments thereon.

3.2.11.45 With regard to the aforesaid target 362, he observed that there were about 20 holes in it clearly resulting from penetrations from inside.

3.2.11.46 He further stated that:

"In addition to the fact that perforation was from inside there are certain features which suggest that they were made by high velocity fragments such as are produced by an explosion. These features are:

(a) Presence of toothed or spiked edges at some parts of the metal which had petalled out from the perforations.

"Tardif and Sterling (Canadian Aeronautics and Space Journal, 1969, 16, 1, 19-27) obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.

(b) Presence of marked curling, in some cases of more than 360°, of some of the petals.

Tradif and Sterling stated that such curling was a feature of explosively produced fragments.

(c) The virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal.

(d) The virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object. This suggested that the production of at least many of the perforations were separate independent events.

(e) One perforation (identified as No. 14) resembles a "bullet hole", that is cleanly punched out - a type of hole usually associated with a high velocity missile.

"There is evidence that the forward part of this item had been folded back inwards along the line of station 760 and then bent back again along a line slightly forward of this station.

"Such folding, may be violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces producing perforations outwards. The overlap of such folding would conceivably have covered the area up to

station 800 and thus included most of the perforations.
"One hole identified as No. 13, was almost certainly caused by a slipping wire rope used as a sling.
"Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken by me of this area and are being examined by R.A.R.D.E. for evidence of fire or explosives".

3.2.11.47 There were several hundred small fragments which were recovered from the same general area as Target 362. While dealing with these Mr. Clancey observed that the production of a large number of small fragments is generally regarded as indicative of an explosion. One piece out of this was isolated, which was about one inch square of sheet alloy, and it was noted by Mr. Clancey that this piece had characteristic spikes on one edge similar to those described by Tardif and Sterling. (This piece is the same as shown in Fig. 362-28).

3.2.11.48 Mr. Clancey also examined a few suit cases which had been recovered. One particular suit case to which reference was made by him was of red plastic material with blue lining. With regard to this he stated that the damaged lining, severely tattered, resembles that of one found after an explosion in an aircraft in Angola. In that case microscopic examination showed definite evidence of damage by an explosion.

3.2.11.49 The later part of the report of Mr. Clancey contained his opinion. With regard to Target 362 his opinion was as follows:
"The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.
"Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.
"A more detailed study, metallurgical and fractographic, is required.
"The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little

information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

"The single "bullet hole", No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

"If the forward part of this item was forcefully and rapidly folded back to impact on the other part it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility".

3.2.11.50 The opinion of Mr. Clancey about the small fragments was as follows:

"The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.

"The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

3.2.11.51 It appeared to the Court that the report of Mr. Clancey required certain clarifications. It was suggested to Boeing Commercial Airplane Company by the Court that Mr. Clancey should appear as a witness. The Court received a message to the effect that Mr. Clancey felt that he could not add anything useful to his report.

3.2.11.52 A close examination of the report of Mr. Clancey shows that the opinion expressed by him in the later part of the report is at considerable variance with the observations contained in the earlier part of the report. Particularly with regard to Target 362 and the small fragments, Mr. Clancey has stated in his observations that there was strong evidence of explosion. In his opinion, however, he has stated that more detailed study is required. It is interesting to note that though Mr.

Clancey has referred to the opinion of Tardif and Sterling, he has not chosen to contradict the conclusions arrived by them. Mr. Clancey has also not stated as to what could possibly have caused the special features which were noted on Target 362.

3.2.11.53 We find the metallurgical report inspires more confidence. Not only is reference and reliance made in the report to other expert opinions contained in various articles written by experts all over the world, certain explosion experiments were also carried out by the experts which led them to the same conclusion.

3.2.11.54 The particulars of the experiments so carried out and the results obtained therefrom have been stated in their report as follows:

EXPLOSION EXPERIMENTS

"To determine the damage by high velocity fragments or shock waves on a structure similar to the one in aircraft cargo hold, the following experiments were conducted on November 30 and December 1, 1985 at the Explosives Research and Development Laboratory, Pune, using plastic explosive (PEKI) and different mixtures of plastic explosive and TNT. The explosive was kept in a box made of sheet metal of 6" x 6" x 6" of 1/16" thickness. This box was kept inside another box made of sheet metal 2' x 2' x 2' of .04 or .06" thickness. The boxes were made of 2024 aluminium alloy sheets used for aircraft skin. To the inner surface of the outer box, hat section stringers similar to those used in the aircraft were riveted. The quantity of explosive used in the inner box was varied from 60 g to 100 g. The explosive was detonated with an electrical detonator. After the explosions the fragments and the panels were collected and examined.

"Experiments were also conducted to produce explosive damage on skin panels, individual hat section stringers and individual stantion tubes. In the case of stantion tubes experiments were carried out placing the explosive charge both inside and outside. The quantity of explosive used was varied from 5 g to 50 g.

"Various types of damages were recorded on all the targets. These include punched holes, petaling and curling around holes, spikes at fracture edges, curved fragments with small radius of curvature and reverse slant fracture. Fig. EXP-1 shows a collection of fragments. The features mentioned above are shown in Fig. EXP-2 to EXP-7. It may be noticed that the features produced by experimental explosion were similar to the features observed largely in target 362 of the wreckage. The small fragments had features similar to those in the fragments from targets 362 and 399.

"Metallography was carried out in (a) a specimen surrounding a punched hole in the skin (b) a specimen surrounding a hole in the stringer, (c) a curl in the stantion and (d) spikes in a fragment. In all these cases, the grains adjacent to the area of explosive damage are having twins. Two typical microstructures are shown in Fig. EXP-8 and EXP-9. Away from these areas the microstructure is normal. Thus it is confirmed that twinning in the microstructure of these structural members is a unique feature of explosive fracture, not produced by any other measns known so far."

3.2.11.55 The findings in the said metallurgical report are also strengthened by the observations of Eric Newton in the article "Investigating Explosive Sabotage in Aircraft" published in the International Journal of Aviation Safety, March 1985, p. 43. Mr. Newton is an acknowledged authority in the detection of explosive sabotage in aircraft. The conclusions contained in the article are based on his review of incidents of explosion between 1946 and 1984 which were known to him. Some of the conclusions arrived at by him which were relevant in the present case are when he states "Generally speaking, the smaller the fragment, higher the velocity of the detonation. Minute fragmentation is indicative of high explosive having been used, and provides clues to the focal point or region of the explosion. The mode of break up of the aircraft itself and its sequence of failure is usually very complicated and quite without the logic dictated by normal aerodynamic overstressing".

3.2.11.56 Mr. Newton has also observed that curling, cork-screwing, and saw tooth edges may also be indicative of an explosion though such fractures by themselves may not be conclusive evidence that an explosion was involved. Firmer evidence, according to him, was of fusing of metal, scorching, pitting and blast effect. He further states that "Perhaps the most conclusive material evidence to be found on metal specimens is cratering, very often in groups, often minute and numerous".

3.2.11.57 Mr. Newton also refers to the positive explosive signatures which remain on a detonation in an aircraft. These positive singatures, according to him, are as follows:

"(a) The formation of distinctive surface effects such as pitting or very small craters formed in metal surfaces, caused by extremely high velocity impacts from small particles of explosive material. Such craters, when viewed under the microscope, have raised and rolled over edges and often have explosive residue in the bottom of the crater.

"(b) Small fragments of metal, some less than 1 mm in diameter, which, under the scanning electron microscope, reveal features such as rolled edges, hot gas washing (orange peel effect, surface melting and pitting and general evidence of heat; such features have been proved and observed following explosive experiments with known explosives). Supporting strong evidence would be if such fragments (normally found embedded in structures, furnishing or suitcases) were found embedded in a body where evidence of burning of tissue is present at the puncture entry and where the fragment came to rest.

"(c) As well as surface effects on metal fragments produced by explosives there are deformation mechanisms which are peculiar to high rates of strain at normal temperature. At normal rates of strain metals deform by usual mechanism associated with dislocation movement. However, because this process in an explosion is thermally activated at very high rates of strain, there is insufficient time for the normal process to occur. In some metals such as copper, iron and steel, deformation in the crystals of the metal takes place by 'twinning', that is to say by parallel lines or cracks cutting across the crystal. Such a phenomenon can occur only if the specimen has been subjected to extreme shock wave loading at velocities in the order of 8000 m/sec. Such specimens, usually distorted must be selected with care, prepared in a metallurgical laboratory, polished, mounted and microscopically examined. Where such twinning of the crystals is found it establishes (a) that the specimen was close to the seat of the explosion and (b) that a military type explosive had been used with a detonating velocity of 8000 m/sec or more. Twinning is rarely produced when shock impact loadings are below 8000 m/sec.

"The above features, singly or combined, are considered to be proof positive evidence of a detonation of a high explosive; they could not be produced in any other way."

3.2.11.58 The metallurgical report indicates that the microscopic examination (conducted by them) discloses such features being present which had been described as positive signatures of the detonation of an explosive device in an aircraft by Mr. Newton. Furthermore, twinning effect has also been noticed at a number of places - around holes and in fragments. These have been categorised by Mr. Newton as positive signature of an explosion.

3.2.11.59 In the primary zone of explosion, metallic structures disintegrate into numerous tiny fragments and usually these fragments contain the above mentioned distinct signatures of explosion. In the present case the explosive damage had occurred at an altitude of 31000 feet when the aircraft was flying over the ocean. The fragments that formed due to explosion must have been scattered over a wide area and it is impossible to locate and recover all of them from the ocean bed. Nevertheless, some of the fragments which were recovered along with the targets 362 and 399 do contain signatures of explosive fracture.

3.2.11.60 From the aforesaid discussion it would, therefore, be safe to conclude that the examination of targets 362 and 399 clearly reveals that there had been a detonation of an explosive device on the Kanishka aircraft and that detonation has taken place not too far away from where these targets had been located.

FIRE

3.3.1 There is no evidence that there was any fire on board the aircraft before it met with the accident.

3.3.2 Amongst the floating wreckage, however, was found, what was later on identified as, a spares equipment box belonging to this aircraft. This box was charred on one side and partially on the bottom. The depth of charring suggested that the burning time was three to four minutes. This box contained some sand and small shellfish. The flesh from the shelfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

FLIGHT RECORDERS

3.4.1 Recovery of Flight Recorders

3.4.1.1 Recovery of the flight recorders was a very difficult and challenging job. At the site of accident, depth of water is about 6700 feet. The job involved fixing the location of recorders and then retrieving them. For this purpose three ships viz. Guardline Locator (a ship provided by Accident Investigation Branch of U.K.), Le Aoife (an Irish Naval Ship) and Leon Thevenin (a French Cable laying ship, charterd by the Government of India) were utilised. Guardline Locator and Le Aoife were solely for fixing the positions of recorders and also had the capability to lift the recorders with the help of its scarab.

3.4.1.2 Both the Cockpit Voice Recorder and the Digital Flight Data Recorder were fitted with Dukane Underwater Acoustic Beacons (Pingers) which enabled establishing the location of flight recorders under water. The Beacons are designed to provide a signal at 37.5 ñ 1 Khz frequency that can be heard for approximately 2 miles in any direction for 30 days after water entry. Its high strength case permits operation in water depth to 20,000 feet. Its pulse repetition rate is not less than 0.9 pulse per second.

3.4.1.3 On 4th July, 1985, Guardline Locator reported strong possibility of two separate sound sources of frequencies between 39 KHz and 42 KHz. On 5th July, Guardline Locator gave coordinates of an area, which it believed contained the pinger. Guardline Locator later reported that using a Dukane Hand Locator, it had located pinger (2) at 5102.6N, 1248.6W. Leon Thevenin then concentrated its search in this area for retrieving the recorders.

3.4.1.4 In response to a query, Messrs Dukane Corporation advised that Pinger transducer is made of ceramic and if cracked during impact, its frequency could be elevated. The pulse rate should, however, be uneffected. Keeping this in mind, the Leon Thevenin increased its Sonar Band one upper frequency limit from 40 KHz to 45 KHz.

3.4.1.5 On 9th July at about 2300 hours the Scarab of Leon Thevenin located the Cockpit Voice Recorder at 5102.67N, 1248.93W and the recorder was brought on the deck at 0747 hrs on 10th July. The CVR was kept in a drum filled with water. The scarab was again lowered on 10th July in the same area and at about 2130 hours faint signals were picked up on Sonar. By about 2200 hours the signals became louder and the pulse rate frequency was calculated to be 72 transmissions per minute. At about 2230 hours the DFDR was also located at 5103.10N, 1249.59W and it was brought on deck at 0245 Z on 11th July.

3.4.1.6 The DFDR was also placed alongside the CVR in the drum filled with water. Leon Thevenin was then advised to return to Cork with the Flight Recorders. Leon Thevenin reached Cork on the morning of 12th July and the flight recorders were placed in two specially fabricated water tight steel containers filled with water. The recorders were then carried to Bombay on the same day by Mr. Satendra Singh, Reginal Controller of Air Safety, Bombay, accompanied by Mr. Vishwanath of Air India for preparing read-outs and transcript of the recorders. Necessary precautions were taken to ensure that the data recorded was not affected during transportation to Bombay.

3.4.1.7 Both the recorders reached Bombay on the morning of 13th July and were kept in the office of the Regional Controller of Air Safety under Armed Police Guard.

3.4.2 Description of Flight Recorders

3.4.2.1 Kanishka was equipped with a Fairchild A-100 Cockpit Voice Recorder Serial No. 5809 and a Lockheed 209E Digital Flight Data Recorder Serial No. 1282. These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the rear pressure bulkhead.

3.4.2.2 The CVR records all crew communications and sounds in the cockpit on a continuous tape loop which has a tape speed of 1-7/8 inches per second. The Recorder has two heads, one head which erases the previous recording and the second which records the current information and thus the last 30 minutes of recorded signals are retained, the previous being automatically erased. It continuously records convervations/sounds from 4 different sources on the following four separate channels:

Channel 1 : Radio channel of pilot

Channel 2 : Radio channel of flight engineer

Channel 3 : Cockpit Area Mike

Channel 4: Radio channel of co-pilot.

3.4.2.3 The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor. Adjacent to this unit was a Lockheed Model 280 Quick Access Recorder that recorded the same serial digital signals on to a 50 hour cassette.

3.4.2.4 The DFDR records 52 basic parameters on a magnetic tape. The tape preserves records of the last 25 hours. The serial digital signal has a bit rate of 768 bits per second and is recorded at a tape speed of 0.37 inches per second.

3.4.3 Examination of Flight Recorders and Tapes

3.4.3.1 General

The recorders brought to Bombay from Cork were opened on 16th July, 1985 at the Air India's Facilities in Bombay in the presence of the Court and Assessors. A team of foreign experts including one each representatives from both the Recorder Manufacturers, three from National Transportation Safety Board, one from Canadian Aviation Safety Board and one from NRC Flight Recorder Playback Centre, Canada were present when the tapes were taken out of the recorders. Apart from them, representatives of the Government of India and Air India were also present.

3.4.3.2 Cockpit Voice Recorder

When the unit was removed from its shipping and storage container, some mechanical damage was immediately evident. The top of the cover had been deformed inwards, probably due to initial external

strong attachments for the horizontally mounted Underwater Acoustic Beacon. The plate had torn away from the light structure behind it. The cause of the damage was not obvious. The light outer cover was removed by cutting it open with hand shears and pliers.

3.4.3.3 When the armoured and insulated containment was opened, the tape transport was found to be in relatively good condition and the tape physically undamaged. Eighteen inches of the tape was pulled from the centre of the tape stack and the tape cut near the stack well clear of the end of recording. The tape was then removed from the recorder, transferred to standard tape reels, laboriously cleaned several times with distilled water and dried with lint free absorbent material.

3.4.3.4 Digital Flight Data Recorder

When the recorder was removed from its shipping and storage container, it was noted that there was very little external damage. A cover on the rear section was removed and it was observed that, when viewed from the front of the recorder, the right hand edges of the four rearmost printed circuit cards were displaced towards the front of the recorder. The left hand edges were restrained by plug-in connectors to the boards. The rearmost card, that controls track selection on the tape, and the one in front of it, had bowed along the right-hand edges and popped out of their plastic guides in the top and bottom of the recorder. Deflection of the other two cards had occurred following failure of the attachments of the right hand ends of the plastic guides to the chassis. The damage could have been caused by a high lontitudinal decelaration, as would occur if the front face of the recorder impacted the water.

3.4.3.5 When the tape deck was opened, it was found that the tape was intact but had become dislodged from the last tape guide when the tape was moving in the direction of the odd-numbered tracks and had also jumped out of the adjacent end-of-tape sensor. One edge of the tape had been streteched in this area. The drive belt to the tape transport was still in its correct position. The tape was stuck to the third tape guide in the odd-numbered track direction and suffered some damage when it was finally detached from it. This was repeaired with a splicing tape.

3.4.3.6 The location of the record heads was marked on the back of the tape with a waterproof felt pen. It was noted that there was slightly more tape on the supply reel for the odd tracks than on the other reel. The tape reels and tape were removed from the recorder, keeping the tape wet with distilled water, and the tape transferred to the standard reels for meticulous cleaning. During the cleaning process, it was found that the edge of the tape had also been stretched locally 336 inches down- stream from the splice repair in the odd track direction. The tape was dried by patting it with absorbent lint-free material before loading it into a serviceable recorder as this was the only means by which it could be replayed at the Air India base.

3.4.3.7 The circuit card controlling track selection was removed from the accident recorder and the status of the latching relays checked to determine the last track on which recording was being made. It was found that the relay states indicated Track 1, but since this requires all relays to be set in the same condition, it was considered possible that they had been mechanically set on water impact. The card was subsequently inserted to another recorder and the Track 1 setting confirmed on a test bench.

3.4.3.8 When a change in track selection was attempted, it was found that the relays would not switch, probably due to the effects of salt water corrosion or high water pressure. It was decided that Track 1 would be considered as the most likely one to contain the accident data with the possibility that it could have occurred on any of the other tracks. When the data was recored, the accident information was found some distance past the mid-point of Track 1.

3.4.4. Recovery of Information

3.4.4.1 Cockpit Voice Recorder Tape

The spool was removed from the CVR and was washed with distilled water, dried and loaded on to another spool. The cleaned and dried tape was taken to the Bhabha Atomic Research Centre (BARC), and a copy of the tape was prepared which was used for preparing transcript and carrying out further analysis. The transcript of the CVR conversation is given in Appendix 2.

3.4.4.2 Shannon Air Traffic Control Tape

A copy of this tape that contains all radio communications between the aircraft and Shannon was provided to the Indian Authorities by the Air Traffic Control Authorities, Shannon. The recording also included the short series of unusual sounds that occurred about the time of the accident.

3.4.4.3 When the CVR and the ATC tapes were played it was found that some adjustment in speed was necessary so as to synchronize the two. This adjustment was independently carried out by different experts who analysed the CVR tapes.

3.4.4.4 Digitial Flight Data Recorder Tape

The Lockheed representative had brought a Lockheed Model 235 Copy Recorder from his plant. This unit copies all the 25 hours of data from the recorder by running it at high speed for only two passes of the tape, an operation lasting only 16 minutes. A copy tape was made by this procedure before embarking on the standard Air India recovery procedure to serve as a back-up tape in the event of physical damage to the original tape in subsequent playback.

3.4.4.5 Air India playback equipment for the DFDR required that the tape be re-installed in another DFDR in which it was driven at high speed. In the standard playback procedure, the tape was first run to the beginning of Track 1 through 6 sequentially on to a computer tape followed by a repeat of Track 1. The computer tape was then taken to Air India's main computing facility where selected information was printed out in engineering units.

3.4.4.6 The first printouts showed that the accident was recorded on Track 1, as indicated by the latching relays, and suggested a rather abrupt end to the recording. There was a loss in bit synchronization in word 26 of the last Subframe 3 of data that was followed by a normal Subframe 4. Prior to the loss in bit synchronization, all measurements appeared normal. Plans were made to borrow the high speed oscillograph recorder previously used to studythe final CVR signals from BARC to examine the end of the recorded serial digital signal in detail.

3.4.4.7 Meanwhile, the critical section of the tape and the heads of the playback recorder were re-cleaned and a second transfer of data on to the computer tape was made. Printouts from this computer tape showed no significant difference from the first one.

3.4.4.8 The recorder was then opened and the tape positioned about 1.5 inches before the final resting place of the tape that was clearly indicated by head imprints on the magnetic oxide coating side. A high speed oscillograph record of a few seconds of data was made and visually decoded. It was found that the recorded GMT was 21 hr 16 min. This time corresponded to 15 min or about 333 inches of the tape after start of the oldest recording downstream of the accident.

3.4.4.9 The tape was then re-positioned using a Lockheed analogue playback unit, that had a display of the recorded time and a stopwatch was used to locate the accident timing. Two oscillograph copies of the end of the serial digital data were made, the second one having more data preceding the end. Visual reading of the traces confirmed that recording became erratic and irrecoverable at the end of Word 26 in Subframe 3 at the recorded time of 07 h : 14m : 35s. The erratic signal continued for about 0.27 inches of the tape before switching back to the data recorded 25 hours earlier.

3.4.4.10 Examination of the printouts confirmed a suspicion that the complete Subframe 4 of data following the partial Subframe 3, was data from 32 seconds earlier that had not been cleared from the data buffer in the computer and that Word 26 of the Subframe 3 was the last normal measurement provided by the recorder.

3.4.4.11 The end of recording occurred at the point on the tape at which some damage had been observed during the cleaning process. It was apparent that, after the end of the recording, the tape had run on for 336 inches before finally coming to rest.

3.4.4.12 A copy tape of the DFDR tape was made at Bombay and taken to Ottawa. Data from the accident flight, the preceeding Toronto-to-Montreal flight and part of the cruise conditions of the earlier flight to Toronto were transcribed on to the computer tape. The tape was edited to minimize errors and converted to engineering units using standards calibration. Time histories of all parameters for periods of interest were plotted. In addition, chart records were made of all parameters in raw data form for the total duration of the last lap of the flight.

3.4.4.13 The DFDR read out shows that the aircraft was cruising at an altitude of 31,000 ft. and a computed air speed of 296 knots till it suddenly stopped recording at 07:14:35 GMT recorded time.

3.4.5 Reports received by the Court

3.4.5.1 The CVR was taken to B.A.R.C. This tape was played by the CVR group a number of times and hard copies of the time information were also prepared using an ultra violet (UV) Recorder. The group consisted of Mr. Satendra Singh, Regional Controller of Air Safety of D.G.C.A., Mr. S.N. Seshadri of BARC, Mr. Paul C. Turner of NTSB, USA, Mr. John G. Young of NTSB, USA and Mr. P. dE Niverville of CASB, Canada. On 18th July, 1985 this group made the following observations after playing the aforesaid tape (UV recording of CVR is at Fig. 1) :-

"The first visible rising signal volume was observed on channel number three the CAM channel It reaches a maximum in about 50 milliseconds. At this time noticeable disturbances are observable on the other three channels. A smaller disturbance is observable on channels 2 and 4 earlier than observable on channel 1. A major disturbance is observed to begin approx. ninety milliseconds following the initial observation on channel number 3 (CAM), on channels 1,2 and 4. Following this point at 75 milliseconds the CAM signal subsides to a lower level but much higher than observed ambient (prior to disturbance) where it remains for approximately 375 milliseconds from initiation when it ceases. Channel four goes off at the same time. Channel 1 goes off twenty five milliseconds earlier. Channel two is inconclusive and had a different pattern. All four channels exhibit a disturbance at approx. 450 milliseconds. The cockpit voice recorder power then shuts off at 650 milliseconds.

The Shannon area control centre tape made the night of the accident was examined and printed. It shows a signal was received at approximately the time the aircraft disappeared from radar. It isn't conclusive at this time that the signal originated from the accident aircraft. The signal was received in pulses for approximately five seconds."

3.4.5.2 The tape was again played on 19th July, 1985 and a further report was prepared which was signed by the aforesaid persons and Mr. B. Caiger of NRC, Canada. In this report it was stated as follows:-
"The Shannon area control centre tape was again printed at .05"/second per inch speed from approximately 22 sec. before the first broadcast from the accident aircraft at 0709.58 until Radio carrier with indecipherable modulation can be heard at 0714:01. The print contains a time encoded signal.
A similar print was made from the CVR channel 4 (Co-Pilot's) of the same audio as received on the ATC tape. Although the tape speed is different, the events when corrected for tape speed errors occur at the same time. It appears that the ATC recording contains the beginning of the aircraft breaking until power is lost to the transmitter since channel one and channel four (Capt + Co-pilot's radio) appear to contain a transmitted signal on the CVR. It is probable that the ATC signal at 0714:01 coincides with the final quarter second of CVR radio channels".
3.4.5.3 On the date i.e. 19th July, 1985, Mr. Paul Turner of NTSB also gave an additional report which is to the following effect :-
"During my observations of numerous cockpit voice recorders I have heard and observed a number of aircraft breakages due to various causes. In this case the explosive sound on the CAM channels occurs prior to any electrical disturbance observable on the selector panel signals. Electrical disturbances can generally be seen prior to audio signal when explosive sounds originate at any significant measureable distance from the microphone (15 feet) and in the area where there is significant electrical systems. It is my opinion that an explosive event occurred close to the cockpit. The CAM signal which follows the explosive event shows a very much higher noice level than cockpit ambient 85 db, indicating to me the cockpit area was penetrated and opened to the atmosphere. The selector panel signals show signatures similar to those of an aircraft breaking up and are apparently caused by electrical systems disturbance (circuit breaker blowing, fuse switching etc.). The lack of Mayday call and apparent inadvertant signal from the cockpit crew incapacitation. The transmitter coming on due to breakup

is phenomena observed previously.
This contains only my personal opinion and in no way should be considered a final determination of cause without corroborating evidence".
3.4.5.4 Copies of the tapes were also sent to some of the participants who wanted to carry out independent analysis.
3.4.5.5 With regard to DFDR the Court received reports from Dr. Caroll Roberts of NTSB and report dated 11th November of Mr. B. Caiger.
3.4.5.6 With regard to CVR the Court received reports from Mr. B. Caiger dated 11th November, 1985, report dated November, 1985 of Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K., report dated 31st August, 1985 of Mr. S.N. Seshadri of BARC, Bombay.
3.4.6 Court Observations
3.4.6.1 Digital Flight Data Recorder
The reports of Dr. Caroll Roberts and Mr. Caiger which also coincide with the report submitted by Mr. Satendra Singh disclose that the DFDR showed no evidence of abnormal values of any of the many parameters being monitored upto a point at which the recorded data signal became irregular for a fraction of a second and recording ceased. Both the DFDR and the CVR stopped at the same time.
3.4.6.2 The short period of irregular digital data that occupied only 0.27 inches of tape, most probably indicates that the recorder was subjected to a sharp angular acceleration in the left wing down sense about the aircraft longitudinal axis.
3.4.6.3 According to Mr. Caiger's report the possibility that the digital recorder was subjected to a sharp disturbance more rapid than violent motion of the aircraft lends some credence to the possibility of a detonatiaon of an explosive device in the aircraft. The other alternative, according to Mr. Caiger, which could have led to this was that the Flight Data Acquisition Unit in the main electronics bay .or its power supply were suddenly disturbed. As the Lockheed Quick Access Recorder was not recovered from the wreckage, this possibility could not be

investigated further. A perusal of the DFDR print out, however, shows that whereas there was a speed limit of 290 knots (.81 Mach) of the aircraft due to carriage of the 5th pod engine, in actual fact the aircraft's speed during cruise varied from 287 to 296 knots. Mr. H.S. Khola asked the Boeing Airplane Company to examine the effect of aircraft cruising at a speed of 296 knots with a 5th pod engine installed on it. The Boeing company sent a reply, inter alia, stating as follows:

"The operating speed limit of Air India 747-237B, JT9D-7J with fifth engine pod was 290 knots indicated airspeed, with an altitude limit of 35,200 feet. Flight testing of this model airplane configuration was successfully accomplished to a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, with no adverse effects.

In the event that the operating speed placard was exceeded an increase in perceptible vibration levels would be felt. As the dive Mach number (0.92) is approached the buffet vibration would increase to level that could become objectional to the flight crew, but would not he bazardous".

3.4.6.4 It would thus be clear that if no adverse effects could have been noticed with a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, there was little likelihbood of the aircraft having been subjected to any adverse effect by reason of the speed varying from 287 to 296 knots while it was cruising at a height of about 31,000 feet.

3.4.6.5 Cockpit Voice Recorder

The Court received four reports of the CVR tape analysis. These reports were of Mr. B. Caiger, Mr. R.A. Davis, Mr. S.N. Seshadri and Mr. Paul C. Turner. Whereas the first three experts appeared and deposed in Court, Mr. Paul Turner did not come.

3.4.6.6. There were certain aspects of the report of Mr. Turner which required clarification. After the Court had failed to secure his presence, it sent a questionnaire to Mr. Turner for his answers thereto. It is indeed unfortunate that till now no reply has been received. It is in this background that the report dated 13th November, 1985 of Mr. Turner and the reports of other experts have to be judged and analysed.

3.4.6.7 Mr. B. Caiger's Report and Deposition

Mr. Caiger has said in his report that the Cockpit Area Microphone signal was studied in detail. According to him, in an aircraft, sound can be transmitted by multiplicity of paths. If an explosive device was located close to the microphone then the short wave from the disturbance would cause a sharp rise in pressure which was not noticed. From more remote location, however, structurally transmitted sounds could reach the microphone first and induce more complex signals. According to Mr. Caiger, at this time he did not have any evidence from occurrences of this nature that would permit any meaningful comparisons or conclusions.

3.4.6.8 Mr. Caiger obtained from the manufacturers details of Automatic Gain Control (AGC) on the cockpit area microphone. According to the information so provided it was indicated that the decrease in amplitude of the recorded noise over about 33 msec after the peak level was reached 40 msec from the start of the disturbance is most probably due to the AGC and that the actual envelope of the pressure levels at the microphone continued to increase until 90 msec from the start before establishing at about four times the recorded level until the 160 msec point when the recorded amplitude started to decrease rapidly. Mr. Caiger could not find any explanation for this marked reduction. Mr. Caiger further recorded that the large amplitude lower frequency signature, that immdediately followed this reduction, is similar to signatures observed by the manufacturer when there was an abrupt break in the line from the cockpit area microphone pre-amplifier output to the voice recorder. No similar signature was observed in tests on the crew audio channels when the appropriate lines to the recorder were similarly interrupted.

3.4.6.9 The observation of Mr. Caiger with regard to ATC tape was as follows :-

"The ATC recording that followed the cockpit area microphone sounds appears at first to contain a series of short intermittant sounds. Closer study reveals that the background noise only returns to its steady level for about 160 msec immediately after the first low level noise and again for about 85 msec just over halfway through the 5.4 sec duration of the recordings. At the end of all routine radio transmissions, a damped sine wave transmitter keying signature is observed with a frequency in the region of 450 Hz. In the accident recordings, only two of these are observed".

"Listening to the sounds, it also appears that a human cry occurs near the end of the recordings. Spectral analysis of these sounds and comparison with voice limitations reveals that the accident sounds do not contain all the pitch harmonic frequencies normally associated with such voice sounds. The origin of all the sounds has not been identified."

3.4.6.10 From the aforesaid investigation Mr. Caiger concluded that :-

"From the voice and data recorders, Air India Flight 182 was proceeding normally enroute from Montreal to London, England at an altitude of 31,000 feet and a computed airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound the cause of which has not yet been identified. The sound continued for about 0.35 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder".

"The initial waveform of the cockpit area microphone signal is not consistant with the sharp pressure rise expected with detonation of an explosive device close to the flight deck but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, we cannot at this time exclude the possibility that it originated from such a device elsewhere in the aircraft".

"Within 1 to 2 seconds of the first detection of the loud sound on the cockpit area microphone, a series of unidentified noises were recorded on the Shannon ATC tape. These extended over a period of 5.4 seconds and are assumed to have origniated from VT-EFO. They gave the impression of abnormal conditions on the flight deck".

3.4.6.11 In his evidence in court, Mr. Caiger explained about Automatic Gain Control. He stated that the CAM channel of the CVR had an Automatic Gain Gontrol in a pre-amplifier that is installed close to the microphone. This AGC is designed to prevent excessively loud signals from saturating the microphone and the associated electronics. He further stated that from the tests conducted by the manufacturers it could be concluded that most likely at 45 msec. point the AGC came into effect which gradually reduced the signal over the next 33 msec. before letting it stabilise at a roughly constant value. This figure of 33 msec. was taken by Mr. Caiger not by carrying out any experiment himself but it was provided to him by the manufacturers. He also stated that there was no positive indication of structural failure being evident from the flight

recorders. Mr. Caiger was asked to explain as to what was the reason for loud sound to which reference had been made in his report. In answer to the said question from the Court he said that there could be a number of reasons. The detonation of an explosive device not close to the microphone was one possibility, the occurrence of some type of structural failure was another possibility. He was further of the opinion that at the present stage of development in structural acoustics, he did not think it was possible to come up with any reasonable estimate of the location of either explosive device or some type of possible structural failure. When asked for his opinion about the sequence of events which he could determine by looking at the sound spectrum, he said as follows:
"From the study that we have made which have of course been augmented by studies done by several other groups it would appear that there was a very sharp bang that was detected by the CAM. Approximately one-third of a second after this happened the line from the CAM to the CVR was disconnected but intermitant power supply was still being sent to the voice recorder for approximately one and a half seconds. During this 1-1/2 seconds period sounds were being transmitted from the 'Kanishka' aircraft that tend to suggest that the aircraft was in some distress. Though it is difficult to be specific about the basis on which we assesss the state of the aircraft, this signal ceased after a period of 5.4 seconds and we have no more audio information concerning the aircraft from that point onwards."

3.4.6.12 Mr. R.A. Davis's Report and Deposition

Mr. R.A. Davis in his report on the analysis of CVR has stated that he did not have with him a faithful copy of the original CVR tape. The tape supplied to his contained signals which warranted investigation but any measurement could be hampered by a decreased signal to noise ratio due to the copying process. Mr. Davis however analysed the tape which admittedly according to him was not of good quality. Mr. Davis in his report states that he carried out a spectrum analysis of the different channels of the CVR. The spectra did contain the sound of a bang. He however, could not find any significant low frequency content in the spectrum which according to him, would have been expected if the sound was of a high explosive detonation.

3.4.6.13 While carrying out detailed study of the tape he also looked out for any evidence of various audio warning signals which may have been buried in the noise. One such audio warning which could have been detected was that of pressurisation warning. Mr. Davis stated that this warning possessed a very defined frequency spectrum which was not present in the signal of the CVR of Kanishka. With regard to this he, however, stated that absence of this signal was not surprising as any decompression would take a finite time before reaching the warning level. Mr. Davis further observed that the presence of warnings due to attititude display disagreement, excessive speed and fire were investigated but with negative results.

3.4.6.14 During the course of investigations, Mr. Davis had compared Kanishka CVR recording with the recordings of an explosive decompression on a DC-10, a bomb in the freight hold of a B-737 and a gun shot on the flight deck of a B-737. According to Mr. Davis the spectrum of VCR tape of B-737 showed a much low frequency content with very little content at upper frequencies. This bomb, in the forward baggage hold of B-737, had exploded while the aircraft was at a low level and therefore the CVR did not have the sound accompanied with that of depressurization. That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a high explosive device, then the spectra should have shown large low frequency content, but this was absent. He further opined that, even if there was a possibility of a bomb remote from the flight deck and of a low power, even then the characteristics of a bomb would still be apparent in the time record. He also analysed the spectrum of the sound of the hand gun shot on a B-737 flight deck and according to him the said signal was sharp edged and did not compare with that of Kanishka's signal.

3.4.6.15 Mr. Davis also analysed the sounds recorded on the ATC tape. He concluded that the sounds emanated from Air India's Kanishka aircraft. According to him the transmission from the ATC is "chopped" until at approximately 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound was similar to that heard in other accidents where there had been a rapid increase in airspeed.

In the noise which continues until the end of the transmission is heard a crying sound. This was originally thought to be a human cry. He, however, noted that a human cry would contain more harmonics than was noticed in this case. It was also reported by Mr. Davis that knocking sounds which were heard during the transmission were initially thought to be due to hand-held microphone vibration. This was discounted because of the frequency of the sounds. He noticed that almost identical sounds were heard on the DC-10 CVR after the decompression had occured and the source of that sound had not been identified. On the DC-10 the pressurization audio warning commenced 2.2 seconds after the decompression. Analysing the ATC tape Mr. Davis observed that no such warning was identified during the open microphone transmission.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-

"It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182.

"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.

"Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone.

Such a situation would be most unusual, if not unique, in that we have never failed to detect sounds of structural failure, decompression, explosives etc., on any accident CVR, even though the event occurred at the rear of the aircraft. If such a device was used on AI 182 it is considered that it would have to be a very small device in order not to be detected (unlikely in itself). Such a device would be unlikely to cause the sudden total destruction which occurred in this instance. It is considered that a device of sufficient power to produce this effect could not fail to be detected on the CVR. The B-747 explosions referred to earlier, blew holes several feet wide in the structure but the crew were still able to control and operate the aircraft.

"It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

3.4.6.17 In reply to a question it was stated by Mr. Davis, when he was examined in Court, that it was true that there was no evidence that rapid decompression was caused by any structural failure. In an answer to another question, as to whether in his opinion there is a low frequency content present in every situation whereever there has been a high explosive device detonated, Mr. Davis answered in the affirmative, he however added that "But we do not have sufficient numbers to indicate that that would always be the case". Mr. Davis, however, agreed that DC-10 aircraft was quite dissimilar to Boeing 747, and the sound of an explosive decompression in the aft cargo hold of a DC-10 would not be identical to an explosive decompression in the aft cargo hold of a Boeing 747.

3.4.6.18 Mr. Davis further agreed that he was looking for low frequencies in Kanishka tape, but he did not know what type of low frequencies should be looked out for because there was no available data anywhere in the world for the sound of a bomb explosion in a Boeing 747. Mr. Davis was however emphatic in saying that he could not measure the distance of the origin of the sound from the cockpit area mike. In his report, and also in the earlier part of the examination, Mr. Davis had referred to the absence of low frequency component in the spectrum and had sought to conclude that such absence showed that there was no detonation of a high explosive device. In an answer to the question put by the Court however, Mr. Davis appeared to have altered his stand. This is evident from the following deposition of Mr. Davis :-

"Court Ques Am I to understand that there must necessarily be a low frequency whenever an explosion occurs?

Ans. No. What we thought was there would be. There was only one sample of explosion in B-737. But we would need more accidents of that nature to able to say that yes we must have a low frequency component.

Court Ques: Am I to understand that the absence of a low frequency component would not therefore necessarily mean that the sound was not that of an explosion?

Ans. Because of the absence of a low frequency component we would not be able to say positively that there was an explosion or it was not explosion."

Court Ques : Would the frequency of a particular type of sound change depending upon the environment in which that sound occurs?

Ans Yes.

Court Ques If an event results in low frequency sounds in one type of environment, can it mean that the same event can result in a high frequency sound in a different environment?

Ans. That must be possible".

3.4.6.19 Mr. S.N. Seshadri's Report and Deposition

A detailed analysis of the CVR and the ATC tapes was also carried out by Mr. S.N. Seshadri at BARC. For the purposes of comparison, CVR tapes of Iranian Air Force Boeing 747 accident as well as that of Indian Airlines Boeing 737 accident were also analysed at BARC.

3.4.6.20 The original CVR tape of Kanishka was played on a 4 channel tape recorder modified to run at 1-7/8" per second. The output of this tape recorder was copied faithfully on an eight channel HP 3968A instrumentation tape recorder. Channels 1 to 4 were used for recording the CVR data and channels 5 for recording a time marker. For further processing and signal analysis this copy of the original tape was

used.
3.4.6.21 The observations of the data so recorded, as contained in the said report inter-alia are as follows :
"Repeated and careful listening to all the four channels revealed the presence of explosive sounds on all these channels occuring nearly at the end at the same time. Speech information is present on channels 3 and 4 during the last few minutes. Channel 1 does not contain any speech data during this period. Channel 2 contains indecipherable speech data about 20 to 25 seconds before the explosive sound".
"It was decided to analyse in detail the tape data during the final few seconds within which significant audio and electrical changes were observed to be present. Data from all the four channels were displayed on a Tektronix 2-channel storage oscilloscope Model 466 for initial observations. Based on this study the relevant portion of the tape was selected for more intensive snalysis. Simultanious ultraviolet recording of all the four channels on this portion of the tape was next carried out".
The following observations are relevant.
1. Channel 3, which corresponds to the area mike shows the first indication of a rising audio signal. This instant is termed, for conveniece, as zero time reference. The signal level rises from the ambient level in the cockpit by about 18.5 db in approximately 45 milliseconds. The signal then starts falling and stablises at a level about 10 db higher than the ambient level before zero time. The signal continues to remain at this level for about 275 milliseconds. The total duration of the signal from zero reference is thus about 360 milliseconds.
2. Channels 1 and 2, which are the radio channels of the pilot and the flight engineer respectively, show start of electrical disturbance signals 45 milliseconds from zero time at which the audio signal on channel 3 is at its maximum. These signals, which have do minant frequencies in the range of 70 to 210 Hz, persist for about 100 milliseconds on both channels. Subsequent to this, channel 1, shows an audio burst lasting about 200 milliseconds. Channel 2 shows a delayed audio burst lasting 25 milliseconds, 220 milliseconds from zero time, or in other words, 175

milliseconds after the peak signal from channel 3. A low amplitude tail appears after this burst and lasts around 40 milliseconds. Channel 4 which is the co-pilot's radio channel shows an electrical disturbance commencing at 85 milliseconds from zero time and lasting around 60 milliseconds. The frequency distribution during this period is similar to those on channels 1 and 2. This is followed
by an audio burst of 230 milliseconds duration. The frequency spectra of the audio portions of channels 1,2 and 4 are reasonably similar."

3.4.6.22 "Correlation of Events of ATC Shannon Tape and Channel 4 of CVR tape :

"It was observed that during the last few minutes before the stoppage of the CVR, information recorded on the ATC tape and channel 4 of the CVR tape are identical. However, the ATC tape contains a series of audio bursts approximately corresponding to the instant at which a single explosive sound is recorded on channel 4. Thus a doubt arose whether the series of audio bursts recorded on the ATC tape had originated from channel 4 of Kanishka CVR since these are not recorded on the CVR tape. In order to obtain an answer to this it was necessary to check with very good accuracy the simultaneity of the explosive sound on channel 4 and the series of audio bursts on the ATC. The procedure followed for the same is given below.

"The ATC Shannon tape and the CVR tape were run on two independent tape recorders. It was found that the speeds of the two tapes were mismatched. In order to match speeds the earliest speech signal on both the tapes.

"Seven seventy that checks maintain three five zero" was used as the reference point. The speech signals which mostly contain the conversation between the co-pilot and ATC Shannon lasts for about 146 seconds. Channel four was kept ready for starting exactly at the reference point. The ATC was next played starting well before the reference point. The tape recorder playing channel 4 was started manually exactly at the time when the reference point on the ATC was audible. By noting the time of ending of the conversation on both the tapes which corresponds to

"Right Sir squaking two zero zero five one eight two" the speed of the recorder playing the ATC tape was corrected by pitch control to approach the speed of CVR tape. The process was repeated a number of times till audibly the speeds were matched. The two tapes were next synchronously played and both the channels were simultaneously recorded on a third recorder to a point well after the explosive sound on channel 4. This tape was used for all further analysis.

"The first significant observation was that the explosive sound on channel 4 coincided with the beginning of the series of audio bursts on the ATC tape as heard by the ear. It was thus clear that both the recordings correspond to those generated by Kanishka during its last moments.

"To confirm this preliminary conclusion which was judged solely by the ear, accurate instrumented tests were carried out. The two channels were simultaneously recorded on an ultraviolet recorder at the four speeds, 0.1"/sec, 1"/sec, 10"/sec and 160"/sec for study of synchronism as well as frequency details. It was noticed that the two waveforms were not exactly suynchronised though by the ear they appeared to be so. In order to find out exactly the difference in synchronisation the following tests were done:

UV recordings at 16" per second were taken at three representative points relating to the communication of ATC with Kanishka. These points correspond to speech portions at 070838 "Five eh Squawking and eh Air India", at 070958 "Right Sir Squawking" and near the blast on channel 4. It was found that the ATC was running slightly faster. At the first point the ATC was leading by 90 milliseconds, and at the second point by 130 milliseconds. The time interval between these points is about 80 sec. By extrapolating this lead to the time of the blast which occurs about 243 sec. from the second point, it is clear that the lead of the ATC with respect to channel 4 at this point will be given by 130 + (130-90) (243/80) which is approximately 250 milliseconds. This error is very small."

"Thus one can conclude that the sounds recorded on the ATC Shannon tape are those which emanated from Kanishka during its last seconds."

3.4.6.23 "Frequency Analysis:
Mr. Seshadri also carried out frequency analysis of the CVR and the ATC tapes. His opinion with regard to the same was the follows:
"Significant audio and electrical disturbances were observed in the final few seconds of the CVR tape. It was therefore decided to analyse all the four channels for their frequency contents at the various places in this pertinent region. For Fourier analysis of each signal, digitized time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

3.4.6.24 "The frequency analysis of electrical disturbances in channels 1,2 and 4 indicate presence of low frequencies in the region of 20 Hz to 600 Hz. The dominant frequencies are in the range of 70 Hz to 210 Hz.

3.4.6.25 "The frequency spectrum of the background noise in channel 3 just before the explosive sound has a broad band spectrum with some dominant frequencies in the region of 650 Hz to 1550 Hz. At the bang, many additional frequencies appear. The frequency spectrum of bang on channel 3 indicates an increase in the bandwidth.

3.4.6.26 "The frequency spectrum of channel 1 at the bang position indicates a fairly broad spectrum with dominant frequencies in the range of 150 Hz to 1 KHz. Channel 2 displays a frequency spectrum at the bang position in which low frequencies are dominant. It has a significant frequency range between 20 Hz to about 1 KHz. The frequency spectrum of channel 4 at the bang is wide-band with a broad peak in the range of 150 Hz to 800 Hz.

3.4.6.27 "At the beginning of the crackling sound, the frequency spectrum shows narrow band peaks around 1.6 KHz. About 90 and 300 milliseconds later, the spectrum changes with additional peaks appearing around 400 Hz, 600 Hz and 1150 Hz. Frequency analysis was also carried out at 600, 800 and 1000 milliseconds before the start of the crackling sound."

3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

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3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal

peaks to its maximum of 18.5 db above ambient level in about 45 milliseconds. A loud audible blast is heard when this channel is played at this point. An analysis of the frequency spectra before this loud blast and during the blast shows a definite change in the frequency composition. From all the above results it can be concluded that an explosion occurred in the aircraft. The exact position in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the Cockpit judging from the rise time of 45 milliseconds.

3.4.6.29 "Explosive sounds on all the four radio channels preceded by electrical disturbance reinforce the evidence provided by channel 3.

3.4.6.30 The synchronised recording and detailed analysis of the ATC and channel 4 confirm that the sounds recorded in the ATC Shannon tape are undoubtedly attributable to the transmissions from AI 182 Kanishka during its last moments. The sounds indicate possible breaking up of the aircraft in mid air and the air blast which follows a decompression. A very detailed UV recording does not indicate the presence of a second explosion."

3.4.6.31 "Copies of CVR tapes of well understood air crashes pertaining to an Indian Airlines Boeing 737 in 1979 and Iranian Air Force Boeing 747 in 1976 were analysed for possible reference in connection with the analysis of the CVR tape of Kanishka.

3.4.6.32 "A definite explosion near the Cockpit was the cause of the crash of the Indian Airlines Boeing 737. An explosive sound recorded on the Cockpit Area Mike shows a rise time of about 8 milliseconds which corresponds to a distance of about 8 feet. This indicates that the rise time is a measure of the distance from the Cockpit Area Mike at which an explosion has occurred.

3.4.6.33 "The Iranian Air Force Boeing 747 broke up in mid air. Analysis of the CVR tape clearly indicates that the frequency spectra of the electrical disturbances are similar to those obtained for Kanishka. Thus the series of audio bursts recorded on the ATC Shannon tape have been most probably generated by the break-up of kanishka in midair.

3.4.6.34 Mr. Seshadri was also examined in Court on 27th January, 1986. In his deposition he very succintly explained some aspects of the work which was done by him. He also dealt with the aspect of AGC to which reference has been made by Mr. R.A. Davis and Mr. Paul Turner in their reports. The relevant part of the testimony in this connection is as follows :-

"We wanted to make sure that the CVR recording and the ATC corresponded to the same aircraft Kanishka. When we played the tapes for the first time we found that there was a difference of about 1 second. Though this figure may be tolerable because of the accuracy of the tape speeds, we wanted to investigate further to make really sure that the ATC corresponded to Kanishka. For this purpose we had simultaneously "recorded channel 4 of the CVR and the ATC on a single tape on 2 channels after synchronising the common speech signals to the best of our ability by the ear. We started with the first speech which was available on both the tapes, namely, "770 that checks maintain 350". This was a conversation with the TWA aircraft which is available on both channel 4 and the ATC. The last sound which is recorded common to CVR and ATC is the speech of the co-pilot who says "right Sir, squaking 2005 182". After this recording though by the ear the explosive sounds on the ATC. as well as the CVR seemed to match, we wanted to check it in more detail. For this purpose we had detailed UV recordings of different portions of the synchronised tapes pertaining to the conversation between ATC and Kanishka. This was done and we noticed that the ATC was running slightly fast. We had about 80 seconds reference time of conservation from Air India Boeing Kanishka and the ATC for reference and we had to extrapolate the information in this section for another 243 seconds at which time the explosive sound occurs. During the beginning of this 80 seconds reference period, we find that the ATC was leading by 90 milli-seconds and at the end of 80 seconds the lead of ATC was 130 milli-seconds. Thus, in 80 seconds, the ATC had gained 40 milliseconds.

"This extrapolated to 243 seconds and gives a figure of 250milliseconds. This is how we arrived at the conclusion that both are synchronised within 250 milliseconds. I would like to bring to the notice of the Court that we have taken great pains to confirm this information by reapeating the tests a number of times. We did not take the 400 cycle signal available on the tape as the time reference. We took for reference the bunching of signals produced by the conversation and the gaps in between the convervation which are very clear on both tapes. Hence we are sure that our results are right. The UV recording which was made has been filed along with my report.

"The main channel which was examined was the CAM channel. This was agreed to by all the experts who were present during the first analysis of the tape at the BARC between 16th and 20th July, 1985. One of the most noticeable things is that channel 3 which corresponds to cockpit area shows the first sign of disturbance. Let us say for reference that the disturbance starts at 0 time. In about 45 milliseconds the signal rises to a peak value which is approximately 18.5 db above the ambient level before the commencement of the signal. After this point the signal decays roughly exponentially in about 40 milliseconds to be almost a steady level which is 10 db above the ambient level before the explosive sound. From this we could draw conclusions. Assuming that an explosion occurred on the aircraft. The explosion produces a shock wave with a steep wave front which travels in air as well as through the aluminium body and the speed of travel will depend upon the distance of the explosive from the point of observation. It will depend on the cube root of the explosive and it will also depend on the ratio of the distance to the cube root of the weight of the explosive. The shock wave is very fast. It can travel at about 10 times the speed of sound. Also when the shock wave hits the aluminium body of the aircraft the vibrating panels which are defined by the stringers and longerons transmit the sound to the CAM location. Because the speed of sound in aluminium is about 19,200 feet per second which is 16 to 18 times that of the speed of sound in air and the shock velocity is also about 10 to 12 times. This signal will be received

"first by the CAM. Nevertheless the shock wave gets attenuated diffracted and refracted during its travels to the cockpit. Hence the signal received at the cockpit will be an attenuated signal and this small signal we have taken as instantaneous with the time of explosion. As the time passes the sound waves travel from the explosion site reinforcing the sound in the cockpit area thereby there is a rise time. Then when all the complete sound information is transmitted we get the peak of the signal and thus the rise time corresponds to the delay between the first rise in signal to the peak as compared to the speed of sound. One may ask the question what is the speed of sound because the aircraft has an explosion and is exposed to the outside environment but since the de-pressurization of the aircraft through the explosive fracture will take a minimum of a few seconds, we can reasonably assume that the pressure of the air in the aircraft corresponds to about 5000 to 6000 feet of altitude. At this presure and temperature, the sound velocity is roughly 1000 feet per second and from the 45 milliseconds delay we concluded that the explosion should have occurred about 40 to 50 feet from the cockpit. A question may be asked that the decay of the signal might be due to the AGC of the CVR coming into action. Mr. Turner, who is an acknowledged expert in the field of CVR has reported that Messrs Fairchild tested the cockpit voice recorders with a 10 db rise and fall of signals at the threshold of AGC and they got a result indicating a decay time of 33 milliseconds. The fall in the waveform of Channel 3 is about 40 milliseconds and is well near 33 milliseconds, so an argument may be advanced that the sound continued to remain steady and the fall in the signal level was effected by the AGC. In order to confirm this we tested the Cockpit Voice Recorder which was identical to the one which was on Kanishka by applying 1 KHz waveform of rectuangular modulation. To our surprise, we found that the decay time roughly was 130 milliseconds as compared to 33 milliseconds given by Mr. Turner. We repeated the tests with an initial background and without any background at all. We further tested with ramp waveforms, in other words, "slowly rising and falling waveforms of triangular shape with modulations of 1000 cycle carrier. This also confirms our finding. In order to clarify how the tests were performed so that others can judge whether it was a realistic test, I will explain the procedure. The modulated waveform was produced by a signal generator. This was fed to an amplifier. The amplifier output was fed to a loudspeaker. The output of the amplifier was checked to ensure that there was no distortion. Thus the signal going into the loudspeaker is the same modulated signal which has been applied at the input of the amplifier. This sound coming from the loudspeaker was recorded on the CVR through the CAM in the laboratory. This is how the test was performed. We were given a CVR tape by the Department of Civil Aviation purported to be that of an explosion which occurred on a Boeing 737 aircraft which crash- landed at Madras. We did the CVR analysis of this aircraft. We first recorded the output of the CVR of Indian Airlines CAM channel on a UV recorder. We found the rise time to be very small. This was of the order of a few milliseconds, about 8 milliseconds or so. We have been told that the explosion occurred just by the side of the front toilet i.e. just behind the cockpit. This to some extent confirms that the rise time is related to the distance of the explosion from the detecting CAM. The next thing that we did was the frequency analysis of this waveform. Mr. Davis has indicated in his report that if an explosion occurs on board the aircraft there should be low frequencies present. When we analysed the frequencies of the Kaniskha aircraft Channel 3, we did not find very low frequencies in case of an explosion abroad the aircraft. When we analysed the Boeing 737 tape we did not find any low frequencies in the signals. The report of Mr. Davis also provides the frequency analysis of a pistol shot which has been fired in the cockpit of the aeroplane. This also shows no low frequency components. So our conclusion, that it is not essential for low frequencies to be present in case of an explosion abroad an aircraft, was confirmed. I will go a step further to say that the frequency received by an area mike which responds to an explosive action abroad the aircraft will contain frequencies of the structure of the defracted " and dragging shock wave, the resonant frequencies of the aluminium panels defined by the longerons and the stiffening channel members and also some frequencies which may be of objects that the shock wave encounters in its path. It is, therefore, impossible to calculate the frequency spectrum that one would expect in the cockpit due to an explosion taking place in the aircraft".

3.4.6.35 In answer to a question Mr. Seshadri categorically stated that the word "explosion" in his report meant "a bomb, a very fast device".

3.4.6.36 Mr. Paul C. Turner's Report

Lastly, a reference may be made to the report dated 13th November, 1985 of Mr. Paul C. Turner. The evaluation of Mr. Turner of the analysis done by him of the CVR and the ATC tapes, as contained in the said report, was as follows:-

"With the foregoing as background, we can make several observations. The CVR record on the CAM channel, captain's channel and flight engineer's channel show that they were all affected at about the same time; the copilot's perhaps 20 milliseconds later. Major disturbances which are recognized as electrical system disturbances can be seen to begin about 60 milliseconds after the initial disturbance. This approximates the time it would take for the electrical system protective circuitry to become active.

3.4.6.37 "A steep wave front which would be indicative of a shock wave cannot be seen on the CAM channel sound spectrum; however, the spectrum analaysis shows that impulse type sounds occurred at the beginning of the event recorded on the CAM channel of the CVR. Since audio signals propagate through aluminium approximately 16 times the speed of sound in air, the CAM channel would probably have been affected by structurally transmitted noise before being affected by airborne noise. The geometry of the aircraft was such that structure borne disturbances could be recorded before the airborne transmitted information appeared at the cockpit microphone and an air transmitted shock wave or steep wave front may not be evident on the CVR.

3.4.6.38 The captain's and copilot's selector box channels recorded signals which appeared to be electrically inducted and similar to those seen on the Huete Boeing 747 breakups. These are then followed by a signal resembling audio frequency noises similar to an open microphone in a noisy environment or the opening of a receiver squelch. Both effects have been seen during aircraft breakups. The audio noise on the captain's and copilot's channels appears to have come from a different source. The flight engineer's channel does not contain audio noise. A spectral diagram of the copilot's and captain's channel noises just show broad band noise across the spectrum. The signal frequncies extend beyond the frequency range of a microphone both on the high and the low end. It does not fit the normal microphone envelope. Spectral diagrams of the event on the CAM channel show the normal microphone preamplifier envelope summed with wide band signal of unspecified origin. Since the signal quits abruptly with a doublet, it indicates that the interference was added upstream of the CVR and was not just reflected in the CVR power supply.

3.4.6.39 "The CVR record shows a signal stayed on for about 200 milliseconds when it appears that the power may have been interrupted to both the radio channel and the CAM channel of the CVR at the same time. It further appears that the signals to the CVR were probably interrupted at 360 milliseconds from the initial disturbance possibly by severance of the signal wires. It further appears from the action of the erase head and record that the main electrical system began to fail at this point and the CVR bus voltage value dropped to a value below 70 volts but not below 20 volts. This fluctuating voltage continued intermittently for a minimum of 1-1/4 seconds at which time the voltage evidently dropped to some value below 20 volts and the recorder ceased to operate. The power for operation of the No. 1 VHF transmitter can be explained by the operation of the standby bus and battery and connection of the No. 1 VHF radio to this standby bus.

3.4.6.40 "The necking down of the signal to a low value shows that no signal was coming to the CVR from the CAM preamplifier. The lack of a signal on the radio channels, which do not need to be erased before being recorded, further suggest that the wires were severed or

"that the transmission to Cork began after what appeared to be the loss of the primary electrical system approximately 1-1/2 seconds following the event. Standby power would have become available upon loss of the primary power, the number one VHF would have become available, and CVR would have ceased to operate.

3.4.6.41 "The action of the erase circuitry in the CVR suggests that the fluctuating voltage seen was coming from the main electrical system bus. Anything else causing this fluctuating voltage down stream of the CVR circuit breaker would probably blow it.

3.4.6.42 "The signal received in Ireland indicated that a radio, most probably this aircraft's No. 1 VHF transmitter, stayed operational for about 5.4 seconds following the event at which time the entire aircraft electrical system ceased to function. This assumes that the No. 1 transmitter ceased to operate due to standby bus failure.

3.4.6.43 "In the conclusion, it appears that a catastrophic event occurred on Kanishka. It was reflected in all channels of the CVR and the CVR power supply at the same time. The main electrical bus began to fail within 0.35 second and the standby bus survived for only 6 seconds more at which time the aircraft's electrical system ceased to function. It appears that the event occurred in a manner to affect the cockpit area microphone operation severely and to force operation of the automatic gain control on the CVR. This loud noise continued for the life of the aircraft's main electrical system as reflected in the CVR.

3.4.6.44 "The mechanism of how the ATC transmission was made from Kanishka to Cork is unclear. The sound was not recorded on the CVR, indepentent studies by Canadian and British investigators have the Cork ATC call originating approximately 1-1/2 seconds following the event on the CVR. This is about the time that standby power would have become available to the No. 1 VHF.

3.4.6.45 "This report should be viewed as an accident investigation tool only and used in conjunction with other evidence gathered during the investigation.

3.4.6.46 "The United States Noard/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

3.4.6.47 It is pertinent to note that according to Mr. Turner there was "catastrophic event" which had occurrred on Kanishka. He has, however, not elucidated as to what this event was.

3.4.6.48 After the receipt of the report, the Court requested the NTSB that Mr. Turner should come and depose. It is unfortunate that permission was not granted to him. Faced with this situation and as it was thought necessary that some clarification was called for, the Court sent a telex to Mr. Turner whereby he was asked to give replies to the queries contained therein. He was requested that the reply be sent by 27th January 1986. A copy of the telex was also forwarded to the American Embassy at New Delhi for sending the same to NTSB by way of confirmation. Previously all communications addressed to NTSB were being routed through American Embassy. No reply has been received by the Court till this day either from NTSB or from Mr. Paul Turner. According to paragraph 5.14 of Annex 13 the State is required, on request from the State conducting the investigation of an accident, to provide to that State with all the relevant information available to it. It was, therefore, obligatory on the NTSB to have seen that the information sought for by the Court by way of answers to the queries was supplied.

3.4.6.49 Court Evaluation

From the reports of all the experts and the testimonies of M/s Caiger, Davis and Seshadri it is clear, and it is agreed to by all of them, that there was a breakup of the aircraft in mid-air. The experts also agreed that the sounds recorded on the ATC Shannon tape at 0714:01 Z emanated from the Kanishka aircraft.

3.4.6.50 Mr. Caiger has not said either in the report or in his statement as to what was the cause of the bang. Mr. Davis, on the other hand, is categorical in stating in his report that there was explosive decompression (meaning rapid decompression) on the aircraft. He has, however, stated in the report that there is no evidence of an explosive device. The main reason for his coming to this conclusion is that he had not been able to find low frequencies in the spectra of the CVR of Kanishka. Mr. Seshadri, on the other hand is equally vehement in concluding that an explosive device had detonated in the front cargo hold of Kanishka.

3.4.6.51 It may be that the frequency spectrum of Kanishka CVR did not contain low frequencies but, as has been admitted by Mr. Davis himself in answer to a Court question, it is not necessary that in the case of every detonation there must necessarily be low frequencies in the spectrum. Frequency spectra of 'Kanishka CVR before 'bang' and at the 'bang' position are shown in Figs. 2 & 3, indicating presence of additional high frequncies at the bang. Indeed in the case of Indian Airlines Boeing 737, which admittedly was a case where there was an explosion of a device within about 8 feet of the CAM, the frequency analysis showed absence of low frequencies. Frequency spectrum of Indian Airlines Boeing 737 CVR is shown at Fig. 4. Merely, because therefore, there were no low frequencies present would not mean that there was no detonating device on board the Kanishka. The CVR of Indian Airlines Boeing 737 has not been analysed either by Mr. Caiger or Mr. Davis. The analysis was, however, conducted by Mr. Seshadri and as is evident from his report, there were marked similarities between the spectra of Indian Airlines 737 and Air India's Kanishka CVR. One of the important reasons for coming to this conclusion, which has been indicated by Mr. Seshadri, is the rise time of the bang signal. From the analysis of the Indian Airlines Boeing 737 tape it was observed that it had taken 8 milliseconds for the peak to be reached. It was also seen that the explosive device was approximately 8 feet away from the cockpit area mike. Keeping this in view Mr. Seshadri observed that in the case of Kanishka the peak of the bang signal was reached in about 40 milliseconds. He, therefore, concluded that the origin of the bang sound was about 40 feet away from the cockpit area mike.

3.4.6.52 It would be pertinent to note that even according to the report of Mr. Davis the rise time in the case of Kanishka, which has been given for the peak is about 40 milliseconds. He, however, does not attach much importance to this because according to him after about 40 ms automatic gain control would become effective.

3.4.6.53 Mr. Davis has no personal experience of the time which it would take for the Automatic Gain Control to take effect. He has got the figures from the manufacturer. Mr. Davis admitted that the time which it will take for the AGC to be effective is not indicated in any published document of the manufacturer.

3.4.6.54 Mr. Seshadri, however, personally carried out the experiments on a Boeing 747 by using an instrument similar to what was on board Kanishka. From the testimony of Mr. Seshadri it is apparent that the results which he got were different. As per his testimony, for the AGC to be effective it will take 130 ms. If this be so then it may be possible to conclude that in the case of Kanishka the peak was reached in 40 ms. and thereafter the signal decayed and the signal was in no way effected by the AGC.

3.4.6.55 A reference may also be made, at this stage, the frequency spectrum of the sound of the hand gun which was fired on a boeing 737 flight deck. Frequency spectrum prepared by Mr. R.A. Davis is shown at Fig. 5. He has stated that the rise time for reaching the peak is almost instantaneous. Same is the case with regard to the frequency spectrum prepared by him of a bomb in a B-737 aircraft where the bomb had been placed in the freight hold which is shown in Fig. 6. A perusal of that spectrum also shows that the peak was reached in approximately 5 ms. The forward freight hold compartment of Boeing 737 is much more than five feet away from the cockpit area mike. If the theory of Mr. Seshadri was to be applied then as per the frequency analysis of this Boeing 737 bomb, the distance from the area mike could not have been more than 5 ft. It is, however, known, as per the report of Davis, that the bomb was actually in the freight hold which would mean not nearer than about 25 feet.

3.4.6.56 From what has been stated in the various reports, as well as in the testimony of the 3 experts who apperared in the Court, the only safe conclusion which can be drawn is that possibly enough study has not been done, due to lack of adequate data, which can lead one to the conclusion as to the exact nature of the sound and the distance from which it originated.

3.4.6.57 The fact that a bang was heard is evident to the ear when the CVR as well as the ATC tapes are played. The bang could have been caused by a rapid decompression but it could also have been caused by an explsoive device. One fact which has, however, to be noticed is that the sound from the explosion must necessarily emanate a few milliseconds or seconds earlier than the sound of rapid decompression because the explosion must necessarily occur before a hole is made, which results in decompression. In the event of there being an explosive detonation then the sound from there must reach the area mike first before the sound of decompression is received by it. The sound may travel either through the air or through the structure of the aircraft, but if there is no explosion of a device, but there is nevertheless an explosive decompression for some other reason, then it is that sound which will reach the area mike. To my mind it will be difficult to say, merely by looking at the spectra of the sound, that the bang recorded on the CVR tape was from an explosive device.

3.4.6.58 There are various hypothesis and theories which the experts have to investigate before any acceptable conclusions are arrived at. It so happens that in the present case we have the opinions of four experts, but they do not agree with one another on some material aspects. Two of the experts, namely, Mr. Caiger and Mr. Davis are categorical in saying that it is not possible to measure the distance of the origin of the sound on the cockpit area mike, whereas Mr. Seshadri has come to a different conclusion. Mr. Paul Turner in his report dated 13th November, 1985 in silent on this aspect, though in his earlier report dated 19th July, 1985 he had categorically said that there was an explosive device close to the cockpit.

3.4.6.59 With regard to the nature of the sound also we have 3 different opinions. Mr. Caiger is unable to give the nature of the sound, Mr. Davis says it is rapid decompression while Mr. Seshadri says it is a sound of an explosive device followed by decompression.

3.4.6.60 In the absence of any other technical literature on the subject, it is not possible for this Court to come to the conclusion as to which of the Experts is right. The only conclusion which can, however, be arrived at is that the aircraft had broken in midair and that there has been a rapid decompression in the aircraft. Just as it is not possible to say that the spectrum discloses that the bang is due to an explosive device similarly, and as has also been admitted by Mr. Caiger and Mr. Davis, it is not possible to say that the bang is due to break up of a structure.

3.4.6.61 The bang could have been due to either of the aforesaid two causes i.e. a bomb explosion or the sound emanating due to rapid decompression. The advantage of carrying out the said analysis is that a number of possible causes of the accident are eliminated. On the other hand, if the analysis is viewed in conjunction with other evidence on the record it is further possible to determine the exact nature or cause of the bang. In the present case the bang, as already noticed, could have been due to the sound originating from the detonation of a device or by reason of rapid decompression. Other evidence on the record, however, clearly indicates that the accident occurred due to a bomb having exploded in the forward cargo hold of Kanishka. The spectra analysis and the conclusions of Mr. S.N. Seshadri are corroborated by other evidence.

TESTS AND RESEARCH

3.5.1 During the course of investigation a number of groups were formed to study and analyse evidence and data which was available. Materials like CVR, ATC and DFDR tapes were also given to the various participants.

3.5.2 The groups as well as other experts studied and analysed the material with them and submitted their reports which have been referred to earlier.

3.5.3 The experts examining the CVR tapes did carry out a number of tests. Different graphs and traces were prepared and the sound was analysed by them. The result of their analysis has been referred to in Chapter 3.4 on Flight Recorders.

3.5.4. The metallurgical examination of some of the recovered pieces was carried out at BARC. The examination of some of the pieces showed different types of damages having been recorded on the targets such as petalling and curling round the holes, spikes etc. The said team carried out certain explosion experiments. Their report on the experiments so carried out has already been set-out in paragraph 3.2 above.

3.5.5 The Indian Air Force has set up an Institute of Aviation Medicine at Bangalore. The Court visited the said Institute on 9th December 1985. During that visit an experiment was conducted in the explosive decompression and high altitude chamber to demonstrate what actually happens during explosive decompression and subsequently on exposure to hypoxia.

3.5.6 Subjects were taken to 8,000 feet in the explosive decompression chamber with oxygen. They were exposed to an altitude of 25,000 feet within one second. During the course of this explosion a loud bang was heard and inside the chamber there was misting and drop in temperature. After this the chamber was allowed to run at 22,000 feet for roughly two minutes and an experiment to show the adverse affects of hypoxia on the subjects was done. In this experiment, subjects were asked to write a given sentence while their oxygen supply was cut off. It was observed that initially the subjects kept on writing the sentence correctly and then after about 120 seconds they started making errors while writing the sentence and finally they stopped writing. At this stage oxygen was re-started and within a few seconds, the subjects started writing their sentence once again. The experiment was completed at this stage and the altitude chamber was brought down to ground level.

3.5.7 The subjects were taken out and were asked questions as to what did they feel. They explained that at the time of explosive decompression, they heard a loud bang, felt cold and saw misting inside the chamber. They also found air escaping from their lungs. On further enquiry about the experiment pertaining to hypoxia, they said that they felt light headed and after that they did not know what happened till they once again noticed that they were writing on a piece of paper.

SECURITY

3.6.1 The evidence and the statements filed on record show that Canadian Security arrangements in place prior to 23rd June, 1985 met the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand baggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

3.6.2 Air India, as required by Canadian regulation, had a security programme. Because of the threat level assessed against the Airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and had received and arranged for extra security for the month of June, 1985. For Air India flight 181/182, Air India provided a security officer from its New York Office to oversee the security at Toronto and Montreal.

3.6.3 As it became apparent during the course of investigation that security would be an important aspect whilch would require the attention of the Court, Mr. Rodney Wallis, Director, Facilitation and Security, International Air Transport Association was good enough to appear in Court on 24th January, 1986. His testimony on certain aspects of security was recorded in camera by the Court on that date. The expert evidence has been taken into consideration while formulating some of the recommendations.

INTERNATIONAL COOPERATION

3.7.1 The manner in which persons and organisations from five different countries combined their resources and efforts in connection with this accident is an object lesson in international cooperation.

3.7.2 From the time the accident occurred, till the conclusion of the investigation proceedings by the Court in Delhi, there has been a consistent interplay amongst different persons and organisations. When all the persons got together, for the first time, at Cork the group was very heterogeneous. Each one had his own point of view, which did not necessarily coincide with that of another. At times, the atmosphere was charged with a bit of tension which continued even when the Court was constituted to investigate into the accident.

3.7.3 It was noticed that not only were the participants a bit apprehensive and suspicious but, during the course of investigation, there were also occasions when there appeared some acrimony between a few of them.

3.7.4 In such a sensitive situation, careful handling was called for. The participants' honesty of purpose could not be doubted. All that was wanted was that there should be an effort to try and understand the point of view of all the persons. This is precisely what the Court tried to do.

3.7.5 It is indeed fortunate that the efforts of the Court, in this regard, succeeded. After the Court had decided that it was not the purpose or the function of the investigation to affix responsibility for any lapse which may have been committed, one could see the general relieving of tension. With the passage of time there was a gradual building up of the confidence of the participants in the conduct of the investigation. The participants' interest for air safety transcended all barriers and any apprehension or suspicion, which was present in the minds of some, was soon dispelled. In its place there grew a deep sense of urgency, anxiety and cooperation in an effort to see that all the participants rendered utmost assistance for the satisfactory completion of the task in hand.

3.7.6 The main beneficiary of this international cooperation was not only the Court investigating the accident but it was the cause of air safety which benefited the most. Countries and Organisations went out of the way to help each other, financially and otherwise, even when they were not obliged to do so. Money and services were readily and voluntarily offered and usually the requirements of the Court were always fulfilled.

3.7.7 As the accident had occurred only about 100 miles off the coast of Ireland, the centre of activity, initially, was centred at Cork. The Government of Ireland, and the Irish people in particular, acted as though they regarded this as a national disaster. Not only did they render every assistance with regard to the search and rescue operation, hospital facilities, police etc. but the people acted as if one of their own kith and kin had died. In the situation which existed they were pillars of strength to the relatives of the deceased. Not only did complete strangers comfort such relatives but, more often than not, they even joined in their grief. The residents of Cork did everything possible to try and mitigate the sorrow of the victims' relatives. Everyone did their small bit, even the children of Cork queued up to place flowers at the coffins of the victims.

3.7.8 The Representatives of the Government of Canada also came to the scene, at the initial stages itself, and rendered full help and cooperation till the last. The major brunt of the mapping and the salvage operations was borne by Canada. Willingly and without any demur it incurred huge expenses, which must have been to the tune of a few million dollars, in carrying out these operations. It rendered full help and assitance to the Court whenever called upon to do so. For example, it offorded full facilities and help to the team which had been sent to Canada by the Court in August, 1985. It was only with the help of the Canadian Government, and the CASB and RCMP in particular, that the Court was able to obtain evidence and information relating to the accident. Without Canadian help the conduct of the investigation would have only been speculative in nature.

3.7.9 On their own, and without any request from the Court or from the Government of India, the Government of United States decided to lend a helping hand in the salvage operations. This was done at a very critical juncture when financial help and expertise were required so as to salvage the important critical pieces of the wreckage. It arranged for the services of a salvage expert and it also made necessary arrangements for the deployment of a second ship, duly fitted with necessary equipment to enable it to salvage some of the heavier pieces of the wreckage. The Court understands that the amount which was contributed in meeting the expenses by the United States was to the tune of U.S. $ 700,000.

3.7.10 The Government of United Kingdom also provided ship and helicopters in connection with the search and rescue operations. Even during the time when salvage operations were being carried out it was the British Helicopters which assisted in transporting personnel to and from the ship which were engaged in the salvage operations. The A.I.B. at Farnborough, on being asked by the Court to do so, carried out a very detailed analysis of the CVR and the ATC tapes.

3.7.11 Being the state of Registry of the aircraft and also the state holding the investigation, the major brunt of the work fell on the shoulders of officers of the Government of India and BARC. They acted as coordinators who had to oversee the work being carried out by persons belonging to diverse organisations and coming from different countries. Young engineers of Air India took turns in going aboard the ships and manning the Control Centre at Cork. They worked in conjunction with the engineers of Boeing and CASB and the crew members of the ships during the salvage operations. Without their enthusiastic participation the progress of the salvage operations would have been severely hampered.

3.7.12 The Scientists from BARC and National Aeronautical Laboratory, Bangalore were ever ready and willing to work together with the experts from abroad. Whenever called upon to do so, they rendered whatever assistance which was desired by the Court and the other participants.

3.7.13 It was seen that when the persons, coming from different countries and backgrounds, worked together with sincerety and honesty of purpose then they functioned smoothly and harmoniously, and usually arrived at an agreed solution or finding. These days it is indeed rare to see such a degree of international cooperation between different persons, organisations and countries.

ANALYSIS AND CONCLUSIONS

4.1 From the evidence which is available what has now to be determined is as to what caused the accident.

4.2 Finding the cause of the accident is usually a deduction from known set of facts. In the present case known facts are not very many, but there are a number of possible events which might have happened which could have led to the crash.

4.3 The first task is to try and marshal the facts which may have a bearing as to the cause of the accident.

4.4 It is undisputed, and there is ample evidence on the record to prove it, that Air India's Kanishka had a normal and uneventful flight out of Montreal. The aircraft had been in air for about five hours and was cruising smoothly at an altitude of 31,000 feet. The readout from the CVR shows that there was no emergency on board till the catastrophic event had occurred. This is corroborated by the printout available from the DFDR. The event occurred at approximately 0714 Z and that brought the aircraft down, and it probably hit the surface of the sea within a distance of 5 miles. The time within which the plane came down at such a steep angle could not have been more than very few minutes. There was a sudden snapping of the communication between the aircraft and the ground. The aircraft had also suddenly disappeared from the radar.

4.5 It is evident that an event had occurred at 31,000 feet which had brought down 'Kanishka'. What could have possibly happened to it? The aircraft was apparently incapacitated and this was due either to it having been hit from outside; or due to some structural failure; or due to the detonation of an explosive device within the aircraft.

4.6 Evidence indicates that after the event had occurred, though the pilots did not or were not in a position to communicate with the ground, they nevertheless appeared to have taken some action. According to Mr. Laflamme, witness No. 12, the examination of the wreckage showed that spoilers had been deployed and this must have been done with a view to enter into emergency descent. He has further speculated that such an emergency descent would support or perhaps cause a rupture in the forward area or a partial damage to the hydraulic system or damage to the control system which created such a condition that the pilots were not able to control the flight. The wreckage fruther showed that the jack screw for the stabilizer trim was found in the nose-up position and it was hard to explain how this got there merely as a result of impact with the water. The trim being in that position could only have been due to the pilot selecting it or as a result of a situation created by an explosion. In that position, and at a high aircraft speed, there would have been an extremely high g-loading on the aircraft.

4.7 It can further be speculated that if an explosion takes place in the forward cargo compartment, the oxygen stream might have been damaged so that when the pilots donned their masks as part of the emergency drill for explosive decompression, they were not breathing enriched oxygen and the time of useful consciousness at about 31,000 feet would be significantly less than 30 seconds under high stress and if the pilots became unconscious as a result of this, then the aircraft would have got out of control which would explain the subsequent events.

4.8 None of the participants have produced any evidence which could lead one to the conclusion, that there was any external hit to the aircraft. In fact in the report dated 13th November, 1985, Mr. Paul Turner has stated as follows:

"The United States Norad/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.

4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.

4.11 The circumstantial and direct evidence which leads to the aforesaid conclusion is as follows :

A. Connection with an explosion at Narita Airport :

On 23rd June, 1985 there was an explosion at the Narita Airport. The explosion occurred when a bomb exploded in a suit case which was to be interlined to Air India's Flight No. 301 from Tokyo to Bangkok. The following events, which had occurred prior to this explosion, clearly establish the connection between the two incidents :

(i) On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight Indian accent. He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vacouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

(ii) On the same date at approxmimately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

(iii) On 20 June, 1985 at about 1210 PDT (1910 GMT), a male appearing to be of Indian origin purchased the tickets with cash from a CP Air Ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to 'M. Singh'. The telephone contact number was also changed. The final itinerary was as follows :

(a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22nd June, 1985
- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22nd June, 1985

(b) L. Singh - CP 003 Vacouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June, 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 time in Tokyo, local 23 June, 1985

(iv) On 22 June, 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that the was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

(v) On Saturday morning, 22 June, 1985, a CP Air passenger agent worked check-in position number 26 at the CP AIR ticket counter, Vancouver International Airport, and recalls dealing with a passenger of

Indian origin booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto his baggage could not be interlined. The passenger insisted and, as the line-up were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that 'M. Singh' checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage.

(vi) The flight manifest for CP 003 shows that on the same day the person using the name of 'L. Singh' with an interline ticket to Bangkok also checked through the same counter, was assigned seat 38H, and checked one piece of baggage.

(vii) A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as 'M. Singh' and 'L. Singh' did not board these respective flights.

(viii) In a statement of William Long, annexed to the affidavit of I.G. Pole, Police Officer, City of Toronto, he has stated that on 22nd June, 1985 he was employed as a driver whose responsibility was to deliver interlined baggage between terminal 2 to Terminal 1 and vice versa at Toronto. He has further stated that he had picked up 4 bags from Terminal 1 which were destined for terminal 2 Air India. Three of these bags were from U.S. Air originating from New York city. Regarding the last bag he stated as follows :

"The fourth bag destined for Air India was, I distinctly remember looking at the baggage tag and it was pink with the CP logo in blue and letters saying CP on it there were also numbers but I can't remember the number, from CP Air and I remember it was from Vancouver. On the bottom of the tag it said vancouver using the initials YVR and the flight number which I can't remember. The bag was destined for India. When I arrived at the CP Air belt there were a number of bags from other airlines on the belt included in these were the three U.S. Air bags destined for Air India. As I was finishing loading the carts, a CP Air station attendant who had been unloading bags from containers, I noticed as I checked once more for anymore bags, drop another bag on the conveyer belt. This was the bag destined for Air India. It was dark brown Samsonite Hard sided Type 01A on the Baggage Identification Chart. After they were loaded onto the cart I took them over to Air Canada domestic belt at Gate 89-91".

To further questions posed to him, Long stated that this bag from CP Air weighed approximately 70 lbs and there was something which rattled inside the bag. He could not say what it was but he said that "it sounded small". When specifically asked whether he thought there was something big inside the bag, he answered in the affirmative, and added that he did not know what was in it but it was heavy. There was discrepancy in the time when he is alleged to have picked up the bags which he had indicated in his schedule when compared with CP Air Vancouver flight which had arrived at 1622 hours. When this was pointed out to Long, he answered "I could have may be got the time wrong, it was during the busy period. It could have been an estimate time. But I do remember the bag came off CP air. It could have been 16:34 Hrs. I don't know."

(ix) The aircraft departed from Toronto for Mirable and London with the suitcase unaccompained by the passenger who had checked it in at Vancouver. Similarly, CP Air 003 departed Toronto for Tokyo with the baggage of one passenger 'L. Singh' to be interlined to Air India flight AI 301 to Bangkok even though 'L Singh' had not boarded that flight.

(x) The linking of the two occurrences namely the blast at Narita Airport and the Air India accident becomes startingly evident if we look at the following chronology of events:

CPA 003 (VANCOUVER-TOKYO) CPA 060 (VANCOUVER-TORONTO) Connection to Connecting to Air India 301 Air India 182 WESTBOUND EASTBOUND All Times GMT Thurs 20 June, 1985 0057 A male called C.P. Air Reservations in Vancouver and after discussing a number of routings, booked a one-way ticket and CPA 060 to Toronto with connections to Air India 182 under the name of Jaswand SINGH. A return ticket was also booked on CPA 003 to Tokyo connecting with Air India 301 to Bangkok in the name of Mohinderbel SINGH.

1912 A male attended the CP Air Ticket Office in Vancouver. He paid $ 3005.00 in cash for the above tickets after changing the ticket of Mohinderbel SINGH to L. SINGH and changing from a return to a one-way ticket. He changed the Jaswand SINGH ticket to M. SINGH.

Saturday 22 June A Mr. SINGH called Reservations and got 1330 confirmation on his one-way ticket to Toronto with luggage to be sent through to India. M. SINGH checked in with seat 10B confirmed to 1550 Toronto. Wanted suitcase interlined to AI 182. Agent relents. 1618 CPA 060 departed Vancouver 18 minutes late. M. SINGH not in assigned seat. L. SINGH checked in for CPA 003 and one suitcase interlined to Air India 301. Assigned seat 38H. CPA 060 arrived Toronto 2022 12 minutes late. Some passengers and baggage interlined to AI 181.
CPA 003 departed 17 min. late for Tokyo. L. SINGH not in 2037 assigned seat. Sunday 23 June Air India 181 departed 0015 Toronto for Mirabel 1 hour 40 minutes late. 0100 Air India arrived Mirabel. 0218 Air India 182 departed Mirabel 1 hour 38 minutes late. CPA 003 arrived Narita Airport, Tokyo. Arrived 14 minutes early 0541 Baggage cart explodes in transit area. 2 killed, 4 injured, 0619 0714 Air India 182 disappeared from Radar
Air India 301 departed Narita. 0805 0815 Air India 182 Scheduled arrival Heathrow (fuel stop).

(xi) It would indeed to too much of a coincidence that two persons, whose tickets were bought at the same time and who had checked in under the names of 'L. Singh' and 'M. Singh' missed their respective flights, more so when 'M. Singh' had insisted at the check in counter at Vancouver that he should be interlined, even though his seat from

Toronto on AI 181/182 was not confirmed, and his baggage (one suitcase) accepted and be routed through to Delhi. If there had been some reason for 'gate no-show' by both of them, one would ordinarily have expected both, or at least one of them, to have made efforts, at that time or thereafter, either to ask for refund of money or they should have contacted the airline staff at the Airport and asked that they should be put on another flight.

(xii) A large amount of money had been spent on the purchase of the two tickets and a question which comes to mind is as to why was this money spent if both the tickets were to be wasted and no one was to travel on them, after having checked in and obtained boarding cards. Furthermore, no effort has been made by any of these two persons to try and lodge a claim for the baggage which they had checked in.

(xiii) The aforesaid facts clearly indicate the connection between the travel plans of so called 'L. Singh' and 'M. Singh'. In fact the manner in which the reservations were changed to the names of 'M. Singh' and 'L. Singh' shows the anxiety of some one to hide behind the identity of persons who bore notorious names.

(xiv) The interlined baggage exploded at Narita Airport and there is strong probability that the suticase from Vancouver, which was interlined to AI 182, contained a device similar to the one which had exploded at Narita Airport on 23 June, 1985.

B. CVR and DFDR both stopped simultaneously:

There was simultaneous interruption of electrical power to the flight recorders. The electrical supply could have been interrupted either because of the cables being cut or because of total electric failure. Power supply wires to the CVR and the DFDR run under the passenger cabin ceiling on the left and the right hand side. The supply of electricity through these cables originates from the MEC compartment, which is in front of the forward cargo hold. If the CVR and the DFDR had stopped due to the breakage of electrical supply wires as a result of possible explosion in the aft cargo hold there would have had to be an instantaneous break of almost the entire section of fuselage, because both these recorders had stoped simultaneously. In such a catastrophic event it is not possible that the bottom skin panels of the aft cargo compartment would remain undistorted, or would have no rupture or holes in them. Furthermore, in such an event the tail portion of the aircraft would have been found in the beginning of the wreckage trail, but this was not so. On the other hand, and explosion in the forward cargo compartment would have resulted in damage to the electrical buses located in the MEC and that would, in turn, result in cutting off the electrical power supply causing simultaneous stoppage of the recorders.

C. The ATC Transponder Stopped Transmitting :

The transponder is located at the bottom of the one of the forward rakes immediately forward of the front cargo compartment. Signals from this also stopped being received by the secondary radar at Shannon. Keeping in view that the CVR and the DFDR had stopped simultaneously at about the same time, when the signals from ATC transponder had also ceased, it is reasonable to presume that there must have been a complete breackdown of electrical supply which had affected all the three units. The only event which could have caused such a damage to paralyse the entire MEC compartment could only have been an explosion in the forward cargo hold. It was not possible that any rapid decompression caused by a structural failure could have disrupted the entire electricl power supply from the MEC compartment. In known cases of aircraft being subjected to rapid decompression there has never been such an instantaneous and total stoppage of electrical power and in fact aircrafts have been known to have continued to fly and communicate with the ground even after decompression.

D. Non-supply of Oxygen :

Oxygen supply cylinders are located in the ceiling of the forward cargo compartment. Any rupture of the only pipeline which supplies oxygen to the passengers would result in there being no surge of oxygen flow, which alone drops the oxygen masks. The inspection of the wreckage shows that there is no indication of the oxygen masks ever having dropped. A rupture of this pipeline, simultaneously with power rupture, could only have been caused if there had been a detonation of the explosive device in the front cargo hold.

E. Damage in air :

The examination of the floating and the other wreckage shows that the right hand wing leading edge, the No. 3 engine fan cowl, right hand inboard mid flap leading edge and the leading edge of the right hand stabilizer were damaged in flight. This damage could have occurred only if objects had been ejected from the front portion of the aircraft when it was still in the air. The cargo door of the front cargo compartment was also found ruptured from above. This also indicates that the explosion perhaps occurred in the forward cargo compartment causing the objects to come out and thereby damaging the components on the right hand side.

F. Evidence of Overpressurization :

The examination of the structural panels and the other parts of the forward cargo compartment and the aft cargo compartment, recovered from the sea bed, indicates that overpressure condition had occurred in both the cargo compartments. The failure of the passenger cabin floor panels in upward direction also indicates that overpressure was created in both the compartments. It cannot be disputed that whenever an explosive detonates very high pressure shockwaves are formed which travel in all directions and high speed fragments of the container, or the loose material, also move away from the source of explosion. It is, therefore, clear that there was overpressurization in the cargo compartments which resulted in such rupture of the cabin floor panels.

G. Holes in the front cargo hold panels

While the skin panels of the aft cargo compartment are fairly straight and undamaged, the panels of the front cargo compartment are ruptured and have a large number of holes. This shows that there was occurrence of an event in the front cargo compartment and not in the aft cargo compartment.

H. Buckling of Seats :

The seats towards the rear of the aircraft had only the aft legs buckled, whereas the seats towards the front had both the front and the aft legs buckled. This indicated that the whole floor was subjected to a vertical force and was more severe towards the front. Moreover, the upper deck storage cabin was found among floating wreckage. The bottom of this cabin was pushed up in the shape of a dome with no evidence of impact damage. This deformation was indicative of having been caused, possibly, as a result of a shockwave.

I. Metallurgical Examination Results :

A metallurgical examination, especially of Targets 362 and 399, clearly confirms that there was an explosion in the forward cargo compartment. Microscopy around some of the holes discloses that they have such characteristics like twinning which can be present only if the holes had been puntured due to the detonation of an explosive device.

J. CVR Tape Analysis :

The report of CVR tape analysis by Mr. S.N. Seshadri also corroborates the aforesaid evidence i.e. that there was a bomb in the forward cargo hold of the aircraft.

RECOMMENDATIONS

5.1 ICAO, IATA and the States should :-

(a) undertake an ongoing review of established aviation security standards to prevent the placement of explosive substances on board commercial aircraft;

(b) establish a programme of monitoring the implimentation of security measures in airports around the world, in cooperation with the Governments concerned. For each airport studied, it should report its findings and recomend any improvements that may be required;

(c) consider establishing a group of civil aviation experts to investigate serious breaches of security. The purpose of these investigations would be to determine the facts of an incident so that necessary measures could be developed and implemented world wide to prevent similar breaches in the future.

Note : As it may take some time for ICAO and IATA to implement these recommendations, at least those countries which have international air traffic should take up effective measures without delay.

5.2 ICAO should :-

(a) develop a model clause on security that could be used in the bilateral air agreements that govern the exchange of air traffic rights between countries;

(b) consider establishing standards for the training of security personnel.

5.3 IATA should develop practical procedures for reconciliation of interlined passengers and their baggage at intermediate airports.

5.4 Interlining of checked-in baggage should not be done if a passenger does not have a confirmed reservation on the onward carrier flight.

5.5 The baggage of interlined passengers should be matched with passengers by the onward carriers before loading the baggage on the aircraft.

5.6 Whenever a Government becomes aware of particular high risk security threat it should notify not only the airline at risk, but also all connecting airlines in order that extra precaution can be taken at potential points of introduction of interline baggage into the system.

5.7 When an Airline is aware of a high security threat it should communicate the same to the host state as well as, if possible and prudent, to the other airlines operating there.

5.8 Passenger count should be done at boarding gate and in case of 'no gate show' of a passenger, his baggage must be off-loaded.

5.9 All checked-in baggage, whether it has been screened by X-ray machine or not, should be personally matched and identified with the passengers boarding an aircraft. Any baggage which is not so identified should be off-loaded. This is advisable as examination of the baggage with the help of an X-ray machine has its own limitations and is not fool proof. Some explosives hidden in Radios, Cameras etc. may not be readily detected by such a machine. In fact an explosive not placed in a metallic container will not be detectable by an X-ray machine. Similarly, a plastic explosive can be given an innocuous shape or form so as to avoid detection by an X-Ray. Reliance on an X-Ray machine alone may in fact provide a false sense of security.

5.10 Effectiveness of the instrument known as PD-4 is highly questionable. It is not advisable to rely on it.

5.11 All unaccompanied baggage should be placed on the aircraft after their contents have been physically checked. In the alternative, it should be loaded only after it has been placed in a decompression chamber and the host state is satisfied that the baggage is clean and the shipper has been identified.

5.12 Airlines should have effective backup security equipment or procedures available in case of machanical break down of security equipment.

5.13 All hand baggage, including that of the crew, should be opened and the contents physically checked even if the said baggage has been x-rayed. This will no doubt be a bit time consuming and laborius but if security is to be meaningful, then slight inconvenience has to be endured in order to ensure a safer flight.

5.14 The manufacturers of aircraft should take effective steps for protecting sensitive parts of the aircraft from explosive damage.

5.15 Studies should be undertaken to determine the feasibility of physically separating the avionics bay and emergency oxygen systems from the cargo area in aircraft so that these sensitive and essential areas of the aircraft cannot be damaged or destroyed by a relatively small explosive deivce concealed in luggage.

5.16 The seats should have safety belts which can act as restraint for the upper part of the body e.g. like a shoulder harness with inertial restraint.

5.17 The seats in the aircraft should be so designed so as to incorporate shock absorbing systems within the seat and they should be manufactured by using material which does not break easily.

5.18 In addition to the cockpit voice recorder, there should be in the cockpit a video/scanning camera which would record the movements and the audio sounds in the cockpit. This will not only assist in ascertaining as to how the pilots act during as emergency but, in the case of hijacking, would also assist in the identification of the hijackers.

5.19 The CVR should record all the conservation and sounds in the cockpit for the entire duration of the flight, and not merely for the last 30 minutes.

5.20 The CVR and the DFDR should be powered from two alternative sources of energy.

5.21 The oxygen for the flight crew should be supplied from two different sources i.e. in the event of an emergency the pilot and the co-pilot must don the oxygen mask and the oxygen must be supplied from different source.

5.22 Suitable provisions should be incorporated in Annex 13 which would give power to an Investigator to record evidence outside the country of investigation and also to summon witness from abroad. It should also be mandatory on the contracting States to give information sought for by an Investigator.

(B. N. KIRPAL)

February 26, 1986 COURT

We agree with the conclusions and recommendations stated above.

ASSESSORS

(V. Ramachandran) (J.S. Gharia)

(J.S. Dhillon) (J.K. Mehra)

(B.K. Bhasin)

ACKNOWLEDGEMENTS

When I was appointed as the Court to investigate into the accident, the magnitude of the task involved was known. With the help, assistance and cooperation of a team of dedicated workers, the work was, however, completed in not too long time. The assistance received from those who helped me cannot be too highly praised.

From amongst my Assessors, Captian B.K. Bhasin was the only one who was permanently stationed in Delhi. We met for the first time on 15th July, 1985 and little did I realise then that, by the time our work would be over, how much I would be depending upon him. Not only was his advice on the technical aspects of flying and air safety invaluable but, whenever any difficulty or a problem arose, I invariably turned to him for assistance and advice which I readily got. I found him having a very practical and positive approach to all the problems but, at the same time, he very rightly was not prepared to compromise on any principal issues.

The only interest Dr. V. Ramachandran appeared to have was to do his work to perfection. No praise can be too high for the manner in which this Metallurgist from landlocked Bangalore volunteered and boarded the salvage ships which were carrying out operations in the cold and choppy waters of Atlantic Ocean. He sarificed all comforts and went to sea with a view to be present on board the ships at the time when salvaged pieces of wreckage were brought on board. His deep knowledge of metallurgy greatly assisted the examination of the salvaged pieces of wreckage. In this connection the entire metallurgical examination was planned and organised by him.

Whenever any information was required concerning explosives, Mr. J.S. Gharia was ever eager and in a position to provide the information.

Mr. J.K. Mehra looked into the engineering aspect of the accident and he spent a lot of time in going through various Air-India Maintenance Manuals. He always made discussions very lively and interesting.

Captain J.S. Dhillon came out of his retirement and provided useful information to the Court on some aspects of flying.

This work would never have been satisfactorily completed without the help and assistance received by the Court from late Mr. S.N. Seshadri of Bhabha Atomic Research Centre. From the time when the CVR was first played by him at BARC on 16 July, 1985 till the very end, he most willingly and pleasantly undertook any assignment which was given to him by the Court. It was a great national loss when he suddenly passed away on 2nd February, 1986, only a few days after he had deomonstrated his brilliance when his testimony, regarding the analysis of the CVR tape, was recorded by me in the Court.

I am also grateful to the other Scientists and staff of B.A.R.C. who rendered considerable assistance to the Court. The facilities made available by Dr. P.K. Iyengar, Director, B.A.R.C. with regard to the finalisation and completion of the report cannot be easily forgotten. In the absence of late Mr. S.N. Seshadri, with whom I had developled a personal rapport, Dr. Ashok Mohan and Mr. V.K. Chadda met with all our requirements in the finalisation and preparation of the Report. Dr. Asundi of BARC and the other Metallurgists of that Organisation and of the National Aeronautical Laboratory also spent a considerable amount of their time and energy in successfully carrying out metallurgical tests and examination of the salvaged pieces.

During the investigation I had to visit Ireland on two occasions. I immediately realised the extent of help, assistance and guidance which was being rendered to all of us by Mr. Kiran Doshi, the Indian Ambassador to Ireland. There was no problem to which he did not have a solution. On my visit to Dublin not only did I enjoy the hospitality of Kiran and his wife Razia but it also gave an opportunity to personally meet Mr. Mitchel, the Minister of Communications, and senior officials of his Ministry, and to express my gratitude to them for all the help and assistance which the Government and people of Ireland had, most willingly, rendered.

At Tokyo the Indian Ambassador and members of his staff looked after all our needs and arranged meetings with the Japanese officials whom we wanted to meet.

As representatives of the Court in Cork, Mr. P.R. Chandrasekhar and Mr. C.D. Kolhe did a commendable job. They kept me informed of the progress which was taking place at Cork and, whenever required to do so, they took vital decisions while coordinating the mapping and salvage operations.

Mr. H.S. Khola, Director of Air Safety, New Delhi willingly carried out all the directions of the Court. Special mention must also be made of Mr. Satendra Singh, Regional Controller of Air Safety, Bombay, who worked day and night when the flight recorders were first opened and the copies of the tapes made and the data analysed.

I have also to express my gratitude to the Counsel who assisted the Court in the Investigation. Without their help and cooperation, it would not have been possible to complete the work in 7-1/2 months.

On my trip to Bombay, the Staff and Management of Centaur Hotel made my stay very comfortable. It was like a home away from home.

The work done during the salvage operarations by four young engineers of Air-India was highly commendable and valuable. All of them namely, Mr. Balasubramanium, Mr. L.S. Carvalho, Mr. G.D. Nayar and Mr. A.K.

Sheode, worked round the clock even during adverse climatic conditions.
The Registrar of the Delhi High Court, Ms. Usha Mehra spared no efforts in rendering every assistance whenever the same was required. She ably marshalled all the resources available in the High Court in order to ensure the smooth and efficient functioning of my office. My own personal staff in particular, headed by Mr. V.P. Ahuja, Court Master and Mr. Balram Chopra, Private Secretary, as usual, rose to the occasion. While Mr. Ahuja kept complete control of hundreds of documents and affidavits which had been filed, Mr. Chopra besides bearing the brunt of the typing work, very ably supervised the work of other Stenographers.
It was most fortunate that I was able to persuade Mr. S.N. Sharma to accept the trying job of being the Secretary to the Court. His vast experience in such Investigations, he had been a Secretary in three such Investigations earlier, made my task much lighter. Moreover, as an Aircraft Engineer, he was always ready to explain technical intricacies involved in the case. Without his help I could not have completed my work within the stipulated time.
(B. N. KIRPAL)
26th February, 1986 COURT
POSITIVELY IDENTIFIED DEBRIS AIR INDIA 747 VT-EFO KANISHKA AIRCRAFT

SECTION TARGET LAT LONG DESCEIPTION 41 DOOR 192 51 03.28 12 47.74 FIRST CLASS AND COCKPIT AREA (+ UPPER DECK DOOR) 41 131 51 03.21 12 47.93 LEFT HAND UPPER DECK SLIDE MECHANISM 41 134 51 03.28 12 47.81 NOSE LANDING GEAR 41 265 51 02.37 12 44.51 LANDING GEAR DOOR (NOSE GEAR) 41 244 51 03.56 12 48.19 UPPER DECK WINDOW TRIM (REVEAL) 41 63 51 02.51 12 47.37 2 FIRST CLASS SEATS 41 77 51 02.59 12 47.83 2 FIRST CLASS SEATS 42 DOOR 193 51 03.30 12 47.85 PIECE OF FUSELAGE, WING PLUS LANDING GEAR (#2 LEFT DOOR) 42 138 51 03.37 12 47.77 SMALL PIECE OF WRECKAGE (BS 800) 42 200 51 03.347 12 47.831 Dual Heat

Exchanger 42 DOOR 204 51 03.33 12 47.87 FORWARD CARGO DOOR + FLOOR 42 255 51 03.72 12 48.01 GALLEY COMPLEX (UPPER DECK) 42 232 51 03.49 12 47.92 'P93' RACK MARKED 'DANGER HIGH VOLTAGE' (BS 670) 42 327 51 01.62 12 43.03 NACA SCOOP 42 DOOR 358 51 03.39 12 47.86 MASS OF DEBRIS (#2 RIGHT DOOR) 42 361 51 03.384 12 47.848 BOX MARKED "FAN BLADES" 42 362 51 03.372 12 47.840 MASS OF DEBRIS FUSELAGE SKIN 42 383 51 03.32 12 47.81 MASS OF DEBRIS WITH UPPER DECK FLOOR 44 DOOR 137 51 03.30 12 47.80 CENTER FUSELAGE SECTION WITH #3 LEFT DOOR 6 WINDOWS AFT OF DOOR AND 13 WINDOWS FORWARD. LEFT UPPER WING SKIN AND ONE MAIL LANDING GEAR ATTACHED. 44 103 51 02.86 12 46.37 LANDING GEAR DOOR 44 105 51 02.81 12 46.04 LEFT WHEEL WELL LANDING GEAR DOOR 44 186 51 03.32 12 47.825 KEEL BEAM 44 195 51 03.32 12 47.78 WING STRUCTURE 44 224 51 03.46 12 48.49 TWO WHEELS FROM MAIN LANDING GEAR 44 239 51 03.62 12 47.38 MAIN BRAKE UNIT WITHOUT AXEL, PLUS EQUALIZING ROD 44 240 51 03.62 12 47.44 MAIN TIRE AND RIM 44 241 51 03.62 12 47.40 MAIN TIRE AND RIM PLUS AXEL 44 242 51 03.61 12 47.40 MAIN BRAKE UNIT 44 267 51 03.35 12 44.45 PART OF LANDING GEAR DOOR 44 275 51 02.13 12 44.10 BODY LANDING GEAR DOOR 44 279 51 02.30 12 44.64 MAIN LANDING GEAR DOOR 44 280 51 02.26 12 44.61 SECTION OF MAIN LANDING GEAR DOOR 44 343 51 03.285 12 47.809 MAIN LANDING GEAR DOOR 59 51 02.57 12 45.73 SECTION OF LANDING GEAR 44 218 51 03.41 12 47.86 STEP WELL AREA (STA 1250-1480)
46 6 51 02.79 12 49.44 SMALL MOTOR 10" x 8" (FAN) 46 7 51 02.90 12 49.92 LOWER SKIN OF CARGO AREA 4' x8' (BS 1480)) 46 #11 51 02.04 12 45.44 PIECE OF OUTER SKIN BODY STATION #1760 PART NO. 65B04325-403 46 25 51 02.21 12 46.27 BODY FRAME (BS 1660-1680) 46 26 51 02.20 12 46.72 CABIN SECTION WITH 4 WINDOWS (ABOVE 'T' IN REG No.) 46 28 51 02.31 12 47.02 SKIN PANEL 1460-1800 46 33 51 02.49 12 48.28 AFT FUSELAGE SKIN

PANEL 'YOUR PALACE IN THE SKY' (AFT OF #5 DOOR) 46 34 51 02.49 12 48.29 RIGHT HAND FUSELAGE SKIN PANEL AT DOOR #5 46 DOOR 40 51 02.47 12 47.41 CARGO DOORS C2, C3 46 47 51 02.39 12 46.61 REAR CARGO FLOOR 46 50 51 02.38 12 46.60 CARGO FLOOR (STA 1500) 46 DOOR 74 51 02.49 12 47.71 FIVE FRAMES AND DOOR-PORT SIDE AFT (#5 LEFT DOOR) 46 78 51 02.52 12 47.95 FRAME SECTION (SHEAR WEB STA 2000-2020) 46 87 51 02.58 12 48.43 BUILT UP STRUCTURE (STA 2412) 46 DOOR 97 51 02.52 12 47.38 FUSELAGE SKIN SECTION WINDOW BELT AREA WITH DOOR FOLDED UNDER FRAME 46 DOOR 101 51 02.84 12 47.14 5 WINDOWS AND DOOR (#4 RIGHT DOOR) 46 292 51 01.81 12 44.24 FRAME (STA 2240) 46 321 51 02.39 12 46.61 '4R' DOOR ENTRANCE WITH NO DOOR AND 10 WINDOWS (BS 1700) 320 51 01.84 12 44.59 FUSELAGE BOTTOM SKIN NEAR OUTFLOW VALUE 46 336 51 01.34 12 42.03 BULK CARGO COMPARTMENT FLOOR AND STRUCTURE 46 369 51 02.17 12 46.20 FUSELAGE PANEL SECTION, 4 WINDOWS 48 31 51 02.37 12 48.43 HORIZONTAL STAB 48 37 51 02.47 12 47.99 VERTICAL TAIL FIN (+ PRESSURE BULKHEAD SECTION) 48 35 51 02.50 12 48.08 AFT PRESSURE BULKHEAD (25%) 48 22 51 02.19 12 45.68 ELECTRICAL PANEL (RUDDER RATIO JUNCTION BOX) 48 27 51 02.20 12 46.83 APU HOUSING 48 66 51 02.59 12 47.54 BODY FRAME (BS 25XX) 48 67 51 02.55 12 47.50 FUSELAGE SKIN (3 FRAMES FORWARD OF APU BS 2638) 48 68 51 02.57 12 47.55 FUSELAGE SECTION (BS 2598) 48 73 51 02.51 12 47.70 PART OF PRESSURE BULKHEAD 48 75 51 02.47 12 47.63 FRAME FOR OVERHEAD LUGGAGE COMPARTMENT (ROW 46 F-G) 48 88 51 02.90 12 48.84 CONTROL LINKAGE FROM TAIL OF AIRCRAFT (ELEVATOR CONTROL QUADRANT) 48 99 51 02.71 12 47.92 FUSELAGE SKIN SECTION (BS 2598) 48 296 51 02.03 12 43.17 PART OF PRESSURE BULKHEAD 48 314 51 01.84 12 44.19 APU AIR DUCT 48 371 51 02.51 12 48.28 AFT FUSELAGE SKIN 10'x15' (HORIZ. STAB CUTOUT)

SECTION TARGET LAT LONG ENGINES 7.13 108 51

02.97 12 47.12 AIRCRAFT ENGINE (WITH STRUT) 149 51 03.26 12 47.38 ENGINE AND STRUT 154 51 03.32 12 47.75 ENGINE SECTION (5th ENGINE) 171 51 03.16 12 47.16 TURBINE SECTION OF ENGINE (POSSIBLY COMPLETE ENGINE) 235 51 03.63 12 47.07 AIRCRAFT ENGINE ENGINE PARTS 106 51 02.98 12 46.41 ENGINE COWLING (INLET) MARKED 'A124' (5th ENGINE) 109 51 02.97 12 47.11 STARTER FOR AIRCRAFT ENGINE 111 51 03.02 12 47.20 ENGINE COWL 116 51 02.99 12 47.80 ENGINE DEVICE 124 51 02.85 12 48.47 FIFTH ENG CENTER DOME 150 51 03.25 12 47.36 PART OF ENGINE 151 51 03.29 12 47.42 SMALL PART OF ENGINE 152 51 03.31 12 47.44 LOWER PORTION OF ENGINE 153 51 03.31 12 47.44 LOWER ENGINE COWLING 155 51 03.32 12 47.44 FAN INNER EXIT AREA 156 51 03.32 12 47.43 PART OF ENGINE 158 51 03.23 12 47.35 PART OF ENGINE COWLING 159 51 03.25 12 47.29 ENGINE COWLING 161 51 03.26 12 47.29 PORTION OF ENGINE COWL 165 51 03.20 12 47.21 THRUST REVERSER SLEEVE 166 51 03.20 12 47.21 UNIDENTIFIED ENGINE PARTS 167 51 03.21 12 47.24 UNIDENTIFIED ENGINE PARTS 168 51 03.20 12 47.22 UNIDENTIFIED ENGINE PART 169 51 03.18 12 47.20 UNIDENTIFIED ENGINE PARTS 170 51 03.19 12 47.19 PART OF DIAPHRAM (OIL COOLER) 172 51 03.25 12 47.21 ENGINE EXHAUST CONE 173 51 03.27 12 47.38 ENGINE EXHAUST CONE AND EXHAUST 237 51 03.690 12 47.10 ENGINE PARTS CASE 238 51 03.72 12 47.10 ENGINE INLET COWL 206 51 03.34 12 47.50 SECTION OF ENGINE EXHAUST STAGE #7 207 51 03.35 12 47.49 ENGINE HOT SECTION AREA 208 51 03.37 12 47.51 ENGINE TAIL CONE 214 51 03.19 12 47.36 CASCADE VANE

STRUTS 7.12 4 51 02.87 12 49.05 #3 ENGINE NACELLE STRUT 157 51 03.23 12 47.36 STRUT (SIMILAR TO 149) 110 51 03.15 12 47.16 NACELLE STRUT WING PARTS 17 120 51 03.01 12 47.98 OUTBOARD AILERON (50%) 16 135 51 03.28 12 47.81 TRAILING EDGE FLAP AND DRAG JACK 16 136 51 03.31

12 47.81 TRAILING EDGE FLAP JACK SKREW 12 140 51 03.35 12 47.83 LEADING EDGE SECTION OF WING 14 145 51 03.34 12 47.85 WING LEADING EDGE VARIABLE CAMBER FLAP 16 177 51 03.34 12 47.91 TRAILING EDGE FLAP 12 181 51 03.38 12 47.87 LOWER CARGO COMPARTMENT AND WING LOWER SKIN 16 183 51 03.38 12 47.87 SECTION OF FLAP SKIN 16 188 51 03.33 12 47.81 TRAILING EDGE FLAP WITH JACK SKREW 16 189 51 03.32 12 47.80 TRAILING EDGE FLAP WITH SKREW JACK 16 191 51 03.32 12 47.78 FLAP ACTUATOR AND FLAP TRACK 16 194 51 03.32 12 47.77 TRAILING EDGE OF FORE FLAP 16 253 51 03.32 12 47.86 PIECE OF TRAILING EDGE FLAP 16 254 51 03.40 12 47.86 PIECE OF TRAILING EDGE FLAP 16 264 51 02.47 12 44.74 TRAILING EDGE FLAP FAIRING 16 277 51 02.18 12 44.40 WING FLAP 16 344 51 03.294 12 47.802 TRAILING EDGE FLAP AND FLAP TRACK 16 384 51 03.33 12 47.80 T/E FLAP TAPER AND DRIVE SHAFT 16 398 51 03.325 12 47.85 PIECE OF TE MID FLAP 15 190 51 03.32 12 47.79 SPOILER ACTUATOR 14 187 51 03.34 12 47.81 LEADING EDGE FLAP SECTION 14 387 51 03.33 12 47.853 PIECE OF L/E FLAP MECHANISM

12 54 51 02.38 12 45.86 LE FROM WING 12 202 51 03.33 12 47.86 WING LOWER SKIN 12 221 51 03.39 12 47.89 UPPER EDGE LEFT WING 12 225 51 03.38 12 48.78 SMALL PIECE OF WING LEADING EDGE PANEL 12 222 51 03.38 12 47.94 WING FILLER & WING PARTS 12 243 51 03.59 12 47.85 PIECE OF LEADING EDGE FLAP 12 252 51 03.38 12 47.84 LOWER WING SECTION 12 262 51 03.85 12 46.92 MID LOWER WING SKIN, ONE AFT FLAP TRACK WITH JACK SKREW 12 266 51 02.36 12 44.46 LANDING GEAR DOOR 12 297 51 01.91 12 43.18 PART OF WING TIP 12 345 51 03.28 12 47.842 'REAR WING SPAR' 12 365 51 03.338 12 47.842 REAR SPAR RIB WITH SPOILER ACTUATOR 12 379 51 03.315 12 47.785 WING REAR SPAR AND SPOILER STA 1150 12 381 51 03.40 12 47.88 LE OF WING SECTION 12 182 51 03.38 12 47.87 POSSIBLE REAR SPAR, (WING STA 802 I.D. ON PART) 17 274 51 02.19 12 43.57 LEFT INBOARD AILERON

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: aniljit singh uppal <aniljitsingh@hotmail.com>
Subject: **PA 103 report**

http://www.open.gov.uk/aaib/n739pa.htm

Air Accidents Investigation Branch
Aircraft Accident Report No 2/90 (EW/C1094)

Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21December 1988

Contents

*   4. SAFETY RECOMMENDATIONS

Operator: Pan American World Airways

Aircraft Type: Boeing 747-121
Nationality: United States of America
Registration: N 739 PA
Place of Accident Lockerbie, Dumfries, Scotland
Latitude 55¡ 07' N
Longitude 003¡ 21' W
Date and Time (UTC): 21 December 1988 at 19.02:50 hrs
All times in this report are UTC
SYNOPSIS

The accident was notified to the Air Accidents Investigation Branch at 19.40 hrs on the 21 December 1988 and the investigation commenced that day. The members of the AAIB team are listed at Appendix A.

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind. Major portions of the wreckage of the aircraft fell on the town of Lockerbie with other large parts landing in the countryside to the east of the town. Lighter debris from the aircraft was strewn along two trails, the longest of which extended some 130 kilometres to the east coast of England. Within a few days items of wreckage were retrieved upon which forensic scientists found conclusive evidence of a detonating high explosive. The airport security and criminal aspects of the accident are the subject of a separate investigation and are not covered in this report which concentrates on the technical aspects of the disintegration of the aircraft.

The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie. Five recommendations are made of which four concern flight recorders, including the funding of a study to devise methods of recording violent positive and negative pressure pulses associated with explosions. The final recommendation is that Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft's structure and systems to explosive damage.

1. FACTUAL INFORMATION

1.1 History of the Flight

Boeing 747, N739PA, arrived at London Heathrow Airport from San Francisco and parked on stand Kilo 14, to the south-east of Terminal 3. Many of the passengers for this aircraft had arrived at Heathrow from Frankfurt, West Germany on a Boeing 727, which was positioned on stand Kilo 16, next to N739PA. These passengers were transferred with their baggage to N739PA which was to operate the scheduled Flight PA103 to New York Kennedy. Passengers from other flights also joined Flight PA103 at Heathrow. After a 6 hour turnround, Flight PA103 was pushed back from the stand at 18.04 hrs and was cleared to taxy on the inner taxiway to runway 27R. The only relevant Notam warned of work in progress on the outer taxiway. The departure was unremarkable.

Flight PA103 took-off at 18.25 hrs. As it was approaching the Burnham VOR it took up a radar heading of 350¡ and flew below the Bovingdon holding point at 6000 feet. It was then cleared to climb initially to flight level (FL) 120 and subsequently to FL 310. The aircraft levelled off at FL 310 north west of Pole Hill VOR at 18.56 hrs. Approximately 7 minutes later, Shanwick Oceanic Control transmitted the aircraft's oceanic clearance but this transmission was not acknowledged. The secondary radar return from Flight PA103 disappeared from the radar screen during this transmission. Multiple primary radar returns were then seen fanning out downwind for a considerable distance. Debris from the aircraft was strewn along two trails, one of which extended some 130 km to the east coast of England. The upper winds were between 250¡ and 260¡ and decreased in strength from 115 kt at FL 320 to 60 kt at FL 100 and 15 to 20 kt at the surface.

Two major portions of the wreckage of the aircraft fell on the town of Lockerbie; other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Residents of Lockerbie reported that, shortly after 19.00 hrs, there was a rumbling noise like thunder which rapidly increased to deafening proportions like the roar of a jet engine under power. The noise appeared to come from a meteor-like object which was trailing flame and came down in the north-eastern part of the town. A larger, dark, delta shaped object, resembling an aircraft wing, landed at about the same time in the Sherwood area of the town. The delta shaped object was not on fire while in the air, however, a very large fireball ensued which was of short duration and carried large amounts of debris into the air, the lighter particles being deposited several miles downwind. Other less well defined objects were seen to land in the area.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	16	243	11
Serious	-	-	2
Minor/None	-	-	3

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1.3 Damage to aircraft

The aircraft was destroyed

1.4 Other damage

The wings impacted at the southern edge of Lockerbie, producing a crater whose volume, calculated from a photogrammetric survey, was approximately 560 cubic metres. The weight of material displaced by the wing impact was estimated to be well in excess of 1500 tonnes. The wing impact created a fireball, setting fire to neighbouring houses and carrying aloft debris which was then blown downwind for several miles. It was subsequently established that domestic properties had been so seriously damaged as a result of fire and/or impact that 21 had to be demolished and an even greater number of homes required substantial repairs. Major portions of the aircraft, including the engines, also landed on the town of Lockerbie and other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Lighter debris from the aircraft was strewn as far as the east coast of England over a distance of 130 kilometres.

1.5 Personnel information

1.5.1 Commander: Male, aged 55 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 720, Lockheed L1011 and Douglas DC3
Medical Certificate: Class 1,valid to April 1989, with the limitation that the holder shall wear lenses that correct for distant vision and possess glasses that correct for near vision

Flying experience:
Total all types: 10,910 hours
Total on type: 4,107 hours
Total last 28 days 82 hours
Duty time: Commensurate with company requirements

Last base check: 11 November 1988
Last route check: 30 June 1988
Last emergencies check: 8 November 1988

1.5.2 Co-pilot: Male, aged 52 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 727
Medical Certificate: Class 1, valid to April 1989, with the limitation that the holder shall possess correcting glasses for near vision
Flying experience:
Total all types: 11,855 hours
Total on type: 5,517 hours
Total last 28 days: 51 hours
Duty time: Commensurate with company requirements
Last base check: 30 November 1988
Last route check: Not required
Last emergencies check: 27 November 1988

1.5.3 Flight Engineer: Male, aged 46 years
Licence: USA Flight Engineer's Licence
Aircraft ratings: Turbojet
Medical certificate: Class 2, valid to June 1989, with the limitation that the holder shall wear correcting glasses for near vision
Flying experience:
Total all types: 8,068 hours
Total on type: 487 hours
Total last 28 days: 53 hours
Duty time: Commensurate with company requirements
Last base check: 30 October 1988
Last route check: Not required
Last emergencies check: 27 October 1988

1.5.4 Flight Attendants: There were 13 Flight Attendants on the aircraft, all of

whom met company proficiency and medical requirements
CLICK HERE TO RETURN TO INDEX
1.6 Aircraft information

1.6.1 Leading particulars

Aircraft type: Boeing 747-121
Constructor's serial number: 19646
Engines: 4 Pratt and Whitney JT9D-7A turbofan

1.6.2 General description

The Boeing 747 aircraft, registration N739PA, was a conventionally designed long range transport aeroplane. A diagram showing the general arrangement is shown at Appendix B, Figure B-1 together with the principal dimensions of the aircraft.

The fuselage of the aircraft type was of approximately circular section over most of its length, with the forward fuselage having a diameter of 21† feet where the cross-section was constant. The pressurised section of the fuselage (which included the forward and aft cargo holds) had an overall length of 190 feet, extending from the nose to a point just forward of the tailplane. In normal cruising flight the service pressure differential was at the maximum value of 8.9 pounds per square inch. The fuselage was of conventional skin, stringer and frame construction, riveted throughout, generally using countersunk flush riveting for the skin panels. The fuselage frames were spaced at 20 inch intervals and given the same numbers as their stations, defined in terms of the distance in inches from the datum point close to the nose of the aircraft [Appendix B, Figure B-2]. The skin panels were joined using vertical butt joints and horizontal lap joints. The horizontal lap joints used three rows of rivets together with a cold bonded adhesive.

Accommodation within the aircraft was predominately on the main deck, which extended throughout the whole length of the pressurised compartment. A separate upper deck was incorporated in the forward part of the aircraft. This upper deck was reached by means of a spiral staircase from the main deck and incorporated the flight crew compartment together with additional passenger accommodation. The cross-section of the forward fuselage differed considerably from the near circular section of the remainder of the aircraft, incorporating an additional smaller radius arc above the upper deck section joined to the main circular arc of the lower cabin portion by elements of straight fuselage frames and flat skin.

In order to preserve the correct shape of the aircraft under pressurisation loading, the straight portions of the fuselage frames in the region of the upper deck floor and above it were required to be much stiffer than the frame portions lower down in the aircraft. These straight sections were therefore of very much more substantial construction than most of the curved sections of frames lower down and further back in the fuselage. There was considerable variation in the gauge of the fuselage skin at various locations in the forward fuselage of the aircraft.

The fuselage structure of N739PA differed from that of the majority of Boeing 747 aircraft in that it had been modified to carry special purpose freight containers on the main deck, in place of seats. This was known as the Civil Reserve Air Fleet (CRAF) modification and enabled the aircraft to be quickly converted for carriage of military freight containers on the main deck during times of national emergency. The effect of this modification on the structure of the fuselage was mainly to replace the existing main deck floor beams with beams of more substantial cross-section than those generally found in passenger carrying Boeing 747 aircraft. A large side loading door, generally known as the CRAF door, was also incorporated on the left side of the main deck aft of the wing.

Below the main deck, in common with other Boeing 747 aircraft, were a number of additional compartments, the largest of which were the forward and aft freight holds used for the storage of cargo and baggage in standard air-transportable containers. These containers were placed within the aircraft hold by means of a freight handling system and were carried on a system of rails approximately 2 feet above the outer skin at the bottom of the aircraft, there being no continuous floor, as such, below these baggage containers. The forward freight compartment had a length of approximately 40 feet and a depth of approximately 6 feet. The containers were loaded into the forward hold through a large cargo door on the right side of the aircraft.

1.6.3 Internal fuselage cavities

Because of the conventional skin, frame and stringer type of construction, common to all large public transport aircraft, the fuselage was effectively divided into a series of 'bays'. Each bay, comprising two adjacent fuselage frames and the structure between them, provided, in effect, a series of interlinking cavities bounded by the frames, floor beams, fuselage skins and cabin floor panels etc. The principal cavities thus formed were:

(i) A semi-circular cavity formed in between the fuselage frames in the lower lobe of the hull, i.e. from the crease beam (at cabin floor level) on one side down to the belly beneath the containers and up to the opposite crease beam, bounded by the fuselage skin on the outside and the containers/cargo liner on the inside [Appendix B, Figure B-3, detail A].

(ii) A horizontal cavity between the main cabin floor beams, the cabin floor panels and the cargo bay liner. This extended the full width of the fuselage and linked the upper ends of the lower lobe cavity [Appendix B, Figure B-3, detail B].

(iii) A narrow vertical cavity between the two containers [Appendix B, Figure B-3, detail C].

(iv) A further narrow cavity around the outside of the two containers, between the container skins and the cargo bay liner, communicating with the lower lobe cavity [Appendix B, Figure B-3, detail D].

(v) A continuation of the semi-circular cavity into the space behind the cabin wall liner [Appendix B, Figure B-3, detail E]. This space was restricted somewhat by the presence of the window assembly, but nevertheless provided a continuous cavity extending upwards to the level of the upper deck floor. Forward of station 740, this cavity was effectively terminated at its upper end by the presence of diaphragms which formed extensions of the upper deck floor panels; aft of station 740, the cavity communicated with the ceiling space and the cavity in the fuselage crown aft of the upper deck.

All of these cavities were repeated at each fuselage bay (formed between pairs of fuselage frames), and all of the cavities in a given bay were linked together, principally at the crease beam area [Appendix B, Figure B-3, region F]. Furthermore, each of the set of bay cavities was linked with the next by the longitudinal cavities formed between the cargo hold liner and the outer hull, just below the crease beam [Appendix B, Figure B-3, detail F]; i.e. this cavity formed a manifold linking together each of the bays within the cargo hold.

The main passenger cabin formed a large chamber which communicated directly with each of the sub floor bays, and also with the longitudinal manifold cavity, via the air conditioning and cabin/cargo bay de-pressurisation vent passages in the crease beam area. (It should be noted that a similar communication did not exist between the upper and lower cabins because there were no air conditioning/depressurisation passages to bypass the upper deck floor.)

1.6.4 Aircraft weight and centre of gravity

The aircraft was loaded within its permitted centre of gravity limits as follows:

Loading:	lb	kg
Operating empty weight	366,228	166,120
Additional crew	130	59
243 passengers (1)	40,324	18,291
Load in compartments:		
1	11,616	5,269
2	20,039	9,090
3	15,057	6,830
4	17,196	7,800
5	2,544	1,154
Total in compartments (2)	66,452	30,143
Total traffic load	106,776	48,434
Zero fuel weight	472,156	214,554
Fuel (Take-off)	239,997	108,862
Actual take-off weight(4)	713,002	323,416
Maximum take-off weight	733,992	332,937

Note 1:
Calculated at standard weights and including cabin baggage.

Note 2:
Despatch information stated that the cargo did not include dangerous goods, perishable cargo, live animals or known security exceptions.

1.6.5 Maintenance details

N739PA first flew in 1970 and spent its whole service life in the hands of Pan American World Airways Incorporated. Its Certificate of Airworthiness was issued on 12 February 1970 and remained in force until the time of the accident, at which time the aircraft had completed a total of 72,464 hours flying and 16,497 flight cycles. Details of the last 4 maintenance checks carried out during the aircraft's life are shown below:

DATE	SERVICE	HOURS	CYCLES
27 Sept 88	C Check (Interior upgrade)	71,502	16,347
2 Nov 88	B Service Check	71,919	16,406
27 Nov 88	Base 1	72,210	16,454

13 Dec 88   Base 2 72,374 16,481

The CRAF modification programme was undertaken in September 1987. At the same time a series of modifications to the forward fuselage from the nose back to station 520 (Section 41) were carried out to enable the aircraft to continue in service without a continuing requirement for structural inspections in certain areas.

All Airworthiness Directives relating to the Boeing 747 fuselage structure between stations 500 and 1000 have been reviewed and their applicability to this aircraft checked. In addition, Service Bulletins relating to the structure in this area were also reviewed. The applicable Service Bulletins, some of which implement the Airworthiness Directives are listed below together with their subjects. The dates, total aircraft times and total aircraft cycles at which each relevant inspection was last carried out have been reviewed and their status on aircraft N739PA at the time of the accident has been established.

N739PA Service Bulletin compliance:

SB 53-2064   Front Spar Pressure Bulkhead Chord Reinforcement and Drag Splice Fitting Rework.
Modification accomplished on 6 July 1974.
Post-modification repetitive inspection IAW (in accordance with) AD 84-18-06 last accomplished on 19 November 1985 at 62,030 TAT hours (Total Aircraft Time) and 14,768 TAC (Total Aircraft Cycles).
SB 53-2088   Frame to Tension Tie Joint Modification - BS760 to 780.
Repetitive inspection IAW AD 84-19-01 last accomplished on 19 June 1985 at 60,153 hours TAT and 14,436 TAC.
SB 53-2200 Lower Cargo Doorway Lower Sill Truss and Latch Support Fitting Inspection Repair and Replacement.
Repetitive inspection IAW AD 79-17-02 R2 last accomplished 2 November 1988 at 71,919 hours TAT and 16,406 TAC.
SB 53-2234   Fuselage - Auxiliary Structure - Main Deck Floor - BS 480 Floor Beam Upper Chord Modification.
Repetitive inspection per SB 53A2263 IAW AD 86-23-06 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
SB 53-2237   Fuselage - Main Frame - BS 540 thru 760 and 1820 thru 1900 Frame Inspection and Reinforcement.
Repetitive inspection IAW AD 86-18-01 last accomplished on 27 February 1987 at 67,088 hours TAT and 15,627 TAC.
SB 53-2267   Fuselage - Skin - Lower Body Longitudinal Skin Lap Joint and

Adjacent Body Frame Inspection and Repair.
Terminating modification accomplished 100% under wing-to-body fairings and approximately 80% in forward and aft fuselage sections on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
Repetitive inspection of unmodified lap joints IAW AD 86-09-07 R1 last accomplished on 18 August 1988 at 71,043 hours TAT and 16,273 TAC.
SB 53A2303 Fuselage - Nose Section - station 400 to 520 Stringer 6 Skin Lap Splice Inspection, Repair and Modification.
Repetitive inspection IAW AD 89-05-03 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.

This documentation, when viewed together with the detailed content of the above service bulletins, shows the aircraft to have been in compliance with the requirements laid down in each of those bulletins. Some maintenance items were outstanding at the time the aircraft was despatched on the last flight, however, none of these items relate to the structure of the aircraft and none had any relevance to the accident.

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1.7 Meteorological Information

1.7.1 General weather conditions

An aftercast of the general weather conditions in the area of Lockerbie at about 19.00 hrs was obtained from the Meteorological Office, Bracknell. The synoptic situation included a warm sector covering northern England and most of Scotland with a cold front some 200 nautical miles to the west of the area moving eastwards at about 35 knots. The weather consisted of intermittent rain or showers. The cloud consisted of 4 to 6 oktas of stratocumulus based at 2,200 feet with 2 oktas of altocumulus between 15,000 and 18,000 feet. Visibility was over 15 kilometers and the freezing level was at 8,500 feet with a sub-zero layer between 4,000 and 5,200 feet.

1.7.2 Winds

There was a weakening jet stream of around 115 knots above Flight Level 310. From examination of the wind profile (see below), there appeared to be insufficient shear both vertically and horizontally to produce any clear air turbulence but there may have been some light turbulence.

Flight Level	Wind
320	260¡/115 knots
300	260¡/ 90 knots
240	250¡/ 80 knots
180	260¡/ 60 knots
100	250¡/ 60 knots
050	260¡/ 40 knots
Surface	240¡/ 15 to 20 gusting 25 to 30 knots

1.8 Aids to navigation

Not relevant.

1.9 Communications

The aircraft communicated normally on London Heathrow aerodrome, London control and Scottish control frequencies. Tape recordings and transcripts of all radio telephone (RTF) communications on these frequencies were available.

At 18.58 hrs the aircraft established two-way radio contact with Shanwick Oceanic Area Control on frequency 123.95 MHz. At 19.02:44 hrs the clearance delivery officer at Shanwick transmitted to the aircraft its oceanic route clearance. The aircraft did not acknowledge this message and made no subsequent transmission.

1.9.1 ATC recording replay

Scottish Air Traffic Control provided copy tapes with time injection for both Shanwick and Scottish ATC frequencies. The source of the time injection on the tapes was derived from the British Telecom "TIM" signal.

The tapes were replayed and the time signals corrected for errors at the time of the tape mounting.

1.9.2 Analysis of ATC tape recordings

From the cockpit voice recorder (CVR) tape it was known that Shanwick was transmitting Flight PA103's transatlantic clearance when the CVR stopped. By synchronising the Shanwick tape and the CVR it was possible to establish that a loud sound was heard on the CVR cockpit area microphone (CAM) channel at 19.02:50 hrs ±1 second.

As the Shanwick controller continued to transmit Flight PA103's clearance instructions through the initial destruction of the aircraft it would not have been possible for a distress call to be received from N739PA on the Shanwick frequency. The Scottish frequency tape recording was listened to from 19.02 hrs until 19.05 hrs for any unexplained sounds indicating an attempt at a distress call but none was heard.

A detailed examination and analysis of the ATC recording together with the flight recorder, radar, and seismic recordings is contained in Appendix C.

1.10 Aerodrome information

Not relevant

1.11 Flight recorders

The Digital Flight Data Recorder (DFDR) and the Cockpit Voice Recorder (CVR) were found close together at UK Ordnance Survey (OS) Grid Reference 146819, just to the east of Lockerbie, and recovered approximately 15 hours after the accident. Both recorders were taken directly to AAIB Farnborough for replay. Details of the examination and analysis of the flight recorders together with the radar, ATC and seismic recordings are contained in Appendix C.

1.11.1 Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded and that the recorder had simply stopped at 19.02:50 hrs ±1 second.

1.11.2 Cockpit voice recorder

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1 Flight Engineer's RTF.
Channel 2 Co-Pilot's RTF.
Channel 3 Pilot's RTF.
Channel 4 Cockpit Area Microphone.

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings were audible on the RTF channels. The CAM channel was particularly noisy, probably due to the combination of the inherently noisy flight deck of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high flight deck noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified and could have been of either acoustic or electrical origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19.02:50 hrs ±1 second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC.

1.12 Wreckage and impact information

1.12.1 General distribution of wreckage in the field

The complete wing primary structure, incorporating the centre section, impacted at the southern edge of Lockerbie. Major portions of the aircraft, including the engines, also landed in the town. Large portions of the aircraft fell in the countryside to the east of the town and lighter debris was strewn to the east as far as the North Sea. The wreckage was distributed in two trails which became known as the northern and southern trails respectively and these are shown in Appendix B, Figure B-4. A computer database of approximately 1200 significant items of wreckage was compiled and included a brief description of each item and the location where it was found

Appendix B, Figures B-5 to B-8 shows photographs of a model of the aircraft on which the fracture lines forming the boundaries of the separate items of structure have been marked. The model is colour coded to illustrate the way in which the wreckage was distributed between the town of Lockerbie and the northern and southern trails.

1.12.1.1 The crater

The aircraft wing impacted in the Sherwood Crescent area of the town leaving a crater approximately 47 metres (155 feet) long with a volume calculated to be 560 cubic metres.

The projected distance, measured parallel from one leading edge to the other wing tip, of the Boeing 747-100 was approximately 143 feet, whereas the span is known to be 196 feet. This suggests that impact took place with the wing structure yawed. Although the depth of the crater varied from one end to the other, its widest part was clearly towards the western end suggesting that the wing structure impacted whilst orientated with its root and centre section to the west.

The work carried out at the main crater was limited to assessing the general nature of its contents. The total absence of debris from the wing primary structure found remote from the crater confirmed the initial impression that the complete wing box structure had been present at the main impact.

The items of wreckage recovered from or near the crater are coloured grey on the model at Appendix B, Figures B-5 to B-8.

1.12.1.2 The Rosebank Crescent site

A 60 feet long section of fuselage between frame 1241 (the rear spar attachment) and frame 1960 (level with the rear edge of the CRAF cargo door) fell into a housing estate at Rosebank Crescent, just over 600 metres from the crater. This section of the fuselage was that situated immediately aft of the wing, and adjoined the wing and fuselage remains which produced the crater. It is colour coded yellow on the model at Appendix B, Figures B-5 to B-8. All fuselage skin structure above floor level was missing except for the following items:

Section containing 3 windows between door 4L and CRAF door;

The CRAF door itself (latched) apart from the top area containing the hinge;
Window belt containing 8 windows aft of 4R door aperture
Window belt containing 3 windows forward of 4R door aperture;
Door 4R.

Other items found in the wreckage included both body landing gears, the right wing landing gear, the left and right landing gear support beams and the cargo door (frames 1800-1920) which was latched. A number of pallets, luggage containers and their contents were also recovered from this site.

1.12.1.3 Forward fuselage and flight deck section.

The complete fuselage forward of approximately station 480 (left side) to station 380 (right side) and incorporating the flight deck and nose landing gear was found as a single piece [Appendix B, Figure B-9] in a field approximately 4 km miles east of Lockerbie at OS Grid Reference 174808. It was evident from the nature of the impact damage and the ground marks that it had fallen almost flat on its left side but with a slight nose-down attitude and with no discernible horizontal velocity. The impact had caused almost complete crushing of the structure on the left side. The radome and right nose landing gear door had detached in the air and were recovered in the southern trail.

Examination of the torn edges of the fuselage skin did not indicate the presence of any pre-existing structural or material defects which could have accounted for the separation of this section of the fuselage. Equally so, there were no signs of explosive blast damage or sooting evident on any part of the structure or the interior fittings. It was noted however that a heavy, semi-eliptical scuff mark was present on the lower right side of the fuselage at approximately station 360. This was later matched to the intake profile of the No 3 engine.

The status of the controls and switches on the flight deck was consistent with normal operation in cruising flight. There were no indications that the crew had attempted to react to rapid decompression or loss of control or that any emergency preparations had been actioned prior to the catastrophic disintegration.

1.12.1.4 Northern trail

The northern trail was seen to be narrow and clearly defined, to emanate from a point very close to the main impact crater and to be orientated in a direction which agreed closely with the mean wind aftercast for the height band from sea level to 20,000 ft. Also at the western end of the northern trail were the lower rear fuselage at Rosebank Crescent, and the group of Nos. 1, 2 and 4 engines which fell in Lockerbie.

The trail contained items of structure distributed throughout its length, from the area slightly east of the crater, to a point approximately 16 km east, beyond which only items of low weight / high drag such as insulation, interior trim, paper etc, were found. For all practical purposes this trail ended at a range of 25 km.

The northern trail contained mainly wreckage from the rear fuselage, fin and the inner regions of both tailplanes together with structure and skin from the upper half of the fuselage forward to approximately the wing mid-chord position. A number of items from the wing were also found in the northern trail, including all 3 starboard Kreuger flaps, most of the remains of the port Kreuger flaps together with sections of their leading edge attachment structures, one portion of outboard aileron approximately 10 feet long, the aft ends of the flap-track fairings (one with a slide raft wrapped around it), and fragments of glass reinforced plastic honeycombe structure believed to be from the flap system, i.e. fore-flaps, aft-flaps, mid-flaps or adjacent fairings. In addition, a number of pieces of the engine cowlings and both HF antennae (situated projecting aft from the wing-tips) were found in this trail.

All items recovered from the northern trail, with the exception of the wing, engines, and lower rear fuselage in Rosebank Crescent, are coloured red on the model of the aircraft in Appendix B, Figures B-5 to B-8.

1.12.1.5 Southern trail

The southern trail was easily defined, except within 12 km of Lockerbie where it tended to merge with the northern trail. Further east, it extended across southern Scotland and northern England, essentially in a straight band as far as the North Sea. Most of the significant items of wreckage were found in this trail within a range of 30 km from the main impact crater. Items recovered from the southern trail are coloured green on the model of the aircraft at Appendix B, Figures B-5 to B-8.

The trail contained numerous large items from the forward fuselage. The flight deck and nose of the aircraft fell in the curved part of this trail close to Lockerbie. Fragments of the whole of the left tailplane and the outboard portion of the right tailplane were distributed almost entirely throughout the southern trail. Between 21 and 27 km east of the main impact point (either side of Langholm) substantial sections of tailplane skin were found, some bearing distinctive signs of contact with debris moving outwards and backwards relative to the fuselage. Also found in this area were numerous isolated sections of fuselage frame, clearly originating from the crown region above the forward upper deck.

1.12.1.6 Datum line

All grid references relating to items bearing actual explosive evidence, together with those attached to heavily distorted items found to originate immediately adjacent to them on the structure, were plotted on an Ordnance Survey (OS) chart. These references, 11 in total, were all found to be distributed evenly about a mean line orientated 079¡(Grid) within the southern trail and were spread over a distance of 12 km. The distance of each reference from the line was measured in a direction parallel to the aircraft's track and all were found to be within 500 metres of the line, with 50% of them being within 250 metres of the line. This line is referred to as the datum line and is shown in Appendix B, Figure B-4.

1.12.1.7 Distribution of wreckage within the southern trail

North of the datum line and parallel to it were drawn a series of lines at distances of 250, 300, 600 and 900 metres respectively from the line, again measured in a direction parallel to the aircraft's track. The positions on the aircraft structure of specific items of wreckage, for which grid references were known with a high degree of confidence, within the bands formed between these lines, are shown in Appendix B, Figures B-10 to 13. In addition, a separate assessment of the grid references of tailplane and elevator wreckage established that these items were distributed evenly about the 600 metre line.

1.12.1.8 Area between trails

Immediately east of the crater, the southern trail converged with the northern trail such that, to an easterly distance of approximately 5 km, considerable wreckage existed which could have formed part of either trail. Further east, between 6 and 11 km from the crater, a small number of sections and fragments of the fin had fallen outside the southern boundary of the northern trail. Beyond this a large area existed between the trails in which there was no wreckage.

1.12.2 Examination of wreckage at CAD Longtown

The debris from all areas was recovered by the Royal Air Force to the Army Central Ammunition Depot Longtown, about 20 miles from Lockerbie. Approximately 90% of the hull wreckage was successfully recovered, identified, and laid out on the floor in a two-dimensional reconstruction [Appendix B, Figure B-14]. Baggage container material was incorporated into a full three-dimensional reconstruction. Items of wreckage added to the reconstructions was given a reference number and recorded on a computer database together with a brief description of the item and the location where it was found.

1.12.2.1 Fuselage

The reconstruction revealed the presence of damage consistent with an explosion on the lower fuselage left side in the forward cargo bay area. A small region of structure bounded approximately by frames 700 & 720 and stringers 38L & 40L, had clearly been shattered and blasted through by material exhausting directly from an explosion centred immediately inboard of this location. The material from this area, hereafter referred to as the 'shatter zone', was mostly reduced to very small fragments, only a few of which were recovered, including a strip of two skins [Appendix B, Figure B-15] forming part of the lap joint at the stringer 39L position.

Surrounding the shatter zone were a series of much larger panels of torn fuselage skin which formed a 'star-burst' fracture pattern around the shatter zone. Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range. In contrast, the star-burst fractures, outside the boundary of the shatter zone, displayed evidence of more typical overload tearing, though some tears appeared to be rapid and, in the area below the missing panels, were multi-branched. These surrounding skin panels were moderately sooted in the regions adjacent to the shatter zone, but otherwise were lightly sooted or free of soot altogether. (Forensic analysis of the soot deposits on frame and skin material from this area confirmed the presence of explosive residues.) All of these skin panels had pulled away from the supporting structure and had been bent and torn in a manner which indicated that, as well as fracturing in the star burst pattern, they had also petalled outwards producing characteristic, tight curling of the sheet material.

Sections of frames 700 and 720 from the area of the explosion were also recovered and identified. Attached to frame 720 were the remnants of a section of the aluminium baggage container (side) guide rail, which was heavily distorted and displayed deep pitting together with very heavy sooting, indicating that it had been very close to the explosive charge. The pattern of distortion and damage on the frames and guide rail segment matched the overall pattern of damage observed on the skins.

The remainder of the structure forming the cargo deck and lower hull was, generally, more randomly distorted and did not display the clear indications of explosive processes which were evident on the skin panels and frames nearer the focus of the explosion. Nevertheless, the overall pattern of damage was consistent with the propagation of explosive pressure fronts away from the focal area inboard of the shatter zone. This was particularly evident in the fracture and bending characteristics of several of the fuselage frames ahead of, and behind station 700.

The whole of the two-dimensional fuselage reconstruction was examined for general evidence of the mode of disintegration and for signs of localised damage, including overpressure damage and pre-existing damage such as corrosion or fatigue. There was some evidence of corrosion and dis-bonding at the cold-bond lap joints in the fuselage. However, the corrosion was relatively light and would not have compromised significantly the static strength of the airframe. Certainly, there was no evidence to suggest that corrosion had affected the mode of disintegration, either in the area of the explosion or at areas more remote. Similarly, there were no indications of fatigue damage except for one very small region of fatigue, involving a single crack less than 3 inches long, which was remote from the bomb location. This crack was not in a critical area and had not coincided with a fracture path.

No evidence of overpressure fracture or distortion was found at the rear pressure bulkhead. Some suggestion of 'quilting' or 'pillowing' of skin panels between stringers and frames, indicative of localised overpressure, was evident on the skin panels attached to the larger segments of lower fuselage wreckage aft of the blast area. In addition, the mode of failure of the butt joint at station 520 suggested that there had been a rapid overpressure load in this area, causing the fastener heads to 'pop' in the region of stringers 13L to 16L, rather than producing shear in the fasteners. Further evidence of localised overpressure damage remote from the source of the explosion was found during the full three-dimensional reconstruction, detailed later in paragraph 1.12.3.2.

An attempt was made to analyse the fractures, to determine the direction and sequence of failure as the fractures propagated away from the region of the explosion. It was found that the directions of most of the fractures close to the explosion could be determined from an analysis of the fracture surfaces and other features, such as rivet and rivet hole distortions. However, it was apparent that beyond the boundary of the petalled region, the disintegration process had involved multiple fractures taking place simultaneously - extremely complex parallel processes which made the sequencing of events not amenable to conventional analysis.

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1.12.2.2 Wing structure and adjacent fuselage area

On completion of the initial layout at Longtown it became evident that, in the area from station 1000 to approximately station 1240 the only identifiable fuselage structure consisted of elements of fuselage skin, stringers and frames from above the cabin window belts. The wreckage from in and around the crater was therefore sifted to establish more accurately what sections of the aircraft had produced the crater. All of the material was highly fragmented, but it was confirmed that the material comprised mostly wing structure, with a few fragments of fuselage sidewall and passenger seats. The badly burnt state of these fragments made it clear that they were recovered from the area of the main impact crater, the only scene of significant ground fire. Amongst these items a number of cabin window forgings were recovered with sections of thick horizontal panelling attached having a length equivalent to the normal window spacing/frame pitch. This arrangement, with skins of this thickness, is unique to the area from station 1100 to 1260. It is therefore reasonable to assume that these fragments formed parts of the missing cabin sides from station 1000 to station 1260, which must have remained attached to the wing centre section at the time of its impact. Because of the high degree of fragmentation and the relative insignificance of the wing in terms of the overall explosive damage pattern, a reconstruction of the wing material was not undertaken. The sections of the aircraft which went into the crater are colour coded grey in Appendix B, Figures B-5 to B-8.

1.12.2.3 Fin and aft section of fuselage

Examination of the structure of the fin revealed evidence of in-flight damage to the leading edge caused by the impact of structure or cabin contents. This damage was not severe or extensive and the general break-up of the fin did not suggest either a single readily defined loading direction, or break-up due to the effects of leading edge impact. A few items of fin debris were found between the northern and southern trails.

A number of sections of fuselage frame found in the northern trail exhibited evidence of plastic deformation of skin attachment cleats and tensile overload failure of the attachment rivets. This damage was consistent with that which would occur if the skin had been locally subjected to a high loading in a direction normal to its plane. Although this was suggestive of an internal overpressure condition, the rear fuselage revealed no other evidence to support this possibility. Examination of areas of the forward fuselage known to have been subjected to high blast overpressures revealed no comparable evidence of plastic deformation in the skin attachment cleats or rivets, most skin attachment failures appearing to have been rapid.

Calculations made on the effects of internal pressure generated by an open ended fuselage descending at the highest speed likely to have been experienced revealed that this could not generate an internal pressure approaching that necessary to cause failure in an intact cabin structure.

1.12.2.4 Baggage containers

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited damage consistent with being close to a detonating high explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence of explosive damage. It was evident, from the main wreckage layout, that the explosion had occurred in the forward cargo hold and, although all baggage container wreckage was examined, only items from this area which showed the relevant characteristics were considered for the reconstruction. Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to Lockerbie, whilst that from the forward hold was scattered along the southern wreckage trail.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this, two adjacent containers, one of metal construction the other fibreglass, were identified as exhibiting damage likely to have been caused by the explosion. Those parts which could be positively identified as being from these two containers were assembled onto one of three simple wooden frameworks, one each for the floor and superstructure of the metal container and one for the superstructure of the fibreglass container. From this it was positively determined that the explosion had occurred within the metal container (serial number AVE 4041 PA), the direct effects of this being evident also on the forward face of the adjacent fibreglass container (serial number AVN 7511 PA) and on the local airframe on the left side of the aircraft in the region of station 700. It was therefore confirmed that this metal container had been loaded in position 14L in agreement with the aircraft loading records. While this work was in progress a buckled section of the metal container skin was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device (IED).

The reconstruction of these containers and their relationship to the aircraft structure is described in detail in Appendix F. Examination of all other components of the remaining containers revealed only damage consistent with ejection into the high speed slipstream and/or ground impact, and that only one device had detonated within the containers on board the aircraft.

1.12.3 Fuselage three-dimensional reconstruction

1.12.3.1 The reconstruction

The two-dimensional reconstruction successfully established that there had been an explosion in the forward hold; its location was established and the general damage characteristics in the vicinity of the explosion were determined. However, the mechanisms by which the failure process developed from local damage in the immediate vicinity of the explosion to the complete structural break-up and separation of the whole forward section of the fuselage, could not be adequately investigated without recourse to a more elaborate reconstruction.

To facilitate this additional work, wreckage forming a 65 foot section of the fuselage (approximately 30 feet each side of the explosion) was transported to AAIB Farnborough, where it was attached to a specially designed framework to form a fully three-dimensional reconstruction [Appendix B, Figures B-16 and B-17] of the complete fuselage between stations 360 & 1000 (from the separated nose section back to the wing cut out). The support framework was designed to provide full and free access to all parts of the structure, both internally and externally. Because of height constraints, the reconstruction was carried out in two parts, with the structure divided along a horizontal line at approximately the upper cabin floor level. The previously reconstructed containers were also transported to AAIB Farnborough to allow correlation of evidence with, and partial incorporation into, the fuselage reconstruction.

Structure and skin panels were attached to the supporting framework by their last point of attachment, to provide a better appreciation of the modes and direction of curling, distortion, and ultimate separation. Thus, the panels of skin which had petalled back from the shatter zone were attached at their outer edges, so as to identify the bending modes of the panels, the extent of the petalled region, and also the size of the resulting aperture in the hull. In areas more remote from the explosion, the fracture and tear directions were used together with distortion and curling directions to determine the mode of separation, and thus the most appropriate point of attachment to the reconstruction. Cabin floor beam segments were supported on a steel mesh grid and a plot of the beam fractures is shown at Appendix B, Figure B-18.

The cargo container base elements were separated from the rest of the container reconstruction and transferred to the main wreckage reconstruction, where the re-assembled container base was positioned precisely onto the cargo deck. To assist in the correlation of the initial shatter zone and petalled-out regions with the position of the explosive device, the boundaries of the skin panel fractures were marked on a transparent plastic panel which was then attached to the reconstruction to provide a transparent pseudo-skin showing the positions of the skin tear lines. This provided a clear visual indication of the relationship between the skin panel fractures and the explosive damage to the container base, thus providing a more accurate indication of the location of the explosive device.

1.12.3.2 Summary of explosive features evident

The three-dimensional reconstruction provided additional information about the region of tearing and petalling around the shatter zone. It also identified a number of other regions of structural damage, remote from the explosion, which were clearly associated with severe and rapidly applied pressure loads acting normal to the skin's internal surface. These were sufficiently sharp-edged to pre-empt the resolution of pressure induced loads into membrane tension stresses in the skin: instead, the effect was as though these areas of skin had been struck a severe 'pressure blow' from within the hull.

The two types of damage, i.e. the direct blast/tearing/petalling damage and the quite separate areas of 'pressure blow' damage at remote sites were evidently caused by separate mechanisms, though it was equally clear that each was caused by explosive processes, rather than more general disintegration.

The region of petalling was bounded (approximately) by frames 680 and 740, and extended from just below the window belt down nearly to the keel of the aircraft [Appendix B, Figure B-19, region A]. The resulting aperture measured approximately 17 feet by 5 feet. Three major fractures had propagated beyond the boundary of the petalled zone, clearly driven by a combination of hull pressurisation loading and the relatively long term (secondary) pressure pulse from the explosion. These fractures ran as follows:

(i) rearwards and downward in a stepped fashion, joining the stringer 38L lap joint at around station 840, running aft along stringer 38L to around station 920, then stepping down to stringer 39L and running aft to terminate at the wing box cut-out [Appendix B, Figure B-19, fracture 1].
(ii) downwards and forward to join the stringer 44L lap joint, then running forward along stringer 44L as far as station 480 [Appendix B, Figure B-19, fracture 2].
(iii) downwards and rearward, joining the butt line at station 740 to run under the fuselage and up the right side to a position approximately 18 inches above the cabin floor level [Appendix B, Figures B-19 and B-20, fracture 3].

The propagation of tears upwards from the shatter zone appeared to have taken the form of a series of parallel fractures running upwards together before turning towards each other and closing, forming large flaps of skin which appear to have separated relatively cleanly.

Regions of skin separation remote from the site of the explosion were evident in a number of areas. These principally were:

(i) A large section of upper fuselage skin extending from station 500 back to station 760, and from around stringers 15/19L up as far as stringer 5L [Appendix B, Figures B-19 and B-20, region B], and probably extending further up over the crown. This panel had separated initially at its lower forward edge as a result of a pressure blow type of impulse loading, which had popped the heads from the rivets at the butt joint on frame 500 and lifted the skin flap out into the airflow. The remainder of the panel had then torn away rearwards in the airflow.
A region of 'quilting' or 'pillowing', i.e. spherical bulging of skin panels between frames and stringers, was evident on these panels in the region between station 560 and 680, just below the level of the upper deck floor, indicative of high internal pressurisation loading [Appendix B, Figure B-19, region C].

(ii) A smaller section of skin between stations 500 and 580, bounded by stringers 27L and 34L [Appendix B, Figure B-19, region D], had also been 'blown' outwards at its forward edge and torn off the structure rearwards. A characteristic curling of the panel was evident, consistent with rapid, energetic separation from the structure.

(iii) A section of thick belly skin extending from station 560, stringers 40R to 44R, and tapering back to a point at stringer 45R/station720 [Appendix B, Figure B-19 and B-20, region E], had separated from the structure as a result of a very heavy 'pressure blow' load at its forward end which had popped the heads off a large number of substantial skin fasteners. The panel had then torn away rearwards from the structure, curling up tightly onto itself as it did so - indicating that considerable excess energy was involved in the separation process (over and above that needed simply to separate the skin material from its supporting structure).

(iv) A panel of skin on the right side of the aircraft, roughly opposite the explosion, had been torn off the frames, beginning at the top edge of the panel situated just below the window belt and tearing downwards towards the belly [Appendix B, Figure B-20, region F]. This panel was curled downwards in a manner which suggested significant excess energy.

Appendix B, Figure B-21 shows a plot of the fractures noted in the fuselage skins between stations 360 and 1000.

The cabin floor structure was badly disrupted, particularly in the general area above the explosion, where the floor beams had suffered localised upward loading sufficient to fracture them, and the floor panels were missing. Elsewhere, floor beam damage was mainly limited to fractures at the outer ends of the beams and at the centreline, leaving sections of separated floor structure comprising a number of half beams joined together by the Nomex honeycomb floor panels.

1.12.3.3 General damage features not directly associated with explosive forces.

A number of features appeared to be a part of the general structural break-up which followed on from the explosive damage, rather than being a part of the explosive damage process itself. This general break-up was complex and, to a certain extent, random. However, analysis of the fractures, surface scores, paint smears and other features enabled a number of discreet elements of the break-up process to be identified. These elements are summarised below.

(i) Buckling of the window belts on both sides of the aircraft was evident between stations 660 and 800. That on the left side appeared to be the result of in-plane bending in a nose up sense, followed by fracture. The belt on the right side had a large radius curve suggesting lateral deflection of the fuselage possibly accompanied by some longitudinal compression. This terminated in a peeling failure of the riveted joint at station 800.

(ii) On the left side three fractures, apparently resulting from in-plane bending/buckling distortion, had traversed the window belt [Appendix B, Figure B-21, detail G]. Of these, the forward two had broken through the window apertures and the aft fracture had exploited a rivet line at the region of reinforcement just forward of the L2 door aperture. On the right side, the window belt had peeled rearwards, after buckling had occurred, separating from the rest of the fuselage, following rivet failure, at the forward edge of the R2 door aperture.

(iii) All crown skins forward of frame 840 were badly distorted and a number of pieces were missing. It was clearly evident that the skin sections from this region had struck the empennage and/or other structure following separation.

(iv) The fuselage left side lower lobe from station 740 back to the wing box cut-out, and from the window level down to the cargo deck floor (the fracture line along stringer 38L), had peeled outwards, upwards and rearwards - separating from the rest of the fuselage at the window belt. The whole of this separated section had then continued to slide upwards and rearwards, over the fuselage, before being carried back in the slipstream and colliding with the outer leading edge of the right horizontal stabiliser, completely disrupting the outer half. A fragment of horizontal stabiliser spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door [Appendix B, Figure B-22].

(v) A large, clear, imprint of semi-eliptical form was apparent on the lower right side at station 360 which had evidently been caused by the separating forward fuselage section striking the No 3 engine as it swung rearwards and to the right (confirmed by No 3 engine fan cowl damage).

1.12.3.4 Tailplane three-dimensional reconstruction

The tailplane structural design took the form of a forward and an aft torque box. The forward box was constructed from light gauge aluminium alloy sheet skins, supported by closely pitched, light gauge nose ribs but without lateral stringers. The aft torque box incorporated heavy gauge skin/stringer panels with more widely spaced ribs. The front spar web was of light gauge material. Leading edge impacts inflicted by debris would therefore have had the capacity to reduce the tailplane's structural integrity by passing through the light gauge skins and spar web into the interior of the aft torque box, damaging the shear connection between top and bottom skins in the process and thereby both removing the bending strength of the box and opening up the weakened structure to the direct effects of the airflow.

Examination of the rebuilt tailplane structure at AAIB Farnborough left little doubt that it had been destroyed by debris striking its leading edges. In addition, the presence on the skins of smear marks indicated that some unidentified soft debris had contacted those surfaces whilst moving with both longitudinal and lateral velocity components relative to the aircraft.

The reconstructed left tailplane [Appendix B, Figure B-23] showed evidence that disruption of the inboard leading edge, followed respectively by the forward torque box, front spar web and main torque box, occurred as a result of frontal impact by the base of a baggage container. Further outboard, a compact object appeared to have struck the underside of the leading edge and penetrated to the aft torque box. In both cases, the loss of the shear web of the front spar appeared to have permitted local bending failure of the remaining main torque box structure in a tip downwards sense, consistent with the normal load direction. For both events to have occurred it would be reasonable to assume that the outboard damage preceded that occurring inboard.

The right tailplane exhibited massive leading edge impact damage on the outboard portion which also appeared to have progressed to disruption of the aft torsion box. A fragment of right tailplane spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door and it is clear that this area of forward left fuselage had travelled over the top of the aircraft and contributed to the destruction of the outboard right tailplane.

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1.12.4 Examination of engines

All four engines had struck the ground in Lockerbie with considerable velocity and therefore sustained major damage, in particular to most of the fan blades. The No 3 engine had fallen 1,100 metres north of the other three engines, striking the ground on its rear face, penetrating a road surface and coming to rest without any further change of orientation i.e. with the front face remaining uppermost. The intake area contained a number of loose items originating from within the cabin or baggage hold. It was not possible initially to determine whether any of the general damage to any of the engine fans or the ingestion noted in No 3 engine intake occurred whilst the relevant engines were delivering power or at a later stage.

Numbers 1, 2 and 3 engines were taken to British Airways Engine Overhaul Limited for detailed examination under AAIB supervision in conjunction with a specialist from the Pratt and Whitney Engine Company. During this examination the following points were noted:

(i) No 2 engine (situated closest to the site of the explosion) had evidence of blade "shingling" in the area of the shrouds consistent with the results of major airflow disturbance whilst delivering power. (This effect is produced when random bending and torsional deflection occurs, permitting the mid-span shrouds to disengage and repeatedly strike the adjacent aerofoil surfaces of the blades). The interior of the air intake contained paint smears and other evidence suggesting the passage of items of debris. One such item of significance was a clear indentation produced by a length of cable of diameter and strand size similar to that typically attached to the closure curtains on the baggage containers.

(ii) No 3 engine, identified on site as containing ingested debris from within the aircraft, nonetheless had no evidence of the type of shingling seen on the blades of No 2 engine. Such evidence is usually unmistakable and its absence is a clear indication that No 3 engine did not suffer a major intake airflow disturbance whilst delivering significant power. The intake structure was found to have been crushed longitudinally by an impact on the front face although, as stated earlier, it had struck the ground on its rear face whilst falling vertically.

(iii) All 3 engines had evidence of blade tip rubs on the fan cases having a combination of circumference and depth greater than hitherto seen on any investigation witnessed on Boeing 747 aircraft by the Pratt and Whitney specialists. Subsequent examination of No 4 engine confirmed that it had a similar deep, large circumference tip rub. These tip-rubs on the four engines were centred at slightly different clock positions around their respective fan cases.

The Pratt and Whitney specialists supplied information which was used to interpret the evidence found on the blades and fan cases including details of engine dynamic behaviour necessary to produce the tip rub evidence. This indicated that the depth and circumference of tip rubs noted would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left.

Pratt and Whitney also advised that:

(i) Airflow disruption such as that presumed to have caused the shingling observed on No 2 engine fan blades was almost invariably the result of damage to the fan blade aerofoils, resulting from ingestion or blade failure.
(ii) Tip rubs of a depth and circumference noted on all four engines could be expected to reduce the fan rotational energy on each to a negligible value within approximately 5 seconds.
(iii) Airflow disruption sufficient to cause the extent of shingling noted on the fan blades of No 2 engine would also reduce the rotational fan energy to a negligible value within approximately 5 seconds.

1.13 Medical and pathological information

The results of the post mortem examination of the victims indicated that the majority had experienced severe multiple injuries at different stages, consistent with the in-flight disintegration of the aircraft and ground impact. There was no pathological indication of an in-flight fire and no evidence that any of the victims had been injured by shrapnel from the explosion. There was also no evidence which unequivocally indicated that passengers or cabin crew had been killed or injured by the effects of a blast. Although it is probable that those passengers seated in the immediate vicinity of the explosion would have suffered some injury as a result of blast, this would have been of a secondary or tertiary nature.

Of the casualties from the aircraft, the majority were found in areas which indicated that they had been thrown from the fuselage during the disintegration. Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section. The fragmented remains of 13 passengers who had been allocated seats around the eight missing persons were found in or near the crater formed by the wing. Whilst there is no unequivocal proof that the missing people suffered the same fate, it would seem from the pattern that the missing passengers remained attached to the wing structure until impact.

1.14 Fire

Of the several large pieces of aircraft wreckage which fell in the town of Lockerbie, one was seen to have the appearance of a ball of fire with a trail of flame. Its final path indicated that this was the No 3 engine, which embedded itself in a road in the north-east part of the town. A small post impact fire posed no hazard to adjacent property and was later extinguished with water from a hosereel. The three remaining engines landed in the Netherplace area of the town. One severed a water main and the other two, although initially on fire, were no risk to persons or property and the fires were soon extinguished.

A large, dark, delta shaped object was seen to fall at about the same time in the Sherwood area of the town. It was not on fire while in the air, however, a fireball several hundred feet across followed the impact. It was of relatively short duration and large amounts of debris were thrown into the air, the lighter particles being carried several miles downwind, while larger pieces of burning debris caused further fires, including a major one at the Townfoot Garage, up to 350 metres from the source. It was determined that the major part of both wings, which included the aircraft fuel tanks, had formed the crater. A gas main had also been ruptured during the impact.

At 19.04 hrs the Dumfries Fire Brigade Control received a call from a member of the public which indicated that there had been a "huge boiler explosion" at Westacres, Lockerbie, however, subsequent calls soon made it clear that it was an aircraft which had crashed. At 19.07 hrs the first appliances were mobile and at 1910 hrs one was in attendance in the Rosebank area. Multiple fires were identified and it soon became apparent that a major disaster had occurred in the town and the Fire Brigade Major Incident Plan was implemented. During the initial phase 15 pumping appliances from various brigades were deployed but this number was ultimately increased to 20.

At 22.09 hrs the Firemaster made an assessment of the situation. He reported that there was a series of fires over an area of the town centre extending 1† by € mile. The main concentration of the fire was in the southwest of the town around Sherwood Park and Sherwood Crescent. Appliances were in attendance at other fires in the town, particularly in Park Place and Rosebank Crescent. Water and electricity supplies were interrupted and water had to be brought into the town.

By 02.22 hrs on 22 December, all main seats of fire had been extinguished and the firemen were involved in turning over and damping down. At 04.42 hrs small fires were still occurring but had been confined to the Sherwood Crescent area.

1.15 Survival aspects

1.15.1 Survivability

The accident was not survivable.

1.15.2 Emergency services

A chronology of initial responses by the emergency services is listed below:-

Time	Event
19.03 hrs	Radio message from Police patrol in Lockerbie to Dumfries and Galloway Constabulary reporting an aircraft crash at Lockerbie.
19.04 hrs	Emergency call to Dumfries and Galloway Fire Brigade.
19.37 hrs	First ambulances leave for Dumfries and Galloway Royal Infirmary with injured town residents. (2- serious; 3- minor)
19.40 hrs	Sherwood Park and Sherwood Crescent residents evacuated to Lockerbie Town Hall.
20.25 hrs	Nose section of N739PA discovered at Tundergarth (approximately 4 km east of Lockerbie).

During the next few days a major emergency operation was mounted using the guidelines of the Dumfries and Galloway Regional Peacetime Emergency Plan. The Dumfries and Galloway Constabulary was reinforced by contingents from Strathclyde and Lothian & Borders Constabularies. Resources from HM Forces were made available and this support was subsequently authorised by the Ministry of Defence as Military Aid to the Civil Power. It included the provision of military personnel and a number of helicopters used mainly in the search for and recovery of aircraft wreckage. It was apparent at an early stage that there were no survivors from the aircraft and the search and recovery of bodies was mainly a Police task with military assistance.

Many other agencies were involved in the provision of welfare and support services for the residents of Lockerbie, relatives of the aircraft's occupants and personnel involved in the emergency operation.

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1.16 Tests and research

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity spherically propagating shock wave which will expand outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant because it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter, irrespective of charge size, thus providing a means of calculating the standoff distance of the explosive charge from the fuselage skin. Calculations suggest that a charge standoff distance of aproximately 25 inches would result in a shattered region approximately 18 to 20 inches in diameter, comparable to the size of the shattered region evident in the wreckage. This aspect is covered in greater detail in [Appendix G].

1.17 Additional information

1.17.1 Recorded radar information

Recorded radar information on the aircraft was available from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen from which it was clear that the flight had progressed in a normal manner until secondary surveillance radar (SSR) was lost.

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. The last secondary return from the aircraft was recorded at 19.02:46.9 hrs, identifying N739PA at Flight Level 310, and at the next radar return there is no SSR data, only 4 primary returns. It was concluded that the aircraft was, by this time, no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items had been ejected at high speed probably to both right and left of the aircraft.

Each rotation of the radar head thereafter showed the number of returns increasing, with those first identified across track having slowed down very quickly and followed a track along the prevailing wind line. The radar evidence then indicated that a further break-up of the aircraft had occurred and formed a parallel wreckage trail to the north of the first. From the absence of any returns travelling along track it was concluded that the main wreckage was travelling almost vertically downwards for much of the time.

A detailed analysis of the recorded radar information, together with the radar, ATC and seismic recordings is contained in Appendix C.

1.17.2 Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event measuring 1.6 on the Richter scale and, with appropriate corrections for the times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

An analysis of the seismic recording, together with the radar, ATC and radar information is contained in Appendix C.

1.17.3 Trajectory analysis

A detailed trajectory analysis was carried out by Cranfield Institute of Technology in an effort to provide a sequence for the aircraft disintegration. This analysis comprised several separate processes, including individual trajectory calculations for a limited number of key items of wreckage and mathematical modelling of trajectory paths adopted by a series of hypothetical items of wreckage encompassing the drag/weight spectrum of the actual wreckage.

The work carried out at Cranfield enabled the reasons for the two separate trails to be established. The narrow northern trail was shown to be created by debris released from the aircraft in a vertical dive between 19,000 and 9,000 feet overhead Lockerbie. The southern trail, longer and straight for most of its length, appeared to have been created by wreckage released during the initial disintegration at altitude whilst the aircraft was in level flight. Those items falling closest to Lockerbie would have been those with higher density which would travel a significant distance along track before losing all along-track velocity, whilst only drifting a small distance downwind, owing to the high speed of their descent. The most westerly items thus showed the greatest such effect. The southern trail therefore had curved boundaries at its western end with the curvature becoming progressively less to the east until the wreckage essentially fell in a straight band. Thus wreckage in the southern trail positioned well to the east could be assumed to have retained negligible velocity along aircraft track after separation and the along-track distribution could be used to establish an approximate sequence of initial disintegration.

The analysis calculated impact speeds of 120 kts for the nose section weighing approximately 17,500 lb and 260 kts for the engines and pylons which each weighed about 13,500 lb. Based on the best available data at the time, the analysis showed that the wing (approximately 100,000 lb of structure containing an estimated 200,000 lb of fuel) could have impacted at a speed, in theory, as high as 650 kts if it had 'flown' in a streamlined attitude such that the drag coefficient was minimal. However, because small variations of wing incidence (and various amounts of attached fuselage) could have resulted in significant increases in drag coefficient, the analysis also recognized that the final impact speed of the wing could have been lower.

1.17.4 Space debris re-entry

Four items of space debris were known to have re-entered the Earth's atmosphere on 21 December 1988. Three of these items were fragments of debris which would not have survived re-entry, although their burn up in the upper atmosphere might have been visible from the Earth's surface. The fourth item landed in the USSR at 09.50 hrs UTC.

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2 ANALYSIS

2.1 Introduction

The airport security and criminal aspects of the destruction of Boeing 747 registration N739PA near Lockerbie on 21 December 1988 are the subjects of a separate investigation and are not covered in this report. This analysis discusses the technical aspects of the disintegration of the aircraft and considers possible ways of mitigating the effects of an explosion in the future.

2.2 Explosive destruction of the aircraft

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage, including those exhibiting positive evidence of a detonating high performance plastic explosive. The scatter of these items about the datum line may have been due partly to velocities imparted by the force of the detonating explosive and partly by the difficulty experienced in pinpointing the location of the wreckage accurately in relatively featureless terrain and poor visibility. However, the random nature of the scatter created by these two effects would have tended to counteract one another, and a major error in any one of the eleven grid references would have had little overall effect on the whole line. There is, therefore, good reason to have confidence in the validity of the datum line.

The items used to define the datum line, included those exhibiting positive evidence of a detonating high performance plastic explosive, would have been the first pieces to have been released from the aircraft. The datum line was projected westwards until it intersected the known radar track of the aircraft in order to derive the position of the aircraft along track at which the explosive items were released and therefore the position at which the IED had detonated. This position was OS grid reference 146786 and is annotated Point C in Appendix B, Figure B-4. Point C was well within the circle of accuracy (±525 metres) of the position at which the loud noise was heard on the CVR (Point B). There can, therefore, be no doubt that the loud noise on the CVR was directly associated with the detonation of the IED and that this explosion initiated the disintegration process and directly caused the loss of the aircraft.

2.3 Flight recorders

2.3.1 Digital flight data recordings

A working group of the European Organisation for Civil Aviation Electronics

(EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to € second. These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the recording from the DFDR fitted to N739PA, which is detailed in Appendix C, showed that the recorded data simply stopped. Following careful examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19.02:50 hrs ±1 second. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or was old data from a previous recording.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when the aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

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2.3.2 Cockpit voice recorders

The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the CVR when it stopped at 19.02:50 hrs ±1 second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

2.3.3 Detection of explosive occurrences

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985, RARDE were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems. This recommendation was accepted.

Preliminary results from the trials indicate that, if a suitable sensor can be developed, its output will need to be recorded in real time and therefore it may require wiring to the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

2.4 IED position within the aircraft

From the detailed examination of the reconstructed luggage containers, discussed at paragraph 1.12.2.4 and in Appendix F, it was evident that the IED had been located within a metal container (serial number AVE 4041 PA), near its aft outboard quarter as shown in Appendix F, Figure F-13. It was also clear that the container was loaded in position 14L of the forward hold which placed the explosive charge approximately 25 inches inboard from the fuselage skin at frame 700. There was no evidence to indicate that there was more than one explosive charge.

2.5 Engine evidence

To produce the fan blade tip rub damage noted on all engines by means of airflow inclined to the axes of the nacelles would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left while all of the engines were attached to the wing.

The shingling damage noted on the fan blades of No 2 engine can only be attributed to airflow disturbance caused by ingestion related fan blade damage occurring when substantial power was being delivered. This is readily explained by the fact that No 2 engine intake is positioned some 27 feet aft and 30 feet outboard of the site of the explosion and that the interior of the intake exhibited a number of prominent paint smears and general foreign object damage. This damage included evidence of a strike by a cable similar to that forming part of the closure curtain of a typical baggage container. It is inconceivable that an independent blade failure could have occurred in the short time frame of this event. By similar reasoning, the absence of such shingling damage on blades of No 3 engine was a reliable indication that it suffered no ingestion until well into the accident sequence.

The combination of the position of the explosive device and the forward speed of the aircraft was such that significant sized debris resulting from the explosion would have been available to be ingested by No 2 engine within milliseconds of the explosion. In view of the fact that the tip rub damage observed on the fan case of No 2 engine is of similar magnitude to that observed on the other three engines it is reasonable to deduce that a manoeuvre of the aircraft occurred before most of the energy of the No 2 engine fan was lost due to the effect of ingestion (seen only in this engine). Since this shingling effect could only readily be produced as a by-product of ingestion whilst delivering considerable power, it is reasonable to assume that this was also occurring before loss of major fan energy due to tip rubbing took place. Hence both phenomena must have been occurring simultaneously, or nearly so, to produce the effects observed and must have occupied a time frame of substantially less than 5 seconds. The onset of this time period would have been the time at which debris from the explosion first inflicted damage to fan blades in No 3 engine and, since the fan is only approximately 40 feet from the location of the explosive device, this would have been an insignificant time interval after the explosion.

It was therefore concluded from this evidence that the wing with all of the engines attached had achieved a marked nose down and left roll attitude change well within 5 seconds of the explosion.

2.6 Detachment of forward fuselage

Examination of the three major structural elements either side of the region of station 800 on the right side of the fuselage makes it clear that to produce the curvature of the window belt and peeling of the riveted joint at the R2 door aperture requires the door pillar to be securely in position and able to react longitudinal and lateral loads. This in turn requires the large section of fuselage on the right side between stations 760 and 1000 (incorporating the right half of the floor) to be in position in order to locate the lower end of the door pillar. Thus both these sections must have been in position until the section from station 560 to 800 (right side) had completed its deflection to the right and peeled from the door pillar. Separation of the forward fuselage must thus have been complete by the time all three items mentioned above had fallen free.

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2.7 Speed of initial disintegration

The distribution of wreckage in the bands between the datum line and the 250, 300, 600 and 900 metre lines was examined in detail. The positions of these items of structure on the aircraft are shown in Appendix B, Figures B-10 to B-13. It should be noted that the position on the ground of these items, although separated by small distances when measured in a direction along aircraft track, were distributed over large distances when measured along the wreckage trail. All were recovered from positions far enough to the east to be in that part of the southern trail which was sufficiently close, theoretically, to a straight line for any curvature effect to be neglected.

The wreckage found in each of the bands enabled an approximate sequence of break-up to be established. It was clear that as the distance travelled from the datum line increased, items of wreckage further from the station of the IED were encountered. The items shown on the diagram as falling on the 250 metre band also include those fragments of lower forward fuselage skin having evidence of explosive damage and presumed to have separated as a direct result of the blast. However, a few portions of the upper forward fuselage were also found within the 250 metre band, suggesting that these items had also separated as a result of the blast.

By the time the 300 metre line was reached much of the structure from the right side in the region of the explosive device had been shed. This included the area of window belt, referred to in paragraph 2.6 above, which gave clear indications that the forward structure had detached to the right and finally peeled away at station 800. It also included the areas of adjacent structure immediately to the rear of station 800 about which the forward structure would have had to pivot. By the time the 600 metre line was reached, there was clearly insufficient structure left to connect the forward fuselage with the remainder of the aircraft. Wreckage between the 600 and 900 metre lines consisted of structure still further from the site of the IED.

There is evidence that a manoeuvre occurred at the time of the explosion which would have produced a significant change of the aircraft's flight path, however, it is considered that the change in the horizontal velocity component in the first few seconds would not have been great. The original groundspeed of the aircraft was therefore used in conjunction with the distribution of wreckage in the successive bands to establish an approximate time sequence of break-up of the forward fuselage. Assuming the original ground speed of 434 Kts, the elapsed flight times from the datum to each of the parellel lines were calculated to be:

Distance (metres)	250	300	600	900
Time (seconds)	1.1	1.3	2.7	4.0

Thus, there is little doubt that separation of the forward fuselage was complete within 2 to 3 seconds of the explosion.

The separate assessment of the known grid references of tailplane and elevator wreckage in the southern trail revealed that those items were evenly distributed about the 600 metre line and therefore that most of the tailplane damage occurred after separation of the forward fuselage was complete.

2.8 The manoeuvre following the explosion

The engine evidence, timing and mode of disintegration of the fuselage and tailplane suggests that the latter did not sustain significant damage until the forward fuselage disintegration was well advanced and the pitch/roll manoeuvre was also well under way.

Examination of the three dimensional reconstruction makes it clear that both main and upper deck floors were disrupted by the explosion. Since pitch control cables are routed through the upper deck floor beams and the roll control cables through the main deck beams, there is a strong possibility that movement of the beams under explosive forces would have applied inputs to the control cables, thus operating control surfaces in both axes.

2.9 Secondary disintegration

The distribution of fin debris between the trails suggests that disintegration of the fin began shortly before the vertical descent was established. No single mode of failure was identified and the debris which had struck the leading edge had not caused major disruption. The considerable fragmentation of the thick panels of the aft torque box was also very different from that noted on the corresponding structure of the tailplanes. It was therefore concluded that the mode of failure was probably flutter.

The finding, in the northern trail, of a slide raft wrapped around a flap track fairing suggests that at a later stage of the disintegration the rear of the aircraft must have experienced a large angle of sideslip. The loss of the fin would have made this possible and also subjected the structure to large side loads. It is possible that such side loading would have assisted the disintegration of the rear fuselage and also have caused bending failure of the pylon attachments of the remaining three engines.

2.10 Impact speed of components

The trajectory analysis carried out by Cranfield Institute of Technology calculated impact speeds of 120 kts for the nose section, and 260 kts for the engines and pylons. These values were considered to be reliable because the drag coefficients could be estimated with a reasonable degree of confidence. Based on the best available data at the time, the analysis also showed that the wing could have impacted at a speed, in theory, as high as 650 kts if it had flown in a streamlined attitude such that the drag coefficient was minimal. However, it was also recognized that relatively small changes in the angle of incidence of the wing would have produced a significant increase in drag with a consequent reduction in impact speed. Refinement of timing information and radar data subsequent to the Cranfield analysis has enabled a revised estimate to be made of the mean speed of the wing during the descent.

The engine evidence indicated that there had been a large nose down attitude change of the aircraft early in the event. The Cranfield analysis also showed that the rear fuselage had disintegrated while essentially in a vertical descent between 19,000 and 9,000 feet over Lockerbie. Assuming that, following the explosion, the wing followed a straight line descending flight profile from 31,000 feet to 19,000 feet directly overhead Lockerbie and then descended vertically until impact, the wing would have travelled the minimum distance practicable. The ground distance between the geographical position at which the disintegration started (Figure B-4, Point B) and the crater made by the wing impact was 2997 ±525 metres (9833 ±1722 feet). The time interval between the explosion and the wing impact was established in Appendix C as 46.5 ±2 seconds. Based on the above times and distances the mean linear speed achieved by the wing would have been about 440 kts.

The impact location of Nos 1, 2, and 4 engines closely grouped in Lockerbie was consistent with their nearly vertical fall from a point above the town. If they had separated at about 19,000 feet and the wing had then flown as much as one mile away from the overhead position before tracking back to impact, the total flight path length of the wing would not have required it to have achieved a mean linear speed in excess of 500 kts.

Any speculation that the flight path of the wing could have been longer would have required it to have undergone manoeuvres at high speed in order to arrive at the 19,000 feet point. The manoeuvres involved would almost certainly have resulted in failure of the primary wing structure which, from distribution of wing debris, clearly did not occur. Alternatively the wing could have travelled more than one mile from Lockerbie after reaching the 19,000 feet point, but this was considered unlikely. It is therefore concluded that the mean speed of the wing during the descent was in the region of 440 to 500 kts.

2.11 Sequence of disintegration

Analysis of wreckage in each of the bands, taken in conjunction with the engine evidence and the three-dimensional reconstruction, suggests the following sequence of disintegration:

(i) The initial explosion triggered a sequence of events which effectively destroyed the structural integrity of the forward fuselage. Little more then remained between stations 560 and 760 (approximately) than the window belts and the cabin sidewall structure immediately above and below the windows, although much of the cargo-hold floor structure appears to have remained briefly attached to the aircraft. [Appendix B, Figure B-24]

(ii) The main portion of the aircraft simultaneously entered a manoeuvre

involving a marked nose down and left roll attitude change, probably as a result of inputs applied to the flying control cables by movement of structure.
(iii) Failure of the left window belt then occurred, probably in the region of station 710, as a result of torsional and bending loads on the fuselage imparted by the manoeuvre (i.e. the movement of the forward fuselage relative to the remainder of the aircraft was an initial twisting motion to the right, accompanied by a nose up pitching deflection).
(iv) The forward fuselage deflected to the right, pivoting about the starboard window belt, and then peeled away from the structure at station 800. During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation was apparently complete within 3 seconds of the explosion.
(v) Structure and contents of the forward fuselage struck the tail surfaces contributing to the destruction of the outboard starboard tailplane and causing substantial damage to the port unit. This damage occurred approximately 600 metres track distance after the explosion and therefore appears to have happened after the fuselage separation was complete.
(vi) Fuselage structure continued to break away from the aircraft and the separated forward fuselage section as they descended.
(vii) The aircraft maintained a steepening descent path until it reached the vertical in the region of 19,000 feet approximately over the final impact point. Shortly before it did so the tail fin began to disintegrate.
(viii) The mode of failure of the fin is not clear, however, flutter of its structure is suspected.
(ix) Once established in the vertical dive, the fin torque box continued to disintegrate, possibly permitting the remainder of the aircraft to yaw sufficiently to cause side load separation of Nos 1, 2 and 4 engines, complete with their pylons.
(x) Break-up of the rear fuselage occurred during the vertical descent, possibly as a result of loads induced by the yaw, leaving a section of cabin floor and baggage hold from approximately stations 1241 to 1920, together with 3 landing gear units, to fall into housing at Rosebank Terrace.
(xi) The main wing structure struck the ground with a high yaw angle at Sherwood Crescent.
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2.12 Explosive mechanisms and the structural disintegration

The fracture and damage pattern analysis was mainly of an interpretive nature involving interlocking pieces of subtle evidence such as paint smears, fracture and rivet failure characteristics, and other complex features. In the interests of brevity, this analysis will not discuss the detailed interpretation of individual fractures or damage features. Instead, the broader 'damage picture' which emerged from the detailed work will be discussed in the context of the explosive mechanisms which might have produced the damage, with a view to identifying those features of greatest significance.

It is important to keep in mind that whilst the processes involved are considered and discussed separately, the timescales associated with shock wave propagation and the high velocity gas flows are very short compared with the structural response timescales. Consequently, material which was shattered or broken by the explosive forces would have remained in place for a sufficiently long time that the structure can be considered to have been intact throughout much of the period that these explosive propagation phenomena were taking place.

2.12.1 Direct blast effect

2.12.1.1 Shock wave propagation

The direct effect of the explosive detonation within the container was to produce a high intensity spherically propagating shock wave which expanded from the centre of detonation close to the side of the container, shattering part of the side and base of the container as it passed through into the gap between the container and the fuselage skin. In breaking out of the container, some internal reflection and Mach stem interaction would have occurred, but this would have been limited by the absorptive effect of the baggage inboard, above, and forward of the charge. The force of the explosion breaking out of the container would therefore have been directed downwards and rearwards.

The heavy container base was distorted and torn downwards, causing buckling of the adjoining section of frame 700, and the container sides were blasted through and torn, particularly in the aft lower corner. Some of the material in the direct path of the explosive pressure front was reduced to shrapnel sized pieces which were rapidly accelerated outwards behind the primary shock front. Because of the overhang of the container's sloping side, fragments from both the device itself and the container wall impacted the projecting external flange of the container base edge member, producing micro cratering and sooting. Metallurgical examination of the internal surfaces of these craters identified areas of melting and other features which were consistent only with the impact of very high energy particles produced by an explosion at close quarters. Analysis of material on the crater surfaces confirmed the presence of several elements and compounds foreign to the composition of the edge member, including material consistent with the composition of the sheet aluminium forming the sloping face of the container.

On reaching the inner surface of the fuselage skin, the incident shock wave energy would partially have been absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of its energy would have been transmitted, as a shock wave, through the skin and into the atmosphere [Appendix B, Figure B-25], but a significant amount of energy would have been returned as a reflected shock wave, back into the cavity between the container and the fuselage skin where Mach stem shock waves would have been formed. Evidence of rapid shattering was found in a region approximately bounded by frames 700 & 720 and stringers 38L & 40L, together with the lap joint at 39L.

The shattered fuselage skin would have taken a significant time to move, relative to the timescales associated with the primary shock wave propagation. Clear evidence of soot and small impact craters were apparent on the internal surfaces of all fragments of container and structure from the shatter zone, confirming that the this material had not had time to move before it was hit by the cloud of shrapnel, unburnt explosive residues and sooty combustion products generated at the seat of the explosion.

Following immediately behind the primary shock wave, a secondary high pressure wave - partly caused by reflections off the baggage behind the explosive material but mainly by the general pressure rise caused by the chemical conversion of solid explosive material to high temperature gas - emerged from the container. The effect of this second pressure front, which would have been more sustained and spread over a much larger area, was to cause the fuselage skin to stretch and blister outwards before bursting and petalling back in a star-burst pattern, with rapidly running tear fractures propagating away from a focus at the shatter zone. The release of stored energy as the skin ruptured, combined with the outflow of high pressure gas through the aperture, produced a characteristic curling of the skin 'petals' - even against the slipstream. For the most part, the skins which petalled back in this manner were torn from the frames and stringers, but the frames and stringers themselves were also fractured and became separated from the rest of the structure, producing a very large jagged hole some 5 feet longitudinally by 17 feet circumferentially (upwards to a region just below the window belt and downwards virtually to the centre line).

From this large jagged hole, three of the fractures continued to propagate away from the hole instead of terminating at the boundary. One fracture propagated longitudinally rearwards as far as the wing cut-out and another forwards to station 480, creating a continuous longitudinal fracture some 43 feet in length. A third fracture propagated circumferentially downwards along frame 740, under the belly, and up the right side of the fuselage almost as far as the window belt - a distance of approximately 23 feet.

These extended fractures all involved tearing or related failure modes, sometimes exploiting rivet lines and tearing from rivet hole to rivet hole, in other areas tearing along the full skin section adjacent to rivet lines, but separate from them. Although the fractures had, in part, followed lap joints, the actual failure modes indicated that the joints themselves were not inherently weak, either as design features or in respect of corrosion or the conditions of the joints on this particular aircraft.

Note: The cold bond process carried out at manufacture on the lap joints had areas of disbonding prior to the accident. This disbonding is a known feature of early Boeing 747 aircraft which, by itself, does not detract from the structural integrity of the hull. The cold bond adhesive was used to improve the distribution of shear load across the joint, thus reducing shear transfer via the fasteners and improving the resistance of the joint to fatigue damage; the fasteners were designed to carry the full static loading requirements of the joint without any contribution from the adhesive. Thus, the loss of the cold bond integrity would only have been significant if it had resulted in the growth of fatigue cracks, or corrosion induced weaknesses, which had then been exploited by the explosive forces. No evidence of fatigue cracking was found in the bonded joints. Inter-surface corrosion was present on most lap joints but only one very small region of corrosion had resulted in significant material thinning; this was remote from the critical region and had not played any part in the break-up.

The cracks propagating upwards as part of the petalling process did not extend beyond the window line. The wreckage evidence suggests that the vertical fractures merged, effectively closing off the fracture path to produce a relatively clean bounding edge to the upper section of the otherwise jagged hole produced by the petalling process. There are at least two probable reasons for this. Firstly the petalling fractures above the shattered zone did not diverge, as they had tended to do elsewhere. Instead, it appears that a large skin panel separated and peeled upwards very rapidly producing tears at each side which ran upwards following almost parallel paths. However, there are indications that by the time the fractures had run several feet, the velocity of fracture had slowed sufficiently to allow the free (forward) edge of the skin panel to overtake the fracture fronts, as it flexed upwards, and forcibly strike the fuselage skin above, producing clear witness marks on both items. Such a tearing process, in which an approximately rectangular flap of skin is pulled upwards away from the main skin panel, is likely to result in the fractures merging. Secondly, this merging tendency would have been reinforced in this particular instance by the stiff window belt ahead of the fractures, which would have tended to turn the fractures towards the horizontal.

It appears that the presence of this initial ('clean') hole, together with the stiff window belt above, encouraged other more slowly running tears to break into it, rather than propagating outwards away from the main hole.

2.12.1.2 Critical crack considerations

The three very large tears extending beyond the boundary of the petalled region resulted in a critical reduction of fuselage structural integrity.

Calculations were carried out at the Royal Aerospace Establishment to determine whether these fractures, growing outwards from the boundary of the petalled hole, could have occurred purely as a result of normal differential pressure loading of the fuselage, or whether explosive forces were required in addition to the pressurisation loads.

Preliminary calculations of critical crack dimensions for a fuselage skin punctured by a 20 by 20 inches jagged hole indicated that unstable crack growth would not have occurred unless the skin stress had been substantially greater than the stress level due to normal pressurisation loads alone. It was therefore clear that explosive overpressure must have produced the gross enlargement of the initially small shattered hole in the hull. Furthermore, it was apparent from the degree of curling and petalling of the skin panels within the star-burst region that this overpressure had been relatively long term, compared with the shock wave overpressure which had produced the shatter zone. A more refined analysis of critical crack growth parameters was therefore carried out in which it was assumed that the long term explosive overpressure was produced by the chemical conversion of solid explosive material into high temperature gas.

An outline of the fracture propagation analysis is given at Appendix D. This analysis, using theoretical fracture mechanics, showed that, after the incident shock wave had produced the shatter zone, significant explosive overpressure loads were needed to drive the star-burst fractures out to the boundary of the petalled skin zone. Thereafter, residual gas overpressure combined with fuselage pressurisation loads were sufficient to produce the two major longitudinal cracks and a single major circumferential crack, extending from the window belt down to beyond the keel centreline.

2.12.1.3 Damage to the cabin floor structure

The floor beams in the region immediately above the baggage container in which the explosive had detonated were extensively broken, displaying clear indications of overload failure due to buckling caused by localised upward loading of the floor structure.

No direct evidence of bruising was found on the top panel of the container. It therefore appears that the container did not itself impact the floor beams, but instead the floor immediately above the container was broken through as a result of explosive overpressure as gases emerged from the ruptured container and loaded the floor panels. Data on floor strengths, provided by Boeing, indicated that the cabin floor (with the CRAF modification) would fail at a uniform static differential pressure of between 3.5 and 3.9 psi (high pressure below the cabin floor), and that the floor panel to floor beam attachments would not fail before the floor beams. Whilst there is no direct evidence of the pressure loading on the floor structure immediately following detonation, there can be no doubt that in the region of station 700 it would have exceeded the ultimate failure load by a large margin.

2.12.2 Indirect explosive damage (damage at remote sites)

All of the damage considered in the foregoing analysis, and the mechanisms giving rise to that damage, resulted from the direct impact of explosive shock waves and/or the short-term explosive overpressure on structure close to the source of the explosion. However, there were several regions of skin separation at sites remote from the explosion (see para 1.12.3.2) which were much more difficult to understand. These remote sites formed islands of indirect explosive damage separated from the direct damage by a sea of more generalised structural failure characterised by the progressive aerodynamic break-up of the weakened forward fuselage. All of these remote damage sites were consistent with the impact of very localised pressure impulses on the internal surfaces of the hull -effectively high energy 'pressure blows' against the inner surfaces produced by explosive shock waves and/or high pressure gas flows travelling through the interior spaces of the hull.

The propagation of explosive shock waves and supersonic gas flows within multiple, interlinking, cavities having indeterminate energy absorption and reflection properties, and ill-defined structural response, is extremely complex. Work has been initiated in an attempt to produce a three-dimensional computer analysis of the shock wave and supersonic flow propagation inside the fuselage, but full theoretical analysis is beyond present resources.

Because of the complexity of the problem, the following analysis will be restricted to a qualitative consideration of the processes which were likely to have taken place. Whilst such an approach is necessarily limited, it has identified a number of propagation mechanisms which appear to have been of fundamental importance to the break-up of Flight PA103, and which are likely to be critical in any future incident involving the detonation of high explosive inside an aircraft hull.

2.12.2.1 Shock wave propagation through internal cavities

When Mach stem shocks are produced not only are the shock pressures very high but they propagate at very high velocity parallel to the reflecting surface. In the context of the lower fuselage structure in the region of Mach stem formation, it can readily be seen that the Mach stem will be perfectly orientated to enter the narrow cavity formed between the outer skin and the cargo liner/containers, bounded by the fuselage frames [Appendix B, Figure B-25]. This cavity enables the Mach stem shock wave to propagate, without causing damage to the walls (due to the relatively low pressure where the Mach stem sweeps their surface), and reach regions of the fuselage remote from the source of the explosion. Furthermore, energy losses in the cavity are likely to be less than would occur in the 'free' propagation case, resulting in the efficient transmission of explosive energy. The cavity would tend to act like a 'shock tube', used for high speed aerodynamic research, confining the shock wave and keeping it running along the cavity axis, with losses being limited to kinetic heating due to friction at the walls.

Paragraph 1.6.3 contains a general description of the structural arrangements in the area of the cargo hold. Before proceeding further and considering how the shock waves might have propagated through this network of cavities, it should be pointed out that the timescale associated with the propagation of the shock waves is very short compared with the timescale associated with physical movement and separation of skin and structure fractured or damaged by the shock. Therefore, for the purpose of assessing the shock propagation through the cavities, the explosive damage to the hull can be ignored and the structure regarded as being intact. A further simplification can usefully be made by considering the structure to be rigid. This assumption would, if the analysis were quantitative, result in over-estimations of the shock strengths. However, for the purposes of a purely qualitative assessment, the assumption should be valid, in that the general trends of behaviour should not be materially altered.

It has already been argued that the shock wave emerging from the container was, in part, reflected back off the inner surface of the fuselage skin, forming a Mach stem shock wave which would then have tended to travel into the semi-circular lower lobe cavity. The Mach stem waves would have propagated away through this cavity in two directions:

(i) under the belly, between the frames [Appendix B, Figure B-3, detail A], and
(ii) up the left side, expanding into the cavity formed by the longitudinal manifold chamber where it joins the lower lobe cavity.
As the shock waves travelled along the cavity, little attenuation or other change of characteristic was likely to have occurred until the shocks passed the entrances to other cavities, or impinged upon projections and other local changes in the cavity. A review of the literature dealing with propagation of blast waves within such cavities provides useful insights into some of the physical mechanisms involved.

As part of a research program carried out into the design of ventilation systems for blast hardened installations intended to survive the long duration blast waves following the detonation of nuclear weapons, the propagation of blast waves along the primary passages and into the side branches of ventilation ducts was studied. The research showed that 90¡ bends in the ducts produced very little attenuation of shock wave pressure; a series of six right angle bends produced only a 30% pressure attenuation, together with an extension of the shock duration. It is therefore evident that the attenuation of shock waves propagating through the fuselage cavities, all of which were short with hardly any right angle turns, would have been minimal.

It was also demonstrated that secondary shock waves develop within the entrance to any side branch from the main duct, produced by the interaction of the primary shock wave with the geometric changes in the duct walls at the side-branch location. These secondary shock waves interact as they propagate into the side branch, combining together within a relatively short distance (typically 7 diameters) to produce a single, plane shock wave travelling along the duct axis. In a rigid, smooth walled structure, this mechanism produces secondary shock overpressures in the side branch of between 30% and 50% of the value of the primary shock, together with a corresponding attenuation of the primary shock wave pressure by approximately 20% to 25%.

This potential for the splitting up and re-transmission of shock wave energy within the lower hull cavities is of extreme importance in the context of this accident. Though the precise form of the interactions is too complex to predict quantitatively, it is evident that the lower hull cavities will serve to convey the overpressure efficiently to other parts of the aircraft. Furthermore, the cavities are not of serial form, i.e. they do not simply branch (and branch again) in a divergent manner, but instead form a parallel network of short cavities which reconnect with each other at many different points, principally along the crease beams. Thus, considerable scope exists for: the additive recombination of blast waves at cavity junctions; for the sustaining of the shock overpressure over a greater time period; and, for the generation of multiple shocks produced by the delay in shock propagation inherent in the different shock path (i.e. cavity) lengths.

Whilst it has not been possible to find a specific mechanism to explain the regions of localised skin separation and peel-back (i.e. the 'pressure blow' regions referred to in para 2.12.2), they were almost certainly the result of high intensity shock overpressures produced locally in those regions as a result of the additive recombination of shock waves transmitted through the lower hull cavities. It is considered that the relatively close proximity of the left side region of damage just below floor level at station 500, [Appendix B, Figure B-19, region D] to the forward end of the cargo hold may be significant insofar as the reflections back from the forward end of the hold would have produced a local enhancement of the shock overpressure. Similarly, 'end blockage effects' produced by the cargo door frame might have been responsible for local enhancements in the area of the belly skin separation and curl-back at station 560 [Appendix B, Figure B-19 and B-20, region E].

The separation of the large section of upper fuselage skin [Appendix B, Figure B-19 and B-20, detail B] was almost certainly associated with a local overpressure in the side cavities between the main deck window line and the upper deck floor, where the cavity is effectively closed off. It is considered that the most probable mechanism producing this region of impulse overpressure was a reflection from the closed end of the cavity, possibly combined with further secondary reflections from the window assembly, the whole being driven by reflective overpressures at the forward end of the longitudinal manifold cavity caused by the forward end of the cargo hold. The local overpressure inside the sidewall cavity would have been backed up by a general cabin overpressure resulting from the floor breakthrough, giving rise to an increased pressure acting on the inner face of the cabin side liner panels. This would have provided pseudo mass to the panels, effectively preventing them from moving inwards and allowing them to react the impulse pressure within the cavity, producing the region of local high pressure evidenced by the region of quilting on the skin panels [Appendix B, Figure B-19, region C].

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2.12.2.2 Propagation of shock waves into the cabin

The design of the air-conditioning/depressurisation-venting systems on the Boeing 747 (and on most other commercial aircraft) is seen as a significant factor in the transmission of explosive energy, as it provides a direct connection between the main passenger cabin and the lower hull at the confluence of the lower hull cavities below the crease beam. The floor level air conditioning vents along the length of the cabin provided a series of apertures through which explosive shock waves, propagating through the sub floor cavities, would have radiated into the main cabin.

Once the shock waves entered the cabin space, the form of propagation would have been significantly different from that which occurred in the cavities in the lower hull. Again, the precise form of such radiation cannot be predicted, but it is clear that the energy would potentially have been high and there would also (potentially) have been a large number of shock waves radiating into the cabin, both from individual vents and in total, with further potential to recombine additively or to 'follow one another up' producing, in effect, sustained shock overpressures.

Within the cabin, the presence of hard, reflective, surfaces are likely to have been significant. Again, the precise way in which the shock waves interacted is vastly beyond the scope of current analytical methods and computing power, but there clearly was considerable potential for additive recombination of the many different shock waves entering at different points along the cabin and the reflected shock waves off hard surfaces in the cabin space, such as the toilet and galley compartments and overhead lockers. These recombination effects, though not understood, are known phenomena. Appendix B, Figure B-26 shows how shock waves radiating from floor level might have been reflected in such a way as produce shock loading on a localised area of the pressure hull.

2.12.2.3 Supersonic gas flows

The gas produced by the explosive would have resulted in a supersonic flow of very high pressure gas through the structural cavities, which would have followed up closely behind the shock waves. Whilst the physical mechanisms of propagation would have been different from those of the shock wave, the end result would have been similar, i.e. there would have been propagation via multiple, linked paths, with potential for additive recombination and successive pressure pulses resulting from differing path lengths. Essentially, the shock waves are likely to have delivered initial 'pressure blows' which would then have been followed up immediately by more sustained pressures resulting from the high pressure supersonic gas flows.

2.13 Potential limitation of explosive damage

Quite clearly the detonation of high explosive material anywhere on board an aircraft is potentially catastrophic and the most effective means of protecting lives is to stop such material entering the aircraft in the first place. However, it is recognised that such risks cannot be eliminated entirely and it is therefore essential that means are sought to reduce the vulnerability of commercial aircraft structures to explosive damage.

The processes which take place when an explosive detonates inside an aircraft fuselage are complex and, to a large extent, fickle in terms of the precise manner in which the processes occur. Furthermore, the potential variation in charge size, position within the hull, and the nature of the materials in the immediate vicinity of the charge (baggage etc) are such that it would be unrealistic to expect to neutralise successfully the effect of every potential explosive device likely to be placed on board an aircraft. However, whilst the problem is intractable so far as a total solution is concerned, it should be possible to limit the damage caused by an explosive device inside a baggage container on a Boeing 747 or similar aircraft to a degree which would allow the aircraft to land successfully, albeit with severe local damage and perhaps resulting in some loss of life or injuries.

In Appendix E the problem of reducing the vulnerability of commercial aircraft to explosive damage is discussed, both in general terms and in the context of aircraft of similar size and form to the Boeing 747. In that discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution.

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2.14 Summary

It was established that the detonation of an IED, loaded in a luggage container positioned on the left side of the forward cargo hold, directly caused the loss of the aircraft. The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential. The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion. The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage, allow the nose and flight deck area to detach within a period of 2 to 3 seconds, and subsequently allow most of the remaining aircraft to disintegrate while it was descending nearly vertically from 19,000 to 9,000 feet.

The investigation has enabled a better understanding to be gained of the explosive processes involved in such an event and to suggest ways in which the effects of such an explosion might be mitigated, both by changes to future design and also by retrospective modification of aircraft. It is therefore recommended that Regulatory Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft structure and systems to explosive damage.

3. CONCLUSIONS

(a) Findings

(i) The crew were properly licenced and medically fit to conduct the flight.

(ii) The aircraft had a valid Certificate of Airworthiness and had been maintained in compliance with the regulations.

(iii) There was no evidence of any defect or malfunction in the aircraft that could have caused or contributed to the accident.

(iv) The structure was in good condition and the minimal areas of corrosion did not contribute to the in-flight disintegration.

(v) One minor fatigue crack approximately 3 inches long was found in the fuselage skin but this had not been exploited during the disintegration.

(vi) An improvised explosive device detonated in luggage container serial number AVE 4041 PA which had been loaded at position 14L in the forward hold. This placed the device approximately 25 inches inboard from the skin on

the lower left side of the fuselage at station 700.
(vii) The analysis of the flight recorders, using currently accepted techniques, did not reveal positive evidence of an explosive event.
(viii) The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential.
(ix) The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion.
(x) The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage.
(xi) Containers and items of cargo ejected from the fuselage aperture in the forward hold, together with pieces of detached structure, collided with the empennage severing most of the left tailplane, disrupting the outer half of the right tailplane, and damaging the fin leading edge structure.
(xii) The forward fuselage and flight deck area separated from the remaining structure within a period of 2 to 3 seconds.
(xiii) The No 3 engine detached when it was hit by the separating forward fuselage.
(xiv) Most of the remaining aircraft disintegrated while it was descending nearly vertically from 19,000 to 9,000 feet.
(xv) The wing impacted in the town of Lockerbie producing a large crater and creating a fireball.

(b) Cause

The in-flight disintegration of the aircraft was caused by the detonation of an improvised explosive device located in a baggage container positioned on the left side of the forward cargo hold at aircraft station 700.

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4. SAFETY RECOMMENDATIONS

The following Safety Recommendations were made during the course of the investigation :

4.1 That manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and the data recoverable after power loss.
4.2 That Airworthiness Authorities re-consider the concept of allowing

buffered data to be stored in a volatile memory.
4.3 That Airworthiness Authorities consider requiring the CVR system to contain a short duration, i.e. no greater than 1 minute, back-up power supply to enable the CVR to respond to events that result in the almost immediate loss of the aircraft's electrical power supply.
4.4 That the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.
4.5 That Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of aircraft structure and systems to explosive damage.

M M Charles
Inspector of Accidents
Department of Transport

July 1990
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APPENDIX A

PERSONNEL CONDUCTING THE INVESTIGATION

The following Inspectors of the Air Accidents Investigation Branch conducted the investigation:

Mr M M Charles	Investigator-in-Charge
Mr D F King	Principal Inspector (Engineering)
Mr P F Sheppard	Assistant Principal Inspector (Engineering)
Mr A N Cable	Senior Inspector (Engineering)
Mr R G Carter	Senior Inspector (Engineering)
Mr P T Claiden	Senior Inspector (Engineering)
Mr P R Coombs	Senior Inspector (Engineering)
Mr S R Culling	

Senior Inspector (Engineering)

Miss A Evans

Senior Inspector (Engineering)

Mr B M E Forward

Senior Inspector (Operations)

Mr P N Giles

Senior Inspector (Operations)

Mr S W Moss

Senior Inspector (Engineering)

Mr R Parkinson

Senior Inspector (Engineering)

Mr J D Payling

Senior Inspector (Operations)

Mr C G Pollard

Senior Inspector (Engineering)

Mr C A Protheroe

Senior Inspector (Engineering)

Mr A H Robinson

Senior Inspector (Engineering)

Mr A P Simmons

Senior Inspector (Engineering)

Mr R G Vance

Senior Inspector (Engineering)

Mr R StJ Whidborne

Senior Inspector (Operations)

The Air Accidents Investigation Branch would like to thank the following organisations from the United Kingdom, United States of America, France, and Canada who participated in the investigation:

Air Line Pilot's Association International

Boeing Commercial Airplane Company

British Airways

British Army

British Geological Survey

Bureau Enquete Accidents

Canadian Aviation Safety Bureau

Civil Aviation Authority

Cranfield Institute of Technology

Federal Aviation Administration

Federal Bureau of Investigation

Independent Union of Flight Attendants

National Transportation Safety Board

Pan American World Airways

Police Service

Royal Aerospace Establishment

Royal Air Force

Royal Armaments Research and Development Establishment

Royal Navy

Royal Ordnance

Royal Signals and Radar Establishment

United Technologies International Operations (Pratt and Whitney)

The Air Accidents Investigation Branch would also like to acknowledge the excellent work of the Dumfries & Galloway Regional Council and to thank all the many voluntary organisations who gave such unstinting support to the investigation.

APPENDIX C

ANALYSIS OF RECORDED DATA

1. Introduction

This appendix describes and analyses the different types of recorded data which were examined during the investigation of the accident to Boeing 747 registration N739PA at Lockerbie on 21 December 1988.
The recorded data consists of that from the Cockpit Voice Recorder (CVR), the Digital Flight Data Recorder (DFDR), Air Traffic Control (ATC) radio telephony (RTF), ATC radar, and British Geological Survey seismic records. The time correlation of the records is also discussed.

2. Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 analogue parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

2.1 DFDR strip and examination

Internal inspection of the DFDR showed that there was considerable disruption to the control electronics circuits. The crash protection was removed and the plastic recording tape was found detached from its various guide rollers and tangled in the tape spools. There was no tension in the negator springs. This indicated that the tape had probably moved since electrical power was removed from the recorder. The position of the tape in relation to the record/replay heads was marked with a piece of splicing tape in order to quantify the movement. To ensure that no additional damage was caused to the tape it was necessary to cut the negator springs to separate the upper and lower tape reels.

The crinkling and stretching of the tape and the damage to the control electronics meant that the tape had to be replayed outside the recorder. AAIB experience has shown that the most efficient method of replaying stretched Lockheed recorder tapes is to re-spool the tape into a known serviceable recorder, in this case a Plessey 1584G.

2.2 DFDR replay

The 25 hour duration of the DFDR was satisfactorily replayed. Data relating to the accident flight was recorded on track 2. The only significant defect in the recording system was that normal acceleration was inoperative. There was one area on the tape, 2 minutes from the end, where data synchronisation was lost for 1 second.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded. The recorded data simply stopped. Figure C-1 is a graphical representation of the main flight parameters.

2.3 DFDR analysis

In order to ensure that all recorded data from the accident flight had been decoded and to examine the quality of the data at the end of the recording, a section of tape, including both the most recently recorded data and the oldest data (data from 25 hours past), was replayed through an ultra-violet (UV) strip recorder. The data was also digitised and the resulting samples used to reconstruct the tape signal on a VDU.

Both methods of signal representation were used to determine the manner by which the recorder stopped. There was no gap between the most recently recorded data and the 25 hour old data. This showed that the recorder stopped while there was an incoming data stream from the FDAU. The recorder, therefore, stopped because its electrical supply was disconnected. The tape signal was examined for any transients or noise signals that would have indicated the presence of electrical disturbances prior to the recorder stopping. None was found and this indicated that there had been a quick clean break of the electrical supply.

The last seconds of data were decoded independently using both the UV record and the digitised signal. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or if it was old data from a previous recording.

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance

Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to ? second.
These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory
device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained
within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when tha
aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been
recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data
contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some
of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although
the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept
of allowing buffered data to be stored in a volatile memory.

3. Cockpit voice recorder (CVR)

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was
located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1
Flight Engineer's RTF.

Channel 2
Co-Pilot's RTF.

Channel 3
Pilot's RTF.

Channel 4
Cockpit Area Microphone.

3.1 CVR strip and examination

To gain access to the recording tape it was necessary to cut away the the outer case and saw through part of the crash protected enclosure. No damage to the tape transport or the recording tape was found. The endless loop of tape was cut and the tape transferred to the replay equipment. The electronic modules in the CVR were crushed and there was evidence of long term overheating of the dropper resistors on the power supply module. The CAM had been crushed breaking internal wiring and damaging components on the printed circuit board.

3.2 CVR replay

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings was audible on the RTF channels. The CAM channel was particularly noisy, this was probably due to the combination of the inherently noisy cockpit of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high cockpit noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified as of either acoustic or electrical in origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual in crew behaviour. The tape record ended with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording. The sound occurred whilst the crew were copying their transatlantic clearance from Shanwick ATC.

3.3 Analysis of the CVR record

3.3.1 The stopping of the recorder

To determine the mechanism that stopped the recorder a bench test rig was constructed utilizing an A100 CVR and an A152 CAM. Figures C-2 to C-5 show the effect of shorting, earthing or disconnecting the CAM signal wires. Figure C-8 shows the CAM channel signal response to the event which occurred on Flight PA103. From this it can be seen that there are no characteristic transients similar to those caused by shorting or earthing the CAM signal wires. Neither does the signal stop cleanly and quickly as shown in Figure C-5, indicating that the CAM signal wires were not interrupted. The UV trace shows the recorded signal decaying in a manner similar to that shown in Figure C-6, which demonstrates the effect of disconnecting electrical power from the recorder. The tests were repeated on other CVRs with similar results and it is therefore concluded that Flight PA103's CVR stopped because its electrical power was removed.

Figures C-9A to C-9D show the recorded signals for the Air India B747 (AI 182) accident in the North Atlantic on 23 June 1985. These show that there is a large transient on the CAM track indicating earthing or shorting of the CAM signal wires and that recorder power-down is more prolonged, indicating attempts to restore the electrical power supply either by bus switching or healing of the fault. The Flight PA103 CVR shows no attempts at power restoration with the break being clean and final.

In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

3.3.2 Information concerning the event

Figure C-8 is an expanded UV trace of the final milliseconds of the CVR record. Three tracks have been used, the flight engineer's RTF channel which contained similar information to the P2's channel has been replaced with a timing signal. Individual sections of interest are identified by number. On the bottom trace, the P1 RTF track, section 1 is part of the Shanwick transatlantic clearance. During this section the loud sound on the CAM channel is evident.

Examination of the DFDR event recordings shows that the Shanwick oceanic clearance was being received on VHF2, the aerial for which is on the underside of the fuselage close to the seat of the explosion.
Section 2 identifies a transient, on the P1 channel, typical of an end of ATC transmission transient for this CVR. The start and finish of most of the recorded ATC transmissions were analysed and they produce a similar signature to the three shown in Figure C-10. The signature on the P1 channel more closely resembles the end of transmission signature and it is open to conjecture that this transient was caused by the explosion damaging the aerial feeder and/or its supporting structure.

Section 3 shows what is considered to be a high speed power supply transient which is evident on all the RTF channels and is probably on the CAM channel, but cannot be identified because of the automatic gain control (AGC), limiting the audio event. This transient is considered to coincide with the loss of electrical power to the CVR. Section 5 identifies the period to the end of recording and this agrees well with tests carried out by AAIB and independently by Fairchild as part of the AI 182 investigation. The typical time from removal of the electrical supply until end of recording is 110 milliseconds.

During the period identified as section 4 it is considered that the disturbances on the RTF channels are electrical transients probably channelled through the communications equipment. Section 6 identifies the 170 millisecond period from the point when the sound was first heard on the CAM until the recording stopped.

The CAM unit is of the old type which has a frequency response of 350 to 3500 Hz. The useable duration of the signal is probably confined to the first 60 milliseconds of the final 170 milliseconds and even during this period the AGC is limiting the signal. In the remaining time the sound is being distorted because power to the recorder has been disconnected. The ambient cockpit noise may have been high enough to have caused the AGC to have been active prior to the event and in this event the full volume of the sound would not be audible. Distortion from the incomplete erasure of the last recording may form part of the recorded signal.

It is not clear if the recorded sound is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case.

Additionally some of the frequencies present on the recording were not present in the original sound, but are the result of the rise in total harmonic distortion caused by the increased amplitude of the incoming signal. Outputs from a frequency analysis of the recorded signal for the same frequency of input to the CVR, but at two input amplitudes, are shown in Figures C-11 and C-12. These illustrate the effects on harmonic distortion as the signal level is increased. Finally the recorded signal does not lend itself to analysis by a digital spectrum analyser as it is, in a large measure, aperiodic and most digital signal analysis algorithms are unable to deal with a short duration signal of this type, however, it is hoped that techniques being developed in Canada will enable more information to be deduced from the end of the recording.

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985 the Royal Armaments Research and Development Establishment (RARDE) were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

Preliminary results from these trials indicates that if a suitable sensor can be developed its output will need to be recorded in real time and therefore it may require wiring into the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

4. Flight recorder electrical system

4.1 CVR/DFDR electrical wiring.

The flight recorders were located in the left rear fuselage just forward of the rear pressure bulkhead. Audio information to the CVR ran along the left hand side of the aircraft, at stringer 11. Electrical power to the CVR followed a similar route on the right hand side of the aircraft crossing to the left side above the rear passenger toilets. DFDR electrical power and signal information followed the same route as the CVR audio information.

4.2 Flight recorder power supply

The DFDR, CVR and the transponders were all powered from the essential alternating current (AC) bus. This bus was capable of being powered by any generator, however, in normal operation the selector switch on the flight engineers panel is selected to "normal" connecting the essential bus to number 4 generator. When the cockpit of Flight PA103 was examined the selector switch was found in the normal position.

4.3 Aircraft alternating current power supplies

AC electrical power to the aircraft was provided by 4 engine driven generators, see Figure C-13. Each generator was driven at constant speed through a constant speed drive (CSD) and connected to a separate bus-bar through a generator control breaker (GCB). The 4 generators were connected to a parallel bus-bar (sync bus) by individual bus tie breakers (BTBs). Control and monitoring of the AC electrical system was achieved through the flight engineer's instrument panel. In normal operation the generators operated in parallel, i.e with the BTBs closed.

4.4 Fault conditions

Analysis of the CVR CAM channel signal indicated that approximately 60 milliseconds after the sound on the CAM channel an electrical transient was recorded on all 4 channels and that approximately 110 milliseconds later the CVR had ceased recording. Within the accuracy of the available timing information it is believed that the incoming VHF was lost at the same time, indicating an AC power supply fault.

The AC electrical system was protected from faults in individual systems or equipment by fuses or circuit breakers. Faults in the generators or in the distribution bus-bars and feeders were dealt with automatically by opening of the GCBs and opening or closing of the BTBs. In the event of fault conditions causing the disconnection of all 4 generators electrical power for essential services, including VHF radio, was provided by a battery located in the cockpit.

The short time interval of 55 milliseconds after which the AC supply to the flight recorders was lost limits the basis on which a fault path analysis of the AC electrical system can be undertaken. On the available information only a differential (feeder) fault could have isolated the bus-bar this quickly, with the generator field control relay taking 20 milliseconds to trip. However, in normal operation, the generators would have been operating in parallel and the essential AC bus-bar would have been supplied via the number 4 BTB from the sync bus. If the fault conditions had continued, a further 40 to 100 milliseconds would have elapsed before the BTB opened. If the BTB was open prior to the fault it would have attempted to close and restore the supply to the essential bus. Any automatic switching causes electrical transients to appear on the CVR and data losses on the FDR. Both the CVR and the FDR indicate that a clean break of the AC supply occurred with no electrical transients associated with BTBs open or closing in an attempt to restore power. In the absence of any additional information only two possibilities are apparent:

i) That all 4 generators were simultaneously affected causing a total loss of AC electrical power. The feeders for the left and right side generators run on opposite sides of the aircraft under the passenger cabin floor. The only situation envisaged that could cause simultaneous loss of all 4 generators is the disruption of the passenger cabin floor across its entire width.

ii) That disruption of the main equipment centre, housing the control units for the AC electrical system, caused the loss of all AC power. However, again it would have to affect both the left and right sides of the aircraft as the control equipment is located at left and right extremes of the main equipment centre.

The nature of the event may also produce effects that are not understood. It is also to be noted that a sudden loss of electrical power to the flight recorders has been reported in other B747 accidents, e.g. Air India, AI 182.

5. Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event caused by the wing section crashing on Lockerbie. The seismic monitors are time correlated with the British Telecom Rugby standard. Using this and calculating the time for the various waves to reach the recording stations it was possible for the British Geological Survey to conclude that the event occurred at 19.03:36.5 hrs ± 1 second.

Attempts were made to correlate various smaller seismic events with other wreckage impacts. However, this was not conclusive because the nearest recording station was above ground and due to the high winds at the time of the accident had considerable noise on the trace. In addition, little of the other wreckage had the mass or impact velocity to stimulate the sensors.

6. Time correlation

6.1 Introduction

The sources of each time encoded recording were asked to provide details of their time standard and any known errors in the timings on their recordings. Although the resolution of the recorded time sources is high it was not possible to attach an accuracy of better than ±1 second due to possible errors in synchronising the recorded time with the associated standard. The following time sources were available and used in determining the significant events in the investigation:-

i) ATC

ATC communications were recorded along with a time signal. The time source for the ATC tape was the British Telecom "Tim" signal. Any error in setting the time when individual tapes are mounted was logged.

ii) Recorded rada data

A time signal derived from the British Telecom "Rugby" standard was included on radar recordings. The Rugby and Tim times were assumed to be of equal accuracy for timing purposes.

iii) The DFDR had UTC recorded.

The source of this time was the flight engineer's clock. This clock was set manually and therefore this time was subject to a significant fixed error as well any inaccuracy in the clock.

iv) The CVR had no time signal.

However, the CVR was correlated with the ATC time through the RTF and with the DFDR, by correlating the press to talk events on the FDR with the press to talk signature on the CVR.

v) Seismic recordings

Seismic recordings included a timing signal derived from the British Telecom Rugby standard.

6.2 Analysis and correlation of times

The Scottish and Shanwick ATC tapes were matched with each other and with the CVR tape. The CVR recording speed was adjusted by peaking its recorded 400 Hz AC power source frequency. This correlation served as a double check on any fixed errors on the ATC recordings and to fix events on the CVR to UTC. The timing of the sound on the CAM channel of the CVR was made simpler because Shanwick was transmitting when it occurred. From this it was possible to determine that the sound on the CVR occurred at 19.02:50 hrs ±1 second.

With the CVR now tied to the Tim standard it was possible to match the RTF keying on the CVR with the RTF keying events on the FDR. These events on the FDR were sampled and recorded once per second, it was therefore possible for a 1 second delay to be present on the FDR. This potential error was reduced by obtaining the best fit between a number of RTF keyings and a time correlation between the FDR and CVR of ±? second was achieved. From this it was determined, within this accuracy, that electrical power was removed from the CVR and FDR at the same time.

From the recorded radar data it was possible to determine that the last recorded SSR return was at 19.02:46.9 hrs and that by the next rotation of the radar head a number of primary returns, some left and right of track, were evident. Time intervals between successive rotations of the radar head became more difficult to use as the head painted more primary returns.

The point at which aircraft wreckage impacted Lockerbie was determined using the time recorded by seismic activity detectors. A seismic event measuring 1.6 on the Richter scale was detected and, with appropriate time corrections for times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

7. Recorded radar information

7.1 Introduction

Recorded radar information on the aircraft was available from from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen, from this it was clear that the flight had progressed in a normal manner until Secondary Surveillance Radar (SSR) was lost. There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost. The Lowther Hill and St. Annes radars did not see this return. The Great Dun Fell radar recording was watched for 1 hour both before and after this single return for any signs of other spurious returns, but none was seen. The return was only present for one paint and no explanation can be offered for its presence.

7.2 Limitations of recorded radar data

Before evaluating the recorded radar data it is important to highlight limitations in radar performance that must be taken into account when interpreting primary radar data. The radar system used for both primary and secondary radar utilised a rotating radar transmitter/receiver (Head). This means that a return was only visible whilst the radar head was pointing at the target, commonly called painting or illuminating the target. In the case of this accident the rotational speeds of the radar heads varied from approximately 10 seconds for the Lowther Hill Radar to 8 Seconds for the Great Dun Fell Radar.

Whilst it was possible to obtain accurate positional information within a resolution of 0.09¡ of bearing and ± 1/16 nautical mile range for an aircraft from SSR, incorporating mode C height encoding, primary radar provided only slant range and bearing and therefore positional information with respect to the ground was not accurate.

The structural break-up of an aircraft releases many items which were excellent radar reflectors eg. aluminium cladding, luggage containers, sections of skin and aircraft structure. These and other debris with reflective properties produce "clutter" on the radar by confusing the radar electronics in a manner similar to chaff ejected by military aircraft to avoid radar detection.

Even when the target is not masked by clutter repetitive detection of individual targets may not be possible because detection is a function of the target effective area which, for wreckage with its irregular shape, is not constant but fluctuates wildly. These factors make it impossible to follow individual returns through successive sweeps of the radar head.

7.3 Analysis of the radar data

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. This information was correlated with the CVR and ATC times to establish a time and position for the aircraft at the initial disintegration.

For the purposes of this analysis the data from Great Dun Fell Radar has been presented. Figures C-14 to C-23 show a mosaic picture of the radar data i.e. each figure contains the information on the preceding figure together with more recently recorded information. Figure C-14 shows the radar returns from an aircraft tracking 321¡(Grid) with a calculated ground speed of 434 kts. Reading along track (towards the top left of Figure C-14) there are 6 SSR returns with the sixth and final SSR return shown decoded: squawk code 0357 (identifying the aircraft as N739PA); mode C indicating FL310; and the time in seconds (68566.9 seconds from 00:00, i.e. 19.02:46.9 hrs).

At the next radar return there is no SSR data, only 4 primary returns. One return is along track close to the expected position of the aircraft if it had continued at its previous speed and heading. There are 2 returns to the left of track and 1 to the right of track. Remembering the point made earlier about clutter, it is unlikely that each of these returns are real targets. It can, however, be concluded that the aircraft is no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items have been ejected at high speed probably to both right and left of the aircraft. Figure C-15 shows the situation after the next head rotation. There is still a return along track but it has either slowed down or the slant range has decreased due to a loss of altitude.

Each rotation of the radar head thereafter shows the number of returns increasing with those first identified across track in Figure C-14 having slowed down very quickly and followed a track along the prevailing wind line. Figure C-20 shows clearly that there has been a further break-up of the aircraft and subsequent plots show a rapidly increasing number of returns, some following the wind direction and forming a wreckage trail parallel to and north of the original break-up debris. Additionally it is possible that there was some break-up between these points with a short trail being formed between the north and south trails. From the absence of any returns travelling along track it can be concluded that the main wreckage was travelling almost vertically downwards for much of the time.

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

8. Conclusions

The almost instant destruction of Flight PA103 resulted in no direct evidence on the cause of the accident being preserved on the DFDR. The CVR CAM track contained a loud sound 170 milliseconds before recording ceased. Sixty milliseconds of this sound were while power was applied to the recorder; after this period the amplitude decreased. It cannot be determine whether the decrease was because of reducing recorder drive or if the sound itself decreased in amplitude. Analysis of both flight recorders shows that they stopped because the electrical supply was removed and that there were valid signals available to both recorders at that time.

The most important contribution to the investigation that the flight recorders could make was to pinpoint the time and position of the event. As the timescale involved was so small in relation to the resolution and accuracy of many of the recorded time sources it was necessary to analyse collectively all the available recordings. From the analysis of the CVR, DFDR, ATC tapes, radar data and the seismic records it was concluded that the loud sound on the CVR occurred at 19.02:50 hrs ±1 second and wreckage from the aircraft crashed on Lockerbie at 19.03:36.5 hrs ±1 second, giving a time interval of 46.5 ±2 seconds between these two events. When the loud sound was recorded on the CVR, the geographical position of the aircraft, based on the evidence of recorded data, was calculated to be within 525 metres of OS Grid Reference 14827826.

Eight seconds after the sound on the CVR the Great Dun Fell radar showed 4 primary radar returns. The returns indicated a spread of wreckage in the order of 1 nautical mile across track. On successive returns of the radar, two parallel wreckage trails are seen to develop with the second trail, to the north, becoming evident 30 to 40 seconds after the first.

APPENDIX D

CRITICAL CRACK CALCULATIONS

It was assumed that the fuselage rupture and associated star-burst petalling process was driven by an expanding 'bubble' of high pressure gas, produced by the conversion of solid explosive material into gas products. As the explosive gas pressures reduced due to dissipation through the structure and external venting, the service differential pressure loading would have taken over from the explosive pressures as the principal force driving the skin fractures.

The high temperature gas would initially have been confined within the container where, because of the low volume, the pressure would have been extremely high (too high for containment) and the gas bubble would have expanded violently into the cavities of the fuselage between the outer skin and the container. This gas bubble would have continued to expand, with an accompanying fall in pressure due to the increasing volume combined with a corresponding drop in temperature.

The precise nature of the gas expansion process could not be determined directly from the evidence and it was therefore necessary to make a number of assumptions about its behaviour, based on the geometry of the hull and the area of fuselage skin which the high pressure bubble would have ruptured. Essentially, it was assumed that the gas bubble would expand freely in the circumferential direction, into the cavity between the fuselage skin and the container. In contrast, the freedom for the bubble to expand longitudinally would have been restricted by the presence of the fuselage frames, which would have partially blocked the passage of gas in the fore and aft directions. However, the pressures acting on the frames would have been such that they would have buckled and failed, allowing the gas to vent into the next 'bay', producing failure of the next frame. This sequential frame-failure process would have continued until the pressure had fallen to a level which the frames could withstand. During the period of frame failure and the associated longitudinal expansion of the gas bubble, this expansion rate was assumed to be half that of the circumferential rate.

It was assumed that venting would have taken place through the ruptured skin and that the boundary of the petalled hole followed behind the expanding gas bubble, just inside its outer boundary, i.e. the expanding gas bubble would have stretched and 'unzipped' the skins as it expanded. This process would have continued until the gas bubble had expanded/vented to a level where the pressure was no longer able to drive the petalling mechanism because the skin stresses had reduced to below the natural strength of the material.

The following structural model was assumed:

(i) The pressurised hull was considered to be a cylinder of radius 128 inches, divided into regular lengths by stiff frames.

(ii) The contributions of the stringers and frames beyond the petalled region were considered to be the equivalent of a reduction of stress in the skins by 20%, corresponding to an increase in skin thickness from 0.064 inches to 0.080 inches.

(iii)

Standing skin loads were assumed to be present due to the service differential pressure, i.e.. it was assumed that no significant venting of internal cabin pressure occurred within the relevant timescale.

(iv)

The mechanism of bubble pressure load transfer into the skins was:

a)

Hoop direction -conventional membrance reaction into hoop stresses

b)

Longitudinal direction - reaction of pressures locally by the frames, restrained by the skins.

The critical crack calculations were based upon the generalised model of a plate under biaxial loading in which there was an elliptical hole with sharp cracks emanating from it. This is a good approximation of
the initial condition, i.e.. the shattered hole, and an adequate representation of the subsequent phase, when the hole was enlarging in its star-burst, petalling, mode.

The analyses of critical crack dimensions in the circumferential and longitudinal directions were based on established Fracture Resistance techniques. The method utilises fracture resistance data for the
material in question to establish the critical condition at which the rate of energy released by the crack just balances the rate of energy absorbed by the material in the cracking process, i.e. the instantaneous
value of the parameter Kr, commonly referred to as the fracture toughness Kc. From this, the relationship between critical stress and crack length can be determined.

Using conventional Linear Elastic Fracture Mechanics (LEFM) with fracture toughness data from RAE experimental work and published geometric factors relating to cracks emanating from elliptical holes,
the stress levels required to drive cracks of increasing lengths in both circumferential and longitudinal directions were calculated. The skin stresses at sequential stages of the expanding gas bubble/skin
petalling process were then calculated and compared with these data.

The results of the analysis indicated that, once the large petalled hole had been produced by explosive gas overpressure, the hoop stresses generated by fuselage pressurisation loads acting alone would have been sufficient to drive cracks longitudinally for large distances beyond the boundaries of the petalled hole. Thus, with residual gas overpressure acting as well, the 43 feet (total length) longitudinal fractures observed in the wreckage are entirely understandable. The calculations also suggested that the hoop fractures, due to longitudinal stresses in the skins, would have extended beyond the boundary of the petalled hole, though the excess stress driving the fractures in this direction would have been much smaller than for the longitudinal fractures, and the level of uncertainty was greater due to the difficulty of producing an accurate model reflecting the diffusion of longitudinal loads into the skins. Nevertheless, the results suggested that the circumferential cracks would extend downwards just beyond the keel, and upwards as far as the window belt - conclusions which accord reasonably well with the wreckage evidence.

APPENDIX E

POTENTIAL REMEDIAL MEASURES

1. Introduction

In the following discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution. On the basis of the Flight PA103 investigation, damage is likely to fall into two categories: direct explosive damage, and indirect explosive damage.

2. Direct explosive damage

The most serious aspect of the direct explosive damage on the structure is the large, jagged aperture in the pressure hull, combined with frame and stringer break-up, which results from the star-burst rupture of the fuselage skin. Because of its uncontrolled size and position, and the naturally radiating cracks which form as part of the petalling process, the skin's critical crack length (under pressurisation loading) is likely to be exceeded, resulting in unstable crack propagation away from the boundary of the aperture. Such cracks can lead to a critical loss of structural integrity at a time when additional loads are likely to be imposed on the structure due to reflected blast pressure and/or aircraft aerodynamic and inertial loading.

A further complicating factor is that the size of this aperture is likely to be sufficiently large to allow complete cargo containers and other debris to be ejected into the airstream, with a high probability of causing catastrophic structural damage to the empennage.

3. Indirect explosive damage

Indirect explosive damage (channelling or ducting of explosive energy in the form of both shock waves and supersonic gas flows) is likely to occur because of the network of interlinked cavities which exist, in various forms, in all large commercial aircraft, particularly below cabin floor level. This channeling mechanism can produce critical damage at significant distances from the source of the explosion.

In addition to the structural damage, aircraft flight control and other critical systems will potentially be disrupted, both by the explosive forces and as a result of structural break-up and distortions. The discussion which follows focuses on possible means of limiting structural damage of the kind which occurred on Flight PA103. Undoubtedly, such measures will also have beneficial effects in limiting systems damage. However, system vulnerability can further be reduced by applying, wherever possible, those techniques used on military aircraft to reduce vulnerability to battle damage; multiplexed, multiply redundant systems using distributed hardware to minimise risk of a single area of damage producing major system disruption. Fly by wire flight control systems potentially offer considerable scope to achieve these goals, but the same distributed approach would also be required for the electronic and other equipment which, in current aircraft, tends to be concentrated into a small number of 'equipment centres'.

4. Remedial measures to reduce structural damage

Whilst pure containment of the explosive energy is theoretically possible, in an aviation context such a scheme would not be viable. Any unsuccessful attempt to contain the explosive will probably produce greater devastation than the original (uncontained) explosion since all the explosive energy would merely be stored until the containment finally ruptured, when the stored energy would be released together with massive fragmentation of the containment.

However, a mixed approach involving a combination of containment, venting, and energy absorption should provide useful gains provided that a systematic rather than piecemeal approach is adopted, and that the scheme also addresses blast channelling. The following scheme is put forward for discussion, primarily as means of identifying, by example, how the various elements of the problem might be approached at a conceptual level and to provide a stimulus for debate. No detailed engineering solutions are offered, but it is firmly believed that the requirements of such a scheme could be met from a technical standpoint. The proposed scheme is based on the need to counter a threat similar to that involving Flight PA103, i.e. a high explosive device placed within a baggage container, however, the principles should be applicable to other aircraft types.

Such a scheme might comprise several 'layers' of defence. The first two layers, one within the other, are essentially identical and provide partial containment of the explosive energy and the redirection of blast out from the compartment via pre-determined vent paths. Although the containment is temporary, it must provide an effective barrier to uncontrolled venting, preventing the escape of blast except via the pre-designated paths.

The third layer comprises a pre-determined area of fuselage skin, adjoining the outer end of the vent path, designed to rupture or burst in a controlled manner, providing a large vent aperture which will not tend to crack or rupture beyond the designated boundaries.

A fourth layer of protection has two elements, both intended to limit the propagation of shock waves through the internal cavities in the hull. The first element comprises the closure of any gaps between the vent apertures in the two innermost containment layers and the vent aperture in the outer skin. This effectively provides an exhaust duct connecting the inner and outer vent apertures to minimise leakage into the intervening structure and cavities around the cargo hold. The second element comprises the incorporation of an energy absorbing lining material within all the cavities in the lower hull, to absorb shock energy, limit shock reflection and limit the propagation of pressure waves which might enter the cavities, for example because of containment layer breakthrough.

5 Possible application to Boeing 747 type aircraft

5.1 Container Modification

The obvious candidates for the inner containment layer are the baggage containers themselves. Existing containers are of crude construction, typically comprising aluminium sheet sides and top attached to an aluminium frame with a fabric reinforced access curtain, or have sides and top of fibreglass laminate attached to a robust aluminium base section.

These containers are stacked in the aircraft in such a manner that on three sides (except for the endmost containers) the baggage within the adjoining containers provides an already highly effective energy absorbing barrier. If the container is modified so that loading access is via the outboard side of the container rather than at the end, i.e. the curtain is put on the faces shown in Figure E-1, then only the top and base are 'unbacked' by other containers, leaving the outboard face as a vent region.

The proposal is therefore that a modified container is developed in which the access is changed from the end to the outside face only, and which is modified to improve the resistance to internal pressures and thus encourage venting via the new access curtain only. How the container is actually modified to achieve the containment requirement is a matter of detail design, but two approaches suggest themselves, both involving the use of composite type materials. The first approach is to adopt a scheme for a rigid container which relies on a combination of energy absorption and burst strength to prevent uncontrolled breakout of explosive energy. The second approach is to use a 'flexible' container, i.e. rigid enough for normal use, but sufficiently flexible to allow gross deformation of shape without rupture. This, particularly if used with a backing blanket made from high performance material to resist fragmentation, could deform sufficiently to allow the container to bear against, and partially crush, adjoining containers. In this way, the shock energy transmission should be significantly reduced and the inherent energy absorption capability and mass of the baggage in adjoining containers could be utilised, whilst still retaining the high pressure gas for long enough to allow venting via the side face. Clearly, care would need to be taken to ensure that the container vent aperture remained as undistorted as possible, to ensure minimal leakage at the interface.

5.2 Cargo bay liner

The existing cargo bay liner is a thin fibreglass laminate which lines the roof and sidewalls of the cargo hold. There is no floor as such; instead, the containers are supported on rails running fore and aft on the tops of the fuselage frame lower segments. In a number of areas, there are zipped fabric panels let into the liner to provide access to equipment located behind. The liner 'ceiling' is suspended on plastic pillars approximately 2 centimeters below the bottom of the main cabin floor beams. The purpose of the liner is solely to act as a general barrier to protect wiring looms and systems components.

The proposal is to produce a new liner designed to provide the second level of containment, essentially at 'floor' and 'roof' level only [Figure E-1]. The dimensional constraints are such that potentially quite thick material could be incorporated (leaving aside the weight problem), permitting not only a rigid liner design, but semi-rigid or flexible linings backed by energy absorbing blanket materials.

The liner would be designed to provide an additional barrier at the base and roof of the containers, which unlike the sides, are not protected by adjoining containers. The outside ends of these barrier elements must effectively seal against the vent apertures in the containers, to minimise leakage into the fuselage cavities.

5.3 Structural blow-out regions.

The final element in the containment/venting part of the scheme is a line of blow-out regions in the fuselage skins, coinciding exactly with the positions of the vent apertures in the cargo containers and cargo bay liner. These should extend along the length of the cargo hold, zoned in such a way that rupture due to rapid overpressure will occur in a controlled manner. The primary function of the blow-out regions would be to provide immediate pressure relief by allowing the inevitable skin rupture to take place only within pre-determined zones, limiting the extent of the skin tearing by means of careful stiffness control at the boundary of the blow-out regions.

The structural requirements of such panels are perhaps the most difficult challenge to meet, particularly for existing designs. However, it is believed that by giving appropriate consideration to the directionality of fastening strengths, and the use of external tear straps, it should be possible to design the structure to carry the normal service loads whilst creating a pre-disposition to rupturing in a controlled manner in response to gross pressure impulse loading.

The implementation of such features will need carefully balanced design in order to provide local stiffening, sufficient to control and direct the tear processes, without creating stiffness discontinuities which could lead to fatigue problems during extended service. However, the degree of reinforcement needed at the blow-out aperture need only be sufficient to limit tearing and to sustain the aircraft long enough to complete the flight unpressurised.

All aircraft have pre-existing strength discontinuities, despite the efforts of the designers to eliminate them. By choosing the positions of butt joints, lap joints, anti-tear straps and similar structural features in future designs, so as to incorporate them into the boundary of the blow-out panel region, the natural "tear here" tendencies of such features could possibly be turned to advantage. In the case of current generation aircraft, the positions of existing lines of weakness at such features will determine the optimum position for structural blow-out areas, and hence the positions of the container and cargo bay liner blow-out panels. A limited amount of local structural reinforcement (e.g. in the form of external anti-tear straps), carried out as part of a modification program, could perhaps fine tune the tearing properties of existing lines of weakness, potentially producing significant improvements.

5.4 Closure of cavities

There are four main classes of cavity which will need to be addressed on the Boeing 747, and most other modern aircraft. These are:

(i) The channels formed between fuselage frames

(ii) The cross-ship cavities between cabin floor beams

(iii) Longitudinal 'manifold' cavities on each side of the cargo deck, running fore and aft in the space behind the upper sidewall areas of the cargo bay liner.

(iv) Air conditioning vents along the bottom of the cabin side-liner panels, which connect the side cavities below cabin floor level with the main passenger cabin.

If the containment barriers (i.e. modified cargo containers and cargo hold liner) can be made to prevent blast breakthrough into these cavities directly, then the only area where transfer can occur is at the interface between the container/cargo hold liner vent apertures and the fuselage skins at the blow-out region. This short distance will need to be sealed in order to form a short 'exhaust duct' between the container vent aperture and the fuselage skin. Since the shock and general explosive pressure will act mainly along the vent-duct axis, the pressure loading on the vent duct walls should not be excessive.

5.5 Attenuation of shock waves in structural cavities

To prevent the 'ducting' of any blast which does enter the fuselage cavities, either because of partial penetration of the containment barriers or leakage at the vent duct interfaces, the scheme requires the provision of lightweight energy absorbing material within the cavities to limit reflection and propagation of pressure waves within the cavities, and radiation of shock waves into the cabin from the conditioning air vents. Materials such as vermiculite, which are of low density yet have excellent explosive energy absorption properties, may have application in this area, perhaps in lieu of the existing insulation material.

Since the existing cavities often serve as part of the air conditioning outflow circuit, some consideration will need to be given to finding an alternative route. However, the flow rates are small compared with the total cross-sectional flow potential of the cavities and this function could be served by separate air conditioning ducts, or perhaps by restricting access to one or two cavities only (thus limiting the risk), or by using some form of blast valve to close off the air conditioning vents. Similarly, the requirement to vent pressure from the cabin in the event of a cargo bay decompression would also need to be addressed.

APPENDIX F

BAGGAGE CONTAINER EXAMINATION, RECONSTRUCTION AND RELATIONSHIP TO THE AIRCRAFT STRUCTURE

1. Introduction

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited blast damage. It was confirmed by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE), after detailed physical and chemical examination, that these items showed conclusive evidence of a detonating high performance plastic explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence from the effect of Improvised Explosive Device (IED). It was evident, from the main wreckage layout that the IED had been located in the forward cargo hold and, although all baggage container wreckage was examined, only items from the forward hold showing the relevant characteristics were considered for the reconstruction. This Appendix documents the reconstruction of two particular containers and, from their position within the forward fuselage, defines the location of the IED.

2 Container Arrangement

Information supplied by Pan Am showed that this aircraft had been loaded with 12 baggage containers and two cargo pallets in the forward hold located as shown in Figure F-1. Three containers were recorded as being of the glass fibre reinforced plastic type (those at positions 11L, 13L and 21L) with the remaining 9 being of metal construction.

3. Container Description

All the baggage containers installed in the forward cargo hold were of the LD3 type (lower deck container, half width - cargo) and designated with the codes AVE, for those constructed from aluminum alloy, and AVA or AVN for those constructed from fibreglass. Each container was specifically identified with a four digit serial number followed by the letters PA and this nine digit identifier was present at the top of three sides of each container in black letters/numbers approximately 5 inches tall. Detail drawings and photographs of a typical metal container are shown in Figure F-2. Each container was essentially a 5 feet cube with a 17 inch extension over its full length to the left of the access aperture. In order to fit within the section of the lower fuselage this extension had a sloping face at its base joining the edge of the container floor to the left vertical sidewall at a position some 20 inches above the floor. The access aperture on the AVE type container was covered by a blue reinforced plastic curtain, fixed to the container at its top edge, braced by two wires and central and lower edge cross bars which engaged with the aperture structure. The strength of this type of container superstructure was provided by the various extruded section edge members, attached to a robust floor panel, with a thin aluminum skin providing baggage containment and weatherproofing.

4. Container Identification

Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to the town of Lockerbie and was characteristically different from that from the forward hold, in that it was generally severely crushed and covered in mud. The forward hold debris, by comparison, was mostly recovered from the southern wreckage trail some distance from Lockerbie and had mainly been torn into relatively large sections.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this two containers, one metal and one fibreglass, were identified as exhibiting damage likely to have been caused by the IED. From the Pan Am records the metal container of these two had been positioned at position 14L, and the fibreglass at position 21L (adjacent positions, 4th and 5th from the front of the forward cargo hold on the left side). The serial numbers of these containers were respectively AVE 4041 PA and AVN 7511 PA.

5. Container Reconstruction

Those parts which could be positively identified as being from containers AVE 4041 PA and AVN 7511 PA were assembled onto one of three wooden frameworks; one each for the floor and superstructure of container 4041, and one for the superstructure of container 7511. Figures F-3 to F-9 show the reconstruction of container 4041 and Figure F-10 shows the reconstructed forward face of container 7511.
Approximately 85% of container 4041 was identified, the main missing sections being the aft half of the sloping face skin and all of the curtain. Two items were included which could not be fracture or tear matched to container 4041, however, they showed the particular type of blast damage exhibited only by items from this container.

While this work was in progress a buckled section of skin from container 4041 was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device.

Examination of all other component parts of the remaining containers from the front and rear cargo holds did not reveal any evidence of blast damage similar to that found on containers 4041 and 7511.

6. Wreckage Distribution

Those items which were positively identified as parts of container 4041 or 7511, and for which a grid reference was available, were found to have fallen close to the southern edge of the southern wreckage trail. This indicated that one of the very early events in the aircraft break-up sequence was the blast damage to, and ejection of, parts of these two containers.

7. Fuselage Reconstruction

In order to gain a better understanding of the failure sequence, that part of the aircraft's fuselage encompassing the forward cargo hold was reconstructed at AAIB Farnborough. After all available blast damaged pieces of structure had been added, the floor of container 4041 was installed as near to its original position as the deformation of the wreckage would allow and this is shown in Figure F-11. The presence of this floor panel in the fuselage greatly assisted the three-dimensional assessment of the IED location. Witness marks between this floor and the aircraft structure, tie down rail, roller rail and relative areas of blast damage left no doubt that container 4041 had been located at position 14L at the time of detonation.

8. Analysis

The general character of damage that could be seen on the reconstructions of containers 4041 and 7511 was not of a type seen on the wreckage of any of the other containers examined. In particular, the reconstruction of the floor of container 4041 revealed an area of severe distortion, tearing and blackening localised in its aft outboard quarter which, together with the results of the forensic examination of items from this part of the container, left no doubt that the IED had detonated within this container.

Within container 4041 the lack of direct blast damage (of the type seen on the outboard floor edge member and lower portions of the aft face structural members) on most of the floor panel in the heavily distorted area suggested that this had been protected by, presumably, a piece of luggage. The downward heaving of the floor in this area was sufficient to stretch the floor material, far enough to be cut by cargo bay sub structure, and distort the adjacent fuselage frames. This supported the view that the item of baggage containing the IED had been positioned fairly close to the floor but not actually placed upon it. The installation of the floor of container 4041 into the fuselage reconstruction (Figure F-11) showed the blast to have been centered almost directly above frame 700 and that its main effects had not only been directed mostly downwards and outboard but also rearwards. The blast effects on the aircraft skin were onto stringer 39L but centered at station 710 (Figure F-12). Downwards crushing at the top, and rearwards distortion of frame 700 was apparent as well as rearwards distortion of frame 720.

With the two container reconstructions placed together it became apparent that a relatively mild blast had exited container 4041 through the rear lower face to the left of the curtain and impinged at an angle on the forward face of container 7511. This had punched a hole, Figure F-10, approximately 8 inches square some 10 inches up from its base and removed the surface of this face inboard from the hole for some 50 inches. Radiating out from the hole were areas of sooting, and other black deposits, extending to the top of the container. No signs were present of any similar damage on other external or internal faces of container 7511 or the immediately adjacent containers 14R and 21R.

The above assessment of the directions of distortion, comparison of damage to both containers, and the related airframe damage adjacent to the container position, enabled the most probable lateral and vertical location of the IED to be established as shown in Figure F-13, centered longitudinally on station 700.

9. Conclusions

Throughout the general examination of the aircraft wreckage, direct evidence of blast damage was exhibited on the airframe only in the area bounded, approximately, by stations 700 and 720 and stringers 38L and 40L. Blast damage was found only on pieces of containers 4042 and 7511, the relative location and character of which left no doubt that it was directly associated with airframe damage. Thus, these two containers had been loaded in positions 14L and 21L as recorded on the Pan Am cargo loading documents. There was also no doubt that the IED had been located within container 14L, specifically in its aft outboard quarter as indicated in Figure F-13, centered on station 700.

Blast damage to the forward face of container 7511 was as a direct result of hot gases/fragments escaping from the aft face of container 4041. No evidence was seen to suggest that more than one IED had detonated on Flight PA103.

APPENDIX G

MACH STEM SHOCK WAVE EFFECTS

1. Introduction

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity shock wave which will propagate outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant for two reasons. Firstly, it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter. This geometric limitation occurs irrespective of charge size (within the range of charge sizes considered realistic for the Flight PA103 scenario), and thus provides a means of calculating the standoff distance of the explosive charge from the fuselage skin. Secondly, the Mach stem may have been a significant factor in transmitting explosive energy through the fuselage cavities, producing damage at a number of separate sites remote from the source of the explosion.

2. Mach stem shock wave formation

A Mach stem shock is formed by the interaction between the incident and reflected shock waves, resulting in a coalescing of the two waves to produce a new, single, shock wave. If an explosive charge is detonated in a free field at some standoff distance from a reflective surface, then the incident shock wave expands spherically until the wave front contacts the reflective surface, when that element of the wave surface will be reflected back (Figure G-1). The local angle between the spherical wave front and the reflecting surface is zero at the point where the reflecting surface intersects the normal axis, resulting in wave reflection directly back towards the source and maximum reflected overpressure at the reflective surface. The angle between the wave front and the reflecting surface at other locations increases with distance from the normal axis, producing a corresponding increase in the oblique angle of reflection of the wave element, with a corresponding reduction in the reflected overpressure. (To a first order of approximation, explosive shock waves can be considered to follow similar reflection and refraction paths to light waves, ref: "Geometric Shock Initiation of Pyrotechnics and Explosives", R Weinheimer, McDonnel Douglas Aerospace Co.) Beyond some critical (conical) angle about the normal axis, typically around 40 degrees, the reflected and incident waves coalesce to form Mach stem shock waves which, effectively, bisect the angle between the incident and reflected waves, and thus travel approximately at right angles to the normal axis, i.e.parallel with the reflective surface (detail "A", figure G-1).

3. Estimation of charge standoff distance from the fuselage skin

Within the constraint of the likely charge size used on Flight PA103, calculations suggested that the initial Mach stem shock wave pressure close to the region of Mach stem formation (i.e. the shock wave face-on pressure, acting at right angles to the skin), was likely to be more than twice that of the incident shock wave, with a velocity of propagation perhaps 25% greater. However, the Mach stem out-of-plane pressure, i.e.the pressure felt by the reflecting surface where the Mach stem touches it, would have been relatively low and insufficient to shatter the skin material. Therefore, provided that the charge had sufficient energy to produce skin shatter within the conical central region where no Mach stems form, the size of the shattered region would be a function mainly of charge standoff distance, and charge weight would have had little influence. Consequently, it was possible to calculate the charge standoff distance required to produce a given size of shattered skin from geometric considerations alone. On this basis, a charge standoff distance of approximately 25 to 27 inches would have resulted in a shattered region of some 18 to 20 inches in diameter, broadly comparable to the size of the shattered region evident on the three-dimensional wreckage reconstruction.

Whilst the analytical method makes no allowance for the effect of the IED casing, or any other baggage or container structure interposed between the charge and the fuselage skin, the presence of such a barrier would have tended to absorb energy rather than re-direct the transmitted shock wave; therefore its presence would have been more critical in terms of charge size than of position. Certainly, the standoff distance predicted by this method was strikingly similar to the figure of 25 inches derived independently from the container and fuselage reconstructions.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: aniljit singh uppal <aniljitsingh@hotmail.com>
Subject: **UAL 811 report**

Microsoft Word 6.0 Document MSWordDoc Word.Document.6 C:\WORD6\TEMPLATE\NORMAL.DOT National Transportation Safety Board National Transportation Safety Board
Washington, D.C. 20594
Brief of Accident
Adopted 06/25/1990
DCA89MA027
FILE NO. 63 02/24/89 HONOLULU, HI AIRCRAFT

REG. NO. N4713U TIME (LOCAL) - 02:09 HST

MAKE/MODEL - BOEING 747-122 AIRCRAFT DAMAGE - Substantial FATAL SERIOUS MINOR/NONE
ENGINE MAKE/MODEL - P&W JT9D-3A CREW 0 3 16
NUMBER OF ENGINES - 4 PASS 9 2 326
OPERATING CERTIFICATES - Flag carrier/domestic
NAME OF CARRIER - UNITED AIRLINES
TYPE OF FLIGHT OPERATION - Scheduled
- International
- Passenger
REGULATION FLIGHT CONDUCTED UNDER - 14 CFR 121

LAST DEPARTURE POINT - HONOLULU, HI CONDITION OF LIGHT - Night (dark)
DESTINATION - AUCKLAND, OF
WEATBER INFO SOURCE- Pilot
AIRPORT PROXIMITY - Off airport/airstrip
AIRPORT NAME - Unk/Nr BASIC WEATHER - Visual (VMC)
RUNWAY IDKNTIFICATION - Unk/Nr LOWEST CEILING - Unk/Nr
RUNWAY LEHGTH/WIDTH (Feet) - Unk/Nr
VISIBILITY - Unk/Nr
RUNWAY SURFACE - Unk/Nr WIND DIR/SPEED - Unk/Nr
RUNWAY SURFACE CONDITION - Unk/Nr
TEMPERATURE (F) - 0
PRECIPITATION - Unk/Nr

PILOT-IN-COMMAND AGE - 59 FLIGHT TIME (Hours)
CERTIFICATES/RATINGS TOTAL ALL AIRCRAFT - 28000

Airline transport LAST 90 DAYS - Unk/Nr
Single-engine land, Multi-engine land, Single-engine sea
TOTAL MRKE/MODEL - 1650
Glider TOTAL INSTRUMENT TIME - Unk/Nr
INSTRUMKNT RATINGS
Airplane

FTL #811 WAS A SCHEDULED PASSENGER FLIGHT FROM LOS ANGELES TO SYDNEY, AUSTRALIA, WITH STOPS IN HONOLULU (HNL), HI, AND AUCKLAND, NEW ZEALAND. THE FLT WAS UNEVENTFUL UNTIL AFTER DEPARTURE FROM HNL. WHILE CLIMBING FROM FL220 TO FL230 THE CREW HEARD A "THUMP" FOLLOWED BY AN EXPLOSION. AN EXPLOSIVE DECOMPRESSION WAS EXPERIENCED AND THE #3 AND #4 ENGS WERE SHUTDOWN BECAUSE OF FOD. THE FLT RETURNED TO HNL AND PASSENGERS WERE EVACUATED. INSPECTION REVERLED THE FORWARD LOWER LOBE CARGO DOOR DEPARTED INFLT CAUSING EXTENSIVE DAMAGE TO THE FUSELAGE AND CABIN ADJACENT TO THE DOOR. NINE PASSENGERS WERE EJECTED AND LOST AT SEA. INVESTIGATION CENTERED AROUND DESIGN AND CERTIFICATION OF THE DOOR WHICH ALLOWED IT TO BE IMPROPERLY LATCHED, AND THE OPERATION AND MAINTENANCE TO ASSURE AIRWORTHINESS OF THE DOOR AND LRTCHING MECHANISM. (SEE NTSB/AAR-90/01)

DCA89MA027
FILE NO. 63 02/24/89 HONOLULU, HI AIRCRAFT REG. NO. N4713U TIME (LOCAL) - 02:09 HST

Occurrence# 1 AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION

Phase of Operation CLIMB - TO CRUISE
Findings
1. - DOOR, CARGO/BAGGAGE - UNLATCHED
2. - DOOR, CARGO/BAGGAGE - SEPARATION
3. - MAINTENANCE, INSPECTION OF AIRCRAFT - IMPROPER - COMPANY MAINTENANCE PBRSONNEL
4. - ACFT/EQUIP, INADEQUATE DESIGN - MANUFACTURER
5. - ACFT/EQUIP, INADEQUATE STANDARD/ REQUIREMENT - FAA(ORGANIZATION)
6. - AIR COND/HEATING/PRESSURIZATION - DECOMPRESSION

The National Transportation Safety Board determines that the Probable Cause(s) of this Accident was: THE SUDDEN OPENING OF THE IMPROPERLY LATCHED FORWARD LOBE CARGO DOOR IN FLIGHT AND THE SUBSEQUENT EXPLOSIVE DECOMPRESSION. CONTRIBUTING TO THE ACCIDENT WAS A DEFICIENCY IN THE DESIGN OF THE CARGO DOOR LOCKING MECHANISMS, WHICH MADE THEM SUSCEPTIBLE TO INSERVICE DAMAGE, AND WHICH ALOWED THE DOOR TO BE UNATCHED, YET TO SHOW A PROPERLY LATCHED AND LOCKED POSITION. ALSO CONTRIBUTING TO THE ACCIDENT WAS THE LACK OF PROPER MAINTENANCE AND INSPECTION OF THE CARGO DOOR BY UNITED AIRLINES, AND A LACK OF TIMELY CORRECTIVE ACTIONS BY BOEING AND THE FAA FOLLOWING A PREVIOUS DOOR OPENING INCIDENT.
Format Revision 7/95
PB92-910402
NTSB/AAR-92/02
(SUPERSEDES NTSB/AAR-90/01)
NATIONAL

TRANSPORTATION
SAFETY
BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION--
LOSS OF CARGO DOOR IN FLIGHT
UNITED AIRLINES FLIGHT 811
BOEING 747-122, N4713U
HONOLULU, HAWAII
FEBRUARY 24, 1989
U.S. GOVERNMENT PRINTING OFFICE: 1989 0-942-365
NTSB/AAR-92/02 PB92-910402
NATIONAL TRANSPORTATION
SAFETY BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989
Adopted: March 18, 1992 Notation 5059C
Abstract: This report explains the explosive decompression resulting from the loss of a cargo door in flight on United Airlines flight 811, a Boeing 747-122, near Honolulu, Hawaii, on February 24, 1989. The safety issues discussed in the report are the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, and emergency response. Recommendations concerning these issues were made to the Federal Aviation Administration, the State of Hawaii, and the U.S. Department of Defense.
CONTENTS

EXECUTIVE SUMMARY

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.

The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.

A year after the accident, the Safety Board was uncertain that the cargo door would be located and recovered from the Pacific Ocean. The Safety Board decided to proceed with a final report based on the available evidence without the benefit of an actual examination of the door mechanism. The original report was adopted by the Safety Board on April 16, 1990, as NTSB/AAR-90/01.

Subsequently, on July 22, 1990, a search and recovery operation was begun by the U.S. Navy with the cost shared by the Safety Board, the Federal Aviation Administration, Boeing Aircraft Company, and United Airlines. The search and recovery effort was supported by Navy radar data on the separated cargo door, underwater sonar equipment, and a manned submersible vehicle. The effort was successful, and the cargo door was recovered in two pieces from the ocean floor at a depth of 14,200 feet on September 26 and October 1, 1990.

Before the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.

Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.

The issues in this investigation centered around the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

As a result of this investigation, the Safety Board issued safety recommendations concerning cargo doors and other nonplug doors on pressurized transport category airplanes, cabin safety, and emergency response.

NATIONAL TRANSPORTATION SAFETY BOAR

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989

1. FACTUAL INFORMATION

1.1 History of the Flight

On February 24, 1989, United Airlines (UAL) flight 811, a Boeing 747-122 (B-747), N4713U, was being operated as a regularly scheduled flight from Los Angeles, California (LAX) to Sydney, Australia (SYD), with intermediate stops in Honolulu, Hawaii (HNL) and Auckland, New Zealand (AKL).

The flightcrew assigned to the LAX/HNL route segment reported no difficulty during their flight.

A flightcrew change occurred when flight 811 arrived at HNL. The oncoming captain stated that he and his crew reported to UAL operations 1 hour and 15 minutes prior to the flight's scheduled departure time from HNL. The crew had completed a 34-hour layover (rest period) in HNL.

The captain reviewed the flight plan, the weather, pertinent NOTAMs, and maintenance records, and signed the Instrument Flight Rules (IFR) clearance before boarding the airplane.

Flight 811 departed HNL gate 10 at 0133 Honolulu Standard Time (HST), 3 minutes after the scheduled departure time, with 3 flight crewmembers, 15 cabin crewmembers, and 337 passengers. The flightcrew attributed the short delay to cabin crew problems with arming the 5L cabin door emergency exit slide and the normal securing of the 2L door after a somewhat extended passenger boarding process. The second officer stated that all cabin and cargo door warning lights were out prior to the airplane's departure from the gate. He said that he dimmed the annunciator panel lights at his station while the airplane was departing the gate area.

The captain was at the controls when the flight was cleared for takeoff on HNL runway 8R at 0152:49 HST. The auxiliary power unit (APU), which was used during the takeoff, was shutdown shortly after making the initial power reduction to climb thrust. The flightcrew reported the airplane's operation to be normal during the takeoff and during the initial and intermediate segments of the climb. The flightcrew observed en route thunderstorms both visually and on the airplane's weather radar, so they requested and received clearance for a deviation to the left of course from the HNL Combined Center Radar Approach Control (CERAP). The captain elected to leave the passenger seat belt sign "on."

The flightcrew stated that the first indication of a problem occurred while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed (IAS) of 300 knots. They heard a sound, described as a "thump," which shook the airplane. They said that this sound was followed immediately by a "tremendous explosion." The airplane had experienced an explosive decompression. They said that they donned their respective oxygen masks but found no oxygen available. The airplane cabin altitude horn sounded and the flightcrew believed the passenger oxygen masks had deployed automatically.

The captain immediately initiated an emergency descent, turned 180(to the left to avoid a thunderstorm, and proceeded toward HNL. The first officer informed CERAP that the airplane was in an emergency descent and appeared to have lost power in the No. 3 engine. The appropriate 7700 emergency code was placed in the airplane's radar beacon transponder and an emergency was declared with CERAP at approximately 0220 HST. The No. 3 engine was shut down shortly after commencing the descent because of heavy vibration, no N1 compressor indication, low

exhaust gas temperature (EGT), and low engine pressure ratio (EPR).
The second officer then left the cockpit to inspect the cabin area and returned to inform the captain that a large portion of the forward right side of the cabin fuselage was missing. The captain subsequently shut down the No. 4 engine because of high EGT and no N1 compressor indication, accompanied by visible flashes of fire. The flightcrew initiated fuel dumping during the descent to reduce the airplane landing weight.
The airplane was cleared for an approach to HNL runway 8L. The final approach was flown at 190 to 200 knots with the No. 1 and No. 2 engines only. During flap extension, the flightcrew observed an indication of asymmetrical flaps as the flap position approached 5(. The flightcrew decided to extend inboard trailing edge flaps to 10(for the landing. The right outboard leading edge flaps did not extend during the flap lowering sequence. The airplane touched down on the runway, approximately 1,000 feet from the approach end, and came to a stop about 7,000 feet later. The captain applied idle reverse on the Nos. 1 and No. 2 engines and employed moderate to heavy braking to stop the airplane. At 0234 (HST), HNL tower was notified by the flightcrew that the airplane was stopped and an emergency evacuation had commenced on the runway.
After the accident, UAL ramp service personnel, who had been involved with the cargo loading and unloading of flight 811 before takeoff from HNL, stated that they had opened and closed the forward cargo door electrically. They said that they had observed no damage to the cargo door. The ramp service personnel said that they had verified that the forward cargo door was flush with the fuselage of the airplane, that the master door latch handle was stowed, and that the pressure relief doors were flush with the exterior skin of the cargo door.
The dispatch mechanic stated that, in accordance with UAL

procedures, he had performed a "circle check" prior to the airplane's departure from the HNL gate. This check included verification that the cargo doors were flush with the fuselage of the airplane, that the master latch lock handles were stowed, and that the pressure relief doors were flush or within 1/2 inch of the cargo door's exterior skin. He said a flashlight was used during this inspection.

The second officer stated that, in accordance with UAL Standard Operating Procedures (SOP) he had performed an operational check of the door warning annunciator lights as part of his portion of the cockpit preparation. The second officer also stated that he used a flashlight while performing an exterior inspection, again in accordance with UAL procedures. The exterior inspection was conducted while ramp service personnel were performing cargo loading operations and the cargo doors were open. He stated that he had observed no abnormalities or damage.

1.2 Injuries to Persons

Injuries Flightcrew Cabincrew Passengers Others Serious *Lost in flight. An extensive air and sea search for the passengers was unsuccessful.

1.3 Damage to the Airplane

The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward.

Examination of all structure around the area of primary damage disclosed no evidence of preexisting cracks or corrosion. All fractures were typical of fresh overstress breaks.

Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos. 3 and 4. No damage was noted on the left side of the airplane, including engines Nos. 1 and 2.

The right wing had sustained impact damage along the leading edge between the No. 3 engine pylon and the No. 17 variable camber leading edge flap. Slight impact damage to the No. 18 leading edge flap was noted.

There was a break and scuff in the wing leading edge aft of engine No. 4 and a scuff in the wing leading edge outboard of engine No. 4. There was a large indentation (to a depth of nearly 8 inches) in the area just above the outboard landing light, and the landing light covers were broken. There was a small puncture in the upper surface of the No. 14 krueger flap and impact damage to the wing leading edge just aft of the No. 14 krueger flap. There was a gash on the upper wing surface aft of the No. 14 krueger flap and leading edge, as well as punctures to the wing leading edge aft of the number 16 krueger flap. The under wing surface aft of the krueger flaps also sustained impact damage.

The right wing also had sustained damage at the wing-to-body fairing and two flap track canoe fairings.1 Wing-to-body fairing damage was limited to surface scraping forward of and below the wing. The outboard surface of the No. 6 flap track canoe fairing revealed a slightly more significant gouge mark. The most severe damage was evident on the inboard surface of the No. 8 flap track canoe fairing, where three separate punctured areas were observed. The trailing edge flaps were not damaged.

The leading edge of the right horizontal stabilizer had several dents. The most severe dents, located 8 to 10 feet from the stabilizer root, were approximately 3 inches wide and 1 inch deep. No punctures were found. The vertical stabilizer had multiple small and elongated indentations with a maximum depth of 1/2 inch near the right base of the leading edge. A small gouge and two small scrapes were noted at midspan of the upper rudder.

A piece of cargo container was found lodged between the No. 3 engine pylon (inboard) and the wing underside. The piece of metal had severed the pneumatic duct for the leading edge flaps. Various nicks and punctures were evident on the inboard side of the No. 3 engine pylon. The No. 4 engine pylon had a small puncture near the leading edge of the wing.

The external surfaces of the No. 3 engine inlet cowl assembly exhibited foreign object damage including small tears, scuffs and a large outwardly directed hole. The entire circumference of all the acoustic (sound attenuator) panels installed on the inlet section of the cowl had been punctured, torn, or dented. None of the No. 3 engine cases were penetrated by objects, nor was there evidence of fire damage to any visible engine components and accessories. The leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage.

External damage to the No. 4 engine inlet and core cowls was confined to the inboard side of the inlet cowl assembly. The damage consisted of one major scuff mark, four lesser scuff marks and one crescent- shaped cut. The sound attenuator panels that were installed in the inlet area of the inlet cowl assembly had not been penetrated. The No. 4 engine fan blade airfoils had sustained both soft and hard object damage from foreign objects.

The cargo door separation resulted in the loss of fuselage shell structure above the cargo door, along with main cabin floor structure below seats 8GH through 12GH (see figure 3). The missing floor area extended inboard from the interior of the right side fuselage wall to the inboard seat track of seats 8GH through

12GH.

The supply and fill lines from the flightcrew oxygen bottle, and the supply line for the passenger oxygen system had been broken below the cabin floor inboard of the missing cargo door.

The two cabin pressurization out-flow valves, located on the underside of the fuselage, aft of the rear cargo compartment, were found fully open. The two over-pressure relief valves located on the forward left side of the airplane were found in the normal closed position. These valves were removed and bench tested. (See section 1.16.3, Pressurization System.) The majority of the cabin floor-to-cargo compartment blowout panels were found activated. The blowout panels are designed to relieve excess pressure differential following an explosive decompression to prevent catastrophic damage to the cabin floor structures.

The estimated damage to the airplane was $14,000,000, based on UAL's costs to repair it.

1.4 Other Damage

No other property damage resulted from this accident.

1.5 Personnel Information

The crew consisted of 3 flight crewmembers (the captain, the first officer, and the second officer) and 15 cabin crewmembers. (See appendix B.)

1.6 Aircraft Information

1.6.1 General

On February 24, 1989, the United Airlines B-747 fleet consisted of 31 airplanes, including: 2 B-747-222B, 11 B-747-SP, 5 B-747-123, and 13 B-747-122 series airplanes. N4713U was equipped with four Pratt & Whitney model JT9D engines.

The accident airplane, serial No. 19875, registered in the United States as N4713U, was manufactured as a Boeing 747-122 transport category airplane by the Boeing Commercial Airplane Company (Boeing), Seattle, Washington, a Division of the Boeing Company. N4713U, the 89th B-747 built by Boeing, was manufactured in accordance with Federal Aviation Administration (FAA) type certificate No. A20WE, as approved on December 30, 1969. The airplane was certificated in accordance with the provisions of 14 CFR Part 25, effective February 1, 1965. The maximum calculated takeoff weight for flight 811 was 706,000 pounds. The flight plan data showed an actual takeoff weight of 697,900 pounds. The center of gravity (CG) for takeoff was computed at 20.4 percent mean aerodynamic chord (MAC). The forward and aft CG limits were 12 and 29.7 percent MAC, respectively.

At the time of the accident, N4713U had accumulated 58,815 total flight hours and 15,028 flight cycles. N4713U had not been involved in any previous accident. Records indicated that the airplane had been inspected and maintained in accordance with the General Maintenance Program as defined in UAL Operations Specifications and in accordance with the FAA approved Aircraft and Powerplants Reliability Program. The records indicated that all required inspection and maintenance actions had been completed within specified time limits and all applicable airworthiness directives (AD) had been accomplished or were in the process of being accomplished, with the exception of AD 88-12-04, which was applicable to the B-747 lower lobe cargo door, and which had only been complied with partially. (See section 1.6.8 for explanation).

1.6.2 Cargo Door Description and Operation

Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Electrical power for operation of the cargo door switches and actuators is supplied from the ground handling bus, which is powered by either external power or the APU. See figure 17 for a diagram of the cargo door electrical circuitry. The engine generators cannot provide power to the ground handling bus. APU generator electrical power to the ground handling bus is interrupted when an engine generator is brought on line after engine start. The APU generator "field" switch can be reengaged by the flightcrew, if necessary on the ground, to power the ground handling bus. The air/ground safety relay automatically disconnects the APU generator from the ground handling bus, if it is energized, when the airplane becomes airborne and the air/ground relay senses that the airplane is off the ground.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with pull-in hook pins on the sides of the door frame. (See figure 4 for cargo door components).

The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. Figure 5 depicts a lock sector and latch cam in an unlocked and locked condition.

Figure 4.--Boeing 747 lower lobe forward cargo door.

Figure 5.--Cargo door latch cam and lock sector in unlocked and

locked ositions.

The door has three electrical actuators for opening/closing and latching of the door. One actuator (main actuator) moves the door from the fully open position to the near closed position, and vice versa. A second actuator (pull-in hook actuator) moves the pull-in hooks closed or open, and the third actuator (latch actuator) rotates the latch cams from the unlatched position to the latched position, and vice versa. The latch actuator has an internal clutch, which slips to limit the torque output of the actuator.

Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull- in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator. The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The B-747 cargo door has eight (8) view ports located beneath the latch cams for direct viewing of the position of the cams by means of alignment stripes. Procedures for using these view ports for verifying the position of the cams were not in place or required by Boeing, the FAA, or UAL (see 1.17.5 for additional information).

Closing the door manually is accomplished through the same sequence of actions without electrical power. The door actuator mechanisms are manually driven to a closed and latched position by the use of a one-half inch socket driver. The door can also be opened manually with the use of the socket driver. There are separate socket drives for the door raising/lowering mechanism, the pull-in hooks, and the latches.

Operating procedures for the normal electrical operation of the forward and aft cargo doors are outlined in the UAL Maintenance Manual (MM). Authorization for deferral of maintenance on the door power system is contained in the UAL B-747 Minimum Equipment List (MEL). In addition, operating procedures for dispatching aircraft with an inoperative door electrical power system (manual operation) are specified in the operator's MEL. The UAL MM differs from Boeing's recommended MM. UAL had modified Boeing printed material or replaced pages with their own methods and procedures for conducting maintenance functions. The modifications to the manufacturer's MM were accepted by the FAA through "approval" by the FAA Principal Maintenance Inspector (PMI). Electrical cargo door open/close operations in the UAL and Boeing MM's are approximately the same, except the final "Caution" statement differs in methods to ensure that the latch cams are closed:

United Airlines Maintenance Manual

CAUTION DO NOT FORCE HANDLE. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

Boeing Airplane Company Maintenance Manual

CAUTION DO NOT FORCE HANDLE. IF RESISTANCE IS FELT, CHECK LATCH ALIGNMENT STRIPES THROUGH VIEWING PORTS IN DOOR. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

The following step in Boeing's MM does not appear in the UAL MM: "Check that the Cargo Door Warning Light on flight engineer panel goes out." The UAL flightcrew checklist includes a check of the warning light as part of the cockpit procedures for dispatch.

Prior to the issuance of AD-88-12-04 (see 1.6.8), UAL ramp service personnel only operated the cargo doors electrically. Manual operation was accomplished only by maintenance personnel.

AD-88-12-04 required the additional procedure of recycling the master latch lock handle following manual operation of the latch actuator.

1.6.3 UAL Boeing 747 Special Procedures--Doors

The Safety Board's investigation revealed that UAL had published a "special maintenance procedure" in the UAL MEL for manual operation of the cargo door. The Maintenance Manual Special Procedures, 5-8-2-52, dated January 1988, were incorporated into UAL's MEL for use by maintenance controllers and work foremen in issuing instructions or procedures to mechanics. The procedure allowed the use of a special 1/2-inch socket drive wrench as the primary tool for use in manually opening or closing the cargo door. The document further authorized, as an alternate tool, an air-driven torque-limiting screwdriver. UAL procedures required approval by San Francisco Line Maintenance and the station maintenance coordinator before an air-driven screwdriver could be used to operate the doors of a B-747 airplane with an inoperative cargo door power system.

At the Safety Board's public hearing, the FAA PMI and the FAA B-747 maintenance inspector for UAL testified that prior to the accident they were unaware of an FAA authorization for UAL's use of an air-driven torque-limiting screwdriver on B-747 cargo doors. However, the FAA's approval for the use of the tool was noted in the MEL section of the airline's maintenance manual. The original approval had occurred before the current inspectors assumed their respective positions. Both testified that they had not reviewed UAL's B-747 MEL because they assumed that the previous inspectors had reviewed it.

According to UAL, the calibration/adjustment for the torque-limited air-driven screwdrivers was tested every six months. Safety Board investigators found no records for the calibration/adjustment of the power tools used to manually open and close UAL B-747 cargo doors.

The Safety Board received statements from UAL supervisory maintenance personnel at all UAL stations and contract facilities for B-747 operations indicating that air-driven screwdrivers had not been used by maintenance personnel to open or close the forward cargo door on N4713U in the months prior to the accident.

1.6.4 UAL Maintenance Program

Airplanes operated by UAL are maintained under an FAA-approved continuous airworthiness maintenance program, as required by 14 CFR Part 121, Subpart L. The requirements of the UAL maintenance program are detailed in their Operations Specifications, dated November 21, 1988. Generally, UAL has an overall in-house capability to perform virtually all of the maintenance required on its own airframes and powerplants. All of the required major airframe and powerplant maintenance for N4713U had been performed at the UAL maintenance facility in San Francisco, California.

UAL's maintenance and inspection program is scheduled either at specific flight hour or calendar intervals. These maintenance and inspection programs are designated as: Service No. 1, Service No. 2, or A, B, C, MPV, and D Checks.

The work scope of Service Checks consists of a general inspection of the airplane and engines, including servicing of consumable fluids, oxygen, and tire pressures. The Service No. 1 check involves an inspection at each maintenance facility where the airplane lands. The Service No. 2 check is performed at a maintenance facility where the airplane is scheduled for at least 12 hours of ground time. The maximum time interval between Service No. 2 Checks is not to exceed 65 flight hours.

The "A" Check is performed at intervals not to exceed 350 flight hours. This check includes an extended inspection of the cockpit, cabin, cargo compartments, landing gear, tires, and brakes. It does not include a detailed inspection of the cargo doors.

The Phase Check ("B" Check) is scheduled on a calendar basis, not to exceed 131 days. The scope of the "B" Check contains items of inspection such as interior safety equipment and functional verification of various aircraft systems and components. It does not include a detailed inspection of the cargo doors.

The "C" Check is heavy maintenance oriented and is scheduled on a calendar basis, every 13 months. The "C" Check work scope is substantial and includes:

structural inspection items;

corrosion repair;

prevention and inspection of critical flight control systems; and,

a detailed inspection of the cargo doors.

The Mid-Period Visit (MPV) Check is a heavy maintenance inspection that is scheduled at intervals not to exceed 5 years. Items requiring scheduled overhaul are contained in the check as well as inspections of the airplane structure and interior.

The D Check, completes the routine scheduled B-747 maintenance plan and is scheduled at intervals not to exceed 9 years. The work scope is very similar to the MPV Check and consists of heavy maintenance to the airplane structure, landing gear, interior, and airplane systems, including the cargo doors.

1.6.5 Maintenance Records Review

A review of the airplane's history indicated that the forward and aft cargo doors were the original doors and neither had been removed for repair or replaced for cause. There was no record of major repair to either door or adjacent airplane structure.

The forward cargo door's forward mid-span latch pin had been removed because of gouging of the pin surface, during the last "C" check on

November 28, 1988. According to the available maintenance documents, including the most recent "D" check, a full cargo door rigging check had not been accomplished. UAL maintenance personnel indicated that no rigging of the forward or aft cargo doors was required during the following checks:

1. "D" check accomplished April 1984;
2. "C" checks accomplished November 11, 1987, and November 28, 1988; and,
3. "B" checks accomplished March 21, 1988 and July 27, 1988;

The records prior to the "D" check in 1984 and the "C" check accomplished in November 1987 were not required to be retained. This procedure complies with FAR 121.380.

The logbook of N4713U was reviewed and all numbered pages were in sequential order with none missing. The airplane had been released for flight by UAL, HNL Maintenance, in accordance with UAL procedures. The Los Angeles to HNL segment of flight 811, on February 23, 1989, generated four logbook discrepancy entries. All items were cleared by HNL maintenance and none were related to the cargo door. No new deferred items were generated and no current deferred items were corrected. The Maintenance Release document for flight 811 indicated that all deferred items were in accordance with the UAL Minimum Equipment List (MEL) and none referenced the forward cargo door.

UAL stores its maintenance information in an "electronic logbook," entitled Aircraft Maintenance Information System (AMIS). This system tracks on a daily and worldwide basis the flightcrew defect reports, all nonroutine maintenance defects, and maintenance corrective actions for the UAL airplane fleet. The system follows an Airline Transport Association (ATA) chapter format. According to UAL, the AMIS information is used as part of UAL's FAA approved maintenance reliability program affording the capability to assess trends at any given time.

A complete history of N4713U was reviewed for the following ATA Chapters:

Chapter-00-Miscellaneous

No significant items associated with the cargo door systems.

Chapter-21-Air Conditioning and Pressurization

An entry, dated August 19, 1988, indicated "Auto and Standby pressure controllers were erratic." UAL maintenance cleared this item as "Checked per Maintenance Manual Chapter (MM) 21-31-00.

Chapter-31-Instruments (Not related to any specific system)

No significant items associated with the cargo door systems.

Chapter-52-Doors (Cargo door section only)

During the period September 7, 1988, through November 1, 1988, a series of five discrepancies on the forward cargo door's electrical opening and closing system were noted. Ground handling personnel were required to operate the door by the manual system. On November 1, 1988, UAL maintenance corrective action for this discrepancy was signed off as, "replaced power unit [lift mechanism] per Maintenance Manual Chapter 52-34-02.

An expanded AMIS history of the N4713U forward cargo door system was prepared beginning December 1, 1988, and continuing until the date of the accident. The history tracked the airplane by each flight and station transited.

During the period December 5, 1988, through December 23, 1988, eight defect reports regarding the opening and closing of the forward cargo door were entered into the system. The reported defects involved problems with the cargo door not always operating with the normal electrical system. Appendix E contains the details of the writeups and corrective actions.

During the period December 23, 1988, through February 23, 1989, two forward cargo door discrepancies were noted on N4713U. On January 3, 1989, the discrepancy was, "Manual lock seals broken." The corrective action was signed off as, "recycled [door] per placard on door and documented. No door problems." On January 15, 1989, the discrepancy was, "cargo door seal, lower aft corner is torn and loose from retainer." The corrective action was "repaired seal." There were no further recorded discrepancies.

On February 23, 1989, a written discrepancy noted "Aft cargo door damaged aft lower corner." The corrective action listed, "Interim repair per (EVA) LM-8-433. Accomplish permanent repair within 60 flight hours."

Chapter-53-Structures (Fuselage)

During the period March 1988, through February 24, 1989, one defect was noted for each of the forward and aft cargo doors on N4713U.

Forward Cargo Door.--On September 6, 1988, the discrepancy was, "Approximately six inches of forward cargo door jamb damaged center of lower side sealing surface." The corrective action was, "Installed doubler and sealed area."

Aft Cargo Door.--On April 22, 1988, the discrepancy was, "Aft cargo door rear sill latch does not spring up to lock." The corrective action was, "Replaced latch."

1.6.6 Service Difficulty Report Information

A review was made of the Service Difficulty Reports (SDRs) for ATA Chapter 52 for all UAL Boeing 747 airplanes. Thirty-nine SDRs were recorded over the period January 31, 1983, through March 21, 1989. The following summarizes data concerning the forward and aft cargo doors:

cases of corrosion;

cases of cracking;

cases of door open (false) indications;

cases where cabin did not pressurize;

cases of cabin pressure loss; and

case of dent caused by ground equipment.

None of the noted SDR cases were recorded for N4713U.

1.6.7 Service Letters and Service Bulletins

Boeing issues information to its customers via Service Letters

(SL's) and Service Bulletins (SB's) to inform operators of reported and anticipated difficulties with various airplane models. Twelve SL's provided guidance for maintenance or information applicable to the B-747 cargo doors. Twenty-nine SB's provided guidance for maintenance or information applicable to the B-747 cargo door.

SB-747-52-2097, "Pressure Relief Door Shroud Installation--Lower Lobe and Side Cargo Doors," was issued on June 27, 1975. Revision 1 to SB-747-52-2097 was issued November 14, 1975. In general, the SB recommended the installation of shrouds on the inboard sides of the cargo door pressure relief door openings. The purpose of the shrouds was to prevent the possibility of the pressure relief doors being rotated (blown) to the closed position during the pressurization cycle. This condition could only occur if the master latch lock handle had been left open and the flightcrew failed to note the cargo door open warning before takeoff.

UAL records for N4713U indicated that SB-747-52-2097 had been complied with and the shrouds had been installed on the forward and aft cargo doors. However, examination of the aft cargo door on N4713U revealed that the shrouds were not in place. UAL could not find records to verify if the shrouds had been installed or if they had been removed from either door.

1.6.8 Airworthiness Directives

There had been 141 Airworthiness Directives (ADs) issued that were applicable to the accident airplane. Two ADs were pertinent to the cargo door. AD 79-17-02-R2 ("Inspection of Fore and Aft Lower Cargo Door Sill Latch Support Fittings,") required an inspection every 1,700 flight hours. The second, AD 88-12-04 ("To Insure That Inadvertent Opening Of The Lower Cargo Door Will Not Occur In Flight,") issued on May 13, 1988, required an initial one time inspection of the cargo door latch locking mechanisms within 30 days of issuance of the AD, and certain repetitive

inspections until terminating action for the AD was taken.
The circumstances of a Pan American World Airways (Pan Am), Boeing 747-122 cargo door opening in flight (see 1.17.1 for details) led to the issuance of Boeing Alert Service Bulletins (ASB) 52A2206 on April 8, 1987, and 52A2209 on August 27, 1987, entitled, "Doors - Cargo Doors Lower Lobe Forward and Aft Cargo Doors, Latch Locking System Tests, Operation and Modification." Tests and investigation revealed that latch lock sectors would, in some instances, not restrain the latch cams from being driven open manually or electrically. Movement of the latch cams without first moving the lock sectors to the stowed [unlocked] position would cause bending, gouging, and breaking of the sectors. The FAA issued AD-88-12-04 to make the provisions of SB's 52A2206 and 52A2209 mandatory.
The terminating action for AD 88-12-04 called for installing steel doublers to add strength to the lock sectors to prevent the latch cams from being able to be driven to the open position manually or electrically with the sectors in the locked position. AD 88-12-04 also required that, if the door could not be operated normally (electrically), a trained and qualified mechanic was to open and close the door manually, rather than ramp service personnel. Further, the AD required an inspection of the lock sectors for damage once a cargo door was restored to electrical operation after any malfunction had required manual operation of the door.
The amount of time allowed for completing the terminating action portion of AD 88-12-04 was either 18 months or 24 months, from the issue date of the AD, depending on the Boeing 747 model series. Terminating action for the AD had not been accomplished on N4713U prior to the accident, nor was it required since, for this airplane, the deadline for compliance with the terminating action was January 1990. According to UAL, N4713U was scheduled for completion of the terminating action in April 1989, when the airplane was scheduled for other heavy

maintenance.
During the Safety Board's investigation it was determined that a clerical error was made by UAL personnel, while attempting to expedite the processing of an advanced copy of a Notice of Proposed Rulemaking (NPRM 87-NM-148-AD), preceding AD 88-12-04. The error involved the omission of one line of text during the typing of the document. Because of that error, the portion of the text of the NPRM (and the final text of the AD) was left out of UAL's maintenance procedures. The omitted text required an inspection of the B-747 cargo door lock sectors every time a cargo door was restored to normal (electrical) operation after manual operation was required.
The UAL maintenance internal auditing system, including quality assurance personnel, did not detect the omission until after the accident. UAL personnel stated that, for unknown reasons, no one within the maintenance or quality assurance programs had reviewed the final AD language for comparison with the UAL maintenance procedure.
A review by Safety Board investigators of forms used by UAL to verify compliance with applicable FAA AD's issued indicated that all of the applicable mandatory ADs were satisfied within their specified time limits. The list provided by UAL to the FAA as part of the FAA's oversight responsibilities showed compliance with AD-88-12-04, with the exception of the terminating action.
Section 1.17.3 contains information relevant to the B-747 cargo door corrective actions taken since the accident.
1.7 Meteorological Information
The accident occurred in night visual meteorological conditions. No adverse weather was experienced, although the flight did have to deviate around thunderstorms during the descent.
1.8 Aids to Navigation
There were no navigational problems.
1.9 Communications

There were no radio communication difficulties between flight 811 and air traffic control (ATC). Members of the flightcrew did not have any difficulty in verbally communicating with each other; however, attempts to communicate with the cabin crewmembers by interphone were unsuccessful following the explosive decompression.

1.10 Aerodrome Information

After the explosive decompression, the airplane returned to HNL, a 14 CFR Part 139 certificated airport on the island of Oahu, Hawaii. The airport is located about 4 miles west of Honolulu, Hawaii.

HNL is a "joint use" airport that is used by the State of Hawaii, the U.S. Air Force, general aviation, commercial, air carrier, air taxi, and military aircraft. Aircraft Rescue and Fire Fighting (ARFF) services are provided by State and Hickam Air Force Base ARFF units. Prior to the emergency landing at Honolulu, flight 811 requested that all available rescue and medical equipment to be on hand when they landed. When the crash alarm was broadcast, all civilian and military fire units responded and were in position in 1-minute at pre-designated stations at runway 8 left.

The Safety Board's investigation revealed that there was no direct radio communications between the State Airport vehicles and Hickam ARFF vehicles. Because there were no direct radio communications, the Chief of the airport's units had to drive his vehicle to the vehicle of the Chief of the Hickam units to coordinate the positioning of ARFF units prior to the landing of United 811.

The Hickam vehicles are painted olive drab camouflage. During the response, the Chief of the State ARFF vehicles observed a near collision between a State and a Hickam vehicle. He attributed this to the camouflaged Hickam vehicle not being visually conspicuous in spite of the fact that each of the vehicles had a red rotating beacon operating. The response took place on a moonless night and in light rain.

1.11 Flight Recorders

The airplane was equipped with a Sundstrand model 573 digital type Flight Data Recorder (DFDR) and a Sundstrand model AV557-B Cockpit Voice Recorder (CVR).

Examination of the data plotted from the DFDR indicated that the flight was normal from liftoff to the accident. The recorder operated normally during the period. However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent.

The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.

1.12 Wreckage and Impact Information

An extensive air and surface search of the ocean conducted immediately following the accident failed to locate the portions of the airplane lost during the explosive decompression. However, the Safety Board, as well as other parties to the investigation, pursued several avenues to search for and recover the cargo door. Navy radar near Honolulu tracked debris that fell from the airplane when the cargo door was lost. Refinement of the radar data led to a probable "splashdown" point in the ocean. Further assistance from the Navy regarding the ocean currents and drift information led to a probable location of the cargo door and associated debris on the ocean floor.

The undersea search operation was begun on July 22, 1990, using the Orion, a state-of-the-art Navy side-scanning sonar "fish." Searching in the area selected by analysis of radar data and undersea currents, the Orion located a debris field on its first pass over the 14,200-foot-deep ocean floor. The second pass located a significant sonar target, which later analysis indicated was probably the cargo door. Since the Orion is only capable of searching, the debris field was marked with transponders for use during the subsequent recovery phase.

On September 14, 1990, the recovery ship Laney Chouest sailed from Pearl Harbor with the manned, deep-sea submersible Sea Cliff. Safety Board, FAA, Boeing, and UAL engineering staff assisted the recovery team aboard the Laney Chouest. After four dives in the area previously identified as the debris field, only pieces of cargo container and other small debris from the airplane had been recovered. (It appears that the significant target identified by the Orion was a piece of cargo container rather than the cargo door.) On the following dive, however, the lower portion of the cargo door was located and recovered. The fuselage structure above the cargo door was located and raised to the surface on the sixth dive, but heavy seas prevented its recovery. The upper portion of the door was recovered during the Sea Cliff's seventh dive on October 1, 1990. Afterward, it was decided that no further effort could be justified to recover the fuselage structure above the cargo door, and the recovery mission was terminated.

Following recovery of the cargo door, each piece was sprayed with a corrosion inhibitor. The ship promptly returned to Pearl Harbor, and the retrieved door portions were removed and examined before being shipped to Seattle, Washington, for detailed examinations under the supervision of Safety Board staff. Visual examinations on the recovery ship and in Pearl Harbor confirmed that the cargo door lock sectors were in the locked position and that the latch cams were in the nearly open position. Figure 6 depicts the position of the lock sectors and cams as recovered from the ocean. There was no evidence of progressive fractures in the door structure.

The cost for the search mission was $193,000, and the cost for the recovery mission was $250,000. These costs were shared by the Safety Board, the FAA, UAL, and Boeing. Section 1.16 contains information on the examination of the recovered wreckage.

1.13 Medical and Pathological Information

Appendix D contains a list of injuries.

1.14 Fire

There was no fire in the cabin or fuselage. The fires in engines No. 3 and 4 were extinguished after the engines were shut down.

1.15 Survival Aspects

The fatal injuries were the result of the explosive nature of the decompression, which swept nine of the passengers from the airplane.

At 0210, the FAA notified the U.S. Coast Guard that a United Airlines, Inc., B-747, with a possible bomb on board, had experienced an explosion and was returning to HNL. The Coast Guard Cutter, Cape Corwin, departed Maui at 0248 to search the area for debris and the missing passengers. Ultimately, 4 shore commands, 13 surface/air units, and approximately 1,000 persons took part in the combined search and rescue (SAR) operation. The search was t™ erminated at 1200 on February 26, 1989, without recovery of any passenger bodies.

The flight attendants had approximately 20 minutes to prepare the cabin and the passengers for an imminent ocean ditching, and subsequently, for an emergency evacuation. During the 20 minutes they attended to injured flight attendants and passengers, attached the face masks to their emergency oxygen bottles, helped each other don life preservers, helped numerous passengers don life preservers, held up safety cards and life vests to call attention to these items for passengers to use, briefed "helper" passengers to assist in the evacuation, cleared debris away from the exit doors and aisles, closed the doors of the storage compartment above doors 2 left and 2 right, prepared the cabin for an emergency evacuation, and told the passengers to brace for impact.

Several problems were experienced by the flight attendants and the passengers following the decompression, while preparing for a possible ditching, and preparing for the emergency evacuation. These problems included difficulties encountered by flight attendants in connecting face masks to their portable oxygen bottles, the lack of a sufficient number of megaphones, limited visibility from a flight attendant seat, overhead storage compartment doors opening, and donning and fastening life preservers.

Federal Aviation Regulation 14 CFR 25.1447 (c)(4) requires that "portable oxygen equipment must be immediately available for each cabin attendant." Those portable oxygen bottles on N4713U, which were readily available, were not immediately usable because the masks were not attached to the regulators. The flight attendants reported difficulties in attaching the masks to the regulators.

The aft purser ran back to the flight attendant jumpseat at door 5-left for a portable oxygen bottle. However, she found no bottle at this location (none was installed). She then ran back to the 4-left jumpseat, by which time she was "light headed." After the aft purser reached jumpseat 4-left, flight attendant No. 14, who was already sitting there, placed an oxygen mask on her face. The aft purser further stated, "considering the fact that in this case there was no other available source of oxygen, you can't imagine how horrible I felt going back there needing oxygen but finding no oxygen bottle at 5-left. It was terrifying."

A portable emergency oxygen bottle was not required to be stowed at the flight attendant seat at exit 5-right; however, one was stowed in the right coat closet behind the flight attendant seat. In addition, the left side closet and rest rooms were physically separated from the right side closet and rest rooms. This arrangement requires a flight attendant, who was seated at exit 5-left to walk around to the right side of the cabin to obtain the oxygen bottle.

Communication between the flight attendants and passengers was very difficult because of the high ambient noise level in the cabin after the decompression, even though the public address (PA) system was operational. Flight attendants were located at each of the 10 exit doors, yet there were only two megaphones required to be on the airplane; one located at door 1-left and another located a 4-left.

The flight attendants, who were responsible for each of these two doors, used the megaphones to broadcast commands to passengers in their immediate areas and to other flight attendants in preparation for the landing and subsequent evacuation. The other 13 flight attendants (including the one deadheading flight attendant) had to shout, use hand signals, and show passengers how to prepare for the evacuation by holding up passenger safety cards, so passengers could review the information and also know how to put on their life preservers.

As soon as the decompression occurred, the flight attendant in the upper deck business class section went to her jumpseat and donned her oxygen mask, life preserver, and restraint system. While she waited for instructions, and because of intense cabin noise she had to communicate with passengers by holding up a safety card and a life preserver. Passengers sitting in the front rows, in turn, showed safety cards and life preservers to other passengers seated behind them. Eventually everyone understood that they were to read the safety card and put on their preservers. However, the 5 foot 3 1/2 inch flight attendant stated that her jumpseat was so low that she could not directly observe the passengers in the 4th row (last).

A two door overhead stowage compartment that had formerly stored a life raft was located above each exit door. These compartments contained blankets and passenger carry-on luggage. At doors 2-left and 2-right the doors of each compartment had opened downward and blocked each exit. Also the contents of the compartments fell to the floor at the exits. The doors had to be closed before the evacuation because they partially blocked the exit.

The chief purser was not able to tighten the life preserver's two straps around her waist and needed the deadheading flight attendant to tighten them for her. Several flight attendants and passengers had difficulties connecting the two straps around their waists. One flight attendant helped about 36 passengers don their preservers.

Safety Board investigators and United Airlines personnel examined several life preservers from each of the types of preservers produced by five manufacturers. The strap of one manufacturer's preserver was very difficult to tighten around the waist while another from the same manufacturer was easy to tighten. The two vests had different strap material and strap adjustment fittings. Also, the straps are very difficult, if not impossible, to tighten when they are pulled at an acute angle from the wearer's body, i.e. from about 45 to 70 degrees. Holding the hands and straps closer to the waist facilitates easier adjustment of the straps.

1.16 Tests and Research

1.16.1 Cargo Door Hardware Examinations

1.16.1.1 Before Recovery of the Door

The following forward cargo door closing and latching components were returned to the Safety Board's Materials Laboratory for analysis after they were documented in place on the airplane:

Two pull-in hook pins, one from the lower end of the forward side of the door body cutout forward frame, and one from the lower end of the aft side of the body cutout aft frame, with housings;

Two mid-span pins, one from the forward side of the door body cutout forward frame, and one from the aft side of the door body cutout aft frame.

All components were initially examined while installed on the airplane. All eight forward cargo door latch pins, with housings, were removed for further laboratory examination. Also, for comparison, one of the latch pins, with housing, from the aft cargo door was also removed. For orientation purposes, the eight lower latch pin assemblies are referred to by number, with the No. 1 latch pin being the most forward on the lower door sill, and the No. 8 pin being the most aft. When referencing a circumferential location on the latch pins or mid-span pins, a clock position was used. The clock code was oriented looking forward with 12 o'clock being straight up and 9 o'clock being directly inboard.

Based on the orientation of the latching mechanisms, the fully unlatched latching cams would first contact the latch pins from about the 1:15 o'clock position to the 7:15 position as the door was closed. As the cams are being latched around the pins, they would rotate approximately 80(, making contact with the pins from about the 4:15 position to the 10:15 position (See figure 7).

Detailed examination of the exposed surface of the pins (the portion of the pins extending from the housings) revealed various types of wear and damage. In general, all of the forward door cargo latch pins had smooth wear over the entire portion of the pin area contacted by the cams during normal closing and opening of the door. The pins also had distinct roughened (smeared) areas between the 6:15 and the 7:30 positions (See figure 8). The roughened areas had evidence of "heat tinting" and transfer of cam material to the surface of the pins. On pins 1 and 8 the roughened areas extended past the pin bottom to the 5:00 position. The 7:30 position approximately corresponds to the area on the pin where the lower surface of the cam would be relative to the pin when the latch cams are in the unlatched or nearly unlatched position.

The forward pull-in hook pin was not significantly bent, but the structure to which it was attached was deformed outward, so the hook pin was deflected significantly outward. Three of the four bolts holding the aft pull-in hook pin had sheared, so the hook pin was also deflected outward. Both hook pin ends were damaged, but neither pin was significantly deformed along its length. There was significant heat tinting on the damaged area of the forward hook pin. Boeing engineering calculations determined that the pull-in hook pins would fail at a 3.5 psi differential cabin pressure with the latch cams unlatched.

The forward mid-span latch pin was relatively undamaged. The aft mid-span latch pin had definite areas of damage. Both pins had wear areas where the cams would contact the pins during latching.

1.16.1.2 After Recovery of the Door

The documentation of the recovered cargo door was divided into four areas: 1) door structure, 2) master latch lock system, 3) latch system, and 4) hook system. A description of the recovered door follows.

1. Door Structure:

The cargo door had fractured longitudinally near the mid-span lap joint near stringer 34R, just beneath the mid-span torque tubes. Except for an area of missing skin between frames 2 and 3 and a portion of frame webs where the upper latch lock torque tube had torn out, the frames and skin of the upper door piece mated to the lower door piece.2 Several areas of the upper door skin along the longitudinal fracture were bent back. In addition, a large area of lower door skin between frame 6 and the aft door edge had peeled downward from the fracture line. The two door pieces are shown together in Figures 9 and 10. Examinations of the fracture surfaces of the skin and frames revealed no evidence of pre-existing cracks. All fractures were typical of overstress separation.

Seven of the eight lock sector slots in the lower beam showed evidence of contact and scraping by the lock sectors. Only the No. 1 lock sector slot was undamaged, although the bracket forward and above the No. 1 slot did appear to have been damaged by contact from the lock sector (slots numbered 1-8, forward-aft). The direction of the scraping on the slots could not be determined conclusively.

The decal covering the latch actuator manual drive port was found broken circumferentially around the edge of the port cover, which was loose and rotated from its normal position (See figure 11). There was an impression in the decal similar to a Phillips-head screw slot in line with the center of the retainer screw securing the cover. There was also a 0.06-inch-long linear slit from 10 to 4 o'clock approximately centered over the retainer screw head (See figures 12 and 13). There was no rotational tearing and no loss of decal material in the area covering the screw head location. During examinations of the door at Boeing, it was noted that the retainer bracket on the inside of the latch actuator manual drive port cover was bowed outward; the port cover was not deformed. The retainer bracket on the inside of the hook actuator manual drive port cover was similarly bowed outward, and the port cover was bowed outward.

The hinge that attaches the cargo door to the fuselage is

comprised of several hinge sections--those attached along the upper edge of the cargo door and those along the fuselage just above the cargo door cutout--interconnected with hinge pins. The hinge pins and all hinge sections from N4713U's forward cargo door were intact; all hinge sections rotated relatively easily. All attach bolts from the hinge sections on the door remained attached; conversely, no bolts remained attached to the hinge sections on the fuselage. Several areas on the hinge sections, such as the fuselage hinge sections, showed evidence of contact from the door during overtravel (See figure 14). In addition, the fuselage forward hinge sections
were slightly bent. The upper flange of the door, to which the door hinges are attached, was not deformed. The forward cargo door can rotate open 143 degrees before the hinge would deform, permitting the door to contact the fuselage above.

Examination of the outer skin contour of the upper door piece revealed that it had been crushed inward. There were also many areas on the outer skin where blue and red paint transfer marks could be seen. These marks were generally forward of the aft pressure-relief door, and the blue marks were located above the red marks. The UAL paint pattern incorporates red and blue stripes along the fuselage above the cargo door. Figure 15 is a plot of the documented paint marks on the upper door piece.

There was no evidence of the pressure relief door shrouds found on the forward door; however, most of the inner door lining to which the shrouds attach was missing.

2. Master Latch Lock System:

All eight lock sectors were found in the locked position--actually past the fully locked position. They had been pulled through the lock sector slots in the lower beam of the cargo door. (When they are fully locked, the lock sectors should be recessed in the lower beam approximately 3/8 inch). All lock sectors had deflected off the high shoulder of the latch cams due to interference with the partially unlatched cams. Prior to disassembly of the components, the interference between the cams and the lock sectors was removed by rotating the cams to the latched position.

Examination of the lock sectors disclosed that the bottom of the lower arm of each lock sector was gouged. For seven of the eight lock sectors, the distance from the main gouge area to the location of the interference between the latch cam and the lock sector was approximately 0.75 inch. (The No. 2 lock sector was corroded and had fractured at the location of the large gouge common to the other seven lock sectors. Consequently, it was not in contact with the No. 2 latch cam when the door was retrieved).

The master latch lock handle housing and trigger were found relatively flush with the door outer skin. The top of the handle was recessed approximately 0.50 inch inward from flush, and the bottom of the handle was protruding approximately 0.40 inch outward from flush (See figure 16). This

Figure 15.--Documented paint marks on outer skin of upper door piece. Dashed line is approximately 8 degrees from horizontal.

position of the handle indicates that the lock sectors were in a position past fully locked. The fuse pin was found in three pieces but was heavily corroded. The handle housing was undamaged.

Two of the three connecting rods between the master latch lock handle and the lock sector torque tube were bowed slightly, but they were otherwise intact. No deformation was observed on any section of the lock sector torque tube, although one of the six bearings assembled on the torque tube had been damaged. The No. 3 bearing inner race and its torque tube locator sleeve were displaced forward approximately 0.20 inch from the bearing housing centerline. The outer race was broken and pushed forward out of the housing.

The lower two connecting rods between the lock sector torque tube and the torque tube below the pressure-relief doors were undamaged; however, the upper connecting rod had separated at the upper, tapered end. The torque tube below the pressure-relief doors were missing, and the pressure-relief door connecting rods had separated at the lower, tapered end. The remaining portion of each rod was undamaged, but the forward pressure-relief door was jammed open into the cutout.

3. Latch System:

All eight lower latch cams were found in a nearly unlatched position, and all of them were binding against the lock sectors except the No. 2 cam (lock sector No. 2 had broken). Latch cams 1-6 were approximately 62 degrees from the fully latched position, and cams 7 and 8 were approximately 70 degrees from fully latched. Full rotation of the latch cams is 80 degrees.

Several of the lower latch cams contained compression and smearing damage on the lower lip of the latch cam cavity ("lower" relative to an open cam). This damage is consistent with the forceful movement of the cams across the latch pins.

The four rods between the latch actuator torque tube and the four bellcranks containing the latch cams were attached and undamaged. No section of the latch actuator torque tube was damaged, and the bearings/supports along the tube were intact. The latch actuator was removed and later disassembled. No anomalies were found.

4. Pull-in Hook System:

The forward and aft pull-in hooks were found near the closed position. Both of them exhibited wear patterns consistent with contact with the pull-in hook pins during door operation. For both the forward and aft hooks, the inboard edge of the pull-in hook channel contained compression and smearing damage consistent with a forceful movement of the hooks over the pins while the hooks were in the closed or nearly closed position.

1.16.2 Forward Cargo Door Electrical Component Examinations

1.16.2.1 Before Recovery of the Door

Several electrical components associated with the operation of the forward cargo door were examined on the airplane and were then removed for further testing. These components included the No. 2 ground handling power bus relay, the air/ground safety relay, the No. 1 auxiliary power circuit breaker, and the outside and inside door control switches. All of these components were tested for both single faults and intermittent failures. The test results showed that all of the switches/relays were functional, although a loose wire connection was found on the outside door control switch. This loose wire connection showed evidence of overheated insulation on the two terminal lugs that attach to terminal No. 5, and there was evidence of a burn (arc point) on the top of the screw head for terminal No. 5. Terminal No. 5 is associated with power for the door "close" cycle, and not the door "open" cycle.

An electrical continuity check was performed on the cockpit cargo door warning light system components that remained with the airplane. This check confirmed the integrity of the circuit from the door area to the cockpit. The examination of the two bulbs that comprise the forward cargo door warning light revealed that one bulb was inoperative. The other bulb, which is in parallel with the inoperative bulb, was found operative. The illumination of the display legend, which reads "FWD CARGO DR" on the flight engineer's panel, was discernible with one bulb inoperative. A functional check of the circuit, which allows the cockpit warning lights to be dimmed during night operations, was also performed. The check consisted of removing the card containing this circuit and installing it in another B-747. The test was satisfactory in that the dim/bright circuit functioned properly.

1.16.2.2 After Recovery of the Door

Switches--General

The cargo door was recovered with all of its position sensing switches installed in their proper locations. The electrical junction box was found attached to the door but damaged. The switches recovered and examined were: S2 Master Latch Lock; S3 Door Warning; S4 Latch Close; S5 Hook Position; S6 Fwd Mid-Span Latch Open; S7 Door Close; S8 Hook Close; and S9 Aft Mid-Span Latch Open. Figure 17 provides a diagram of the cargo door's electrical circuitry.

Five of the eight position-sensing switches installed on the door had evidence of external damage to the switch housing. The damage on four switches (S2,S3,S4,S8) consisted of primarily compression dimpling on the housing. The S5 switch exhibited mechanical impact damage on the switch housing and mounting bracket. The striker assembly for switch S8 was loose (2 of 3 rivet fasteners sheared). The electrical wiring recovered with the door exhibited signs of tensile separation from overload at all failure points examined.

Each switch was photographed and its installed position was documented. Electrical continuity readings were taken with an ohmmeter across the poles of each switch at the first point of wire separation as found on the door. After the readings were recorded, all switches were removed from the door so that photographs and x-rays of each switch could be taken. Electrical continuity readings were retaken.

Disassembly of each switch consisted of: (1) drilling two holes in the switch housing to release trapped water from the switch (2) cutting a small window in the switch housing to examine the internal basic switches (3) removing the housing, (4) removing the internal bracket, and (5) removing basic switch covers.

During the drilling step, water was released from every switch when the holes were drilled in the switch housing. The water was filtered into a glass container. The quantity was not measured but appeared to be less than 5 mL. The residue from the filtered water trapped on the filter media had a blue-green color.

After the switch housing was removed, an ohmmeter was connected across the 1-2 poles of the switches that would not transfer electrical continuity (S2,S3,S4,S6,S7) when actuated. The rivets were then drilled out of the internal bracket. After the last of the two rivets were drilled out, the switch contacts

Figure 17b.--Diagram of cargo door electrical circuitry.

transferred to the other pole on S2, S3, and S4. On S6, the used3 basic switch was held closed by its plunger. S7 transferred after the switch housing and water inside were removed.

During removal of the basic switch covers, a trend was noted in the discoloration of some of the basic switches. The used switch had a reddish-brown coloration. The unused switch was not discolored.

Each switch was found to be wired correctly to its poles and through its contacts within the basic switches. All contacts operated with light finger pressure after removal of the basic switch covers. There was no evidence of pitting, excessive corrosion, or heat distress in the contacts of any of the switches. The following sections detail pertinent observations concerning each switch.

The S2 master latch lock is given particular significance because of its function to protect against inadvertent door operation and is thus described in more detail. It is a single-pole double-throw (SPDT) switch used to sense the unlocked position of the door lock sectors. The switch is mounted in the aft lower corner of the door. A bracket attached to the No. 7 lock sector depresses the switch when the door lock sectors are rotated to their unlocked position. When the bracket attached to the lock sector contacts the switch plunger and depresses it, the circuit path through the switch is closed and 28VDC electrical control power to the door is established. When the force on the plunger is relaxed, the circuit is opened and 28VDC electrical control circuit is removed.

The wires leading to the S2 switch had been cut by the team after the recovery in an attempt to test continuity through the switch.

The door recovery team reported that it found continuity through the 1-3 contacts but not through the 1-2 contacts. The switch plunger was actuated by the recovery team. The recovery team noted that the switch did not transfer continuity during these tests. The operation of the switch plunger would normally transfer continuity. Subsequent detailed examination of the S2 switch confirmed the findings of the recovery team.

The area around the upper face of the internal bracket was bent toward the basic switches and had evidence of corrosion residue. The bracket was found broken. The switch contacts transferred from the 1-3 actuated position to the 1-2 nonactuated position when the bracket was removed. Scanning electron microscope examination of the fracture surfaces revealed evidence of overload and corrosion.

The external switch housing was dented. The final examination performed on the switch consisted of removing the plastic covers on the basic switches. Prior to removal of the basic switch covers, it was noted that the cover to the used basic switch was cracked. The contacts functioned normally when exercised by light finger pressure.

Microscopic examination revealed a black discoloration near one of the lower contact posts of the used basic switch. Energy dispersive spectrometric examination of the residue disclosed the presence of gold, iron, magnesium, sodium, and chlorine. No mechanical or electrical anomalies were detected with the basic switch contacts.

Additional testing was performed by Boeing on switches of a similar design to those used on the accident airplane's cargo door. The testing was conducted to identify conditions that would result from salt water immersion at a pressure depth of 14,200 feet for 18 months. The testing verified that external damage to the switch housing occurred at pressure depths of 7,000 feet and greater. Switch seal leakage and subsequent internal corrosion

was also noted. None of the testing performed by Boeing duplicated internal switch damage that caused basic switch contact closure or internal damage to the switch support bracket.
Wiring:
The electrical wiring recovered with the cargo door was documented in place before being removed for further tests. About 40 percent or 112 feet of wire from the original length of approximately 274 feet was recovered and examined. Of this amount, about 46 feet of wire installed in the aircraft forward of the cargo door was not examined. Most of the wires leading from the door to the fuselage were not recovered. There was no visible external evidence of burning, arcing, or heat distress in any of the wires removed. Several areas of wire insulation damage were found.
Thirty five wires were identified that could provide a possible short circuit path that could drive the latch actuator open with or without failures of other door electrical components if the ground handling bus was energized. The wires were schematically coded by function. Wires coded (-..-..-) were denoted for wiring that provides open command logic to the latch actuator. Wires coded (--.--.--.) were denoted for additional wiring enabled by an activated (failed) S2 switch. Wires coded (-o-o-o-o) were denoted for wiring providing 28VDC power from the C285 circuit.
Potential short circuit paths were identified for the cargo door that could provide 28VDC to the latch actuator control circuit relay. These potential short circuit paths can cause the latch actuator to drive the latches toward their open position if 115VAC power is available to the latch actuator motor. The potential short circuit paths include two bare wires shorting against each other, bare wire-to-metal structure-to-bare wire contact, wire to conductive fluid (such as water) to wire, or a combination of the aforementioned.
Conductive contact of (-o-o-o-o) or (--.--.--) coded wire with (-..-..-)

coded wire could potentially result in providing a 28VDC circuit path to the latch actuator open circuit. Direct wire-to-wire paths are coded in Figure 17 as defined above. The two-wire short circuit paths are identified as wire pairs consisting of wire 101-20 shorting with any of the following wires; 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

If the S2 master latch lock switch fails in the "Not Locked" position, there are additional wire pairs that provide short circuit paths. These are coded in Figure 17 as (--.--.--) to (-..-..-..) wire pairs.

Short Circuit Wire Damage Simulation Tests:

Tests were conducted by Boeing and United to simulate typical examples of bare wire short circuiting to determine the extent of visible wire damage that would be expected in the 28VDC cargo door control circuit.

United performed tests on BMS 13-42 wire, the wire type used in the B-747 cargo door control circuit. Visible electrical short circuit damage on bare BMS 13-42 wire surfaces was difficult to create at 28VDC. Surface damage was considered visible when detected by microscopic examination at 15X magnification. United testing simulated the relay coil resistance variations that would be found during typical in-service conditions. A current of 1.0 A at 28VDC created visible surface damage on momentary bare wire-to-bare wire contact. Multiple contacts at 1.0 A provided a more positive indication. A single momentary contact between two bare BMS 13-42 wires with 0.160 A at 28VDC did not create visible surface damage. Contact between a BMS 13-42 bare wire and Alclad 2024-T3 metal (airplane and cargo door structure) with 0.160A at 28VDC did not create visible surface damage.

Boeing performed wire tests on BMS 13-48 20 gauge wire. The test setup used the MS27418-2B door latch actuator control relay in parallel with the 60B00311-2 door restraint solenoid, the actual electrical loads used in the B-747 cargo door latch actuator control circuit. A single momentary contact of a bare 28VDC power wire, with a bare wire connecting to the relay of the solenoid, showed small pithead area developed at the point of wire contact that was visible without magnification.

Wire Examination Procedure:

All of the recovered wires were examined in the Safety Board's Materials Laboratory on a mylar sheet to simulate their installed positions. Labels were used to identify the coded wires using the manufacturer's original wire identification numbers imprinted on each wire's insulation. Wire pairs for direct electrical short circuiting were located in two common wire bundles installed on the cargo door. One common wire bundle was associated with the P3 plug connector, the other with the P4 plug junction box. The wire bundles were examined visually for areas of obvious insulation damage. Each individual wire was also examined with a stereo-microscope. Representative wire damage features were photographed.

Wire Damage Found:

Seven wires numbered 101-20, 102-20, 105-20, 107-20, 108-20, 122-20, and 135-20 had visible damage located near a 3.8 inch position as measured from the P3 plug pin tips. This common position on the wire corresponds to a 360-degree loop in the wire bundle, which is located immediately below the junction box. Figures 18 and 19 show typical wire damage. Wire 122-20 had an open insulation area approximately 0.25 inch long. The other four wires had flattened insulation damage areas.

In the P4 plug connector wire bundle, three wires displayed insulation damage. Wires 113-20, 121-20, and 124-20 had transverse insulation nicks, which exposed bare conductors. All three had insulation nicks 3 inches from the P4 plug pin tips; wires 121-20 and 124-20 had additional insulation nicks 34 inches from the plug pin tips. The two P4 insulation damage locations corresponded to wire bundle clamp positions.

1.16.3 Pressurization System

The pressure relief valves located on the left side of the fuselage in the forward cargo compartment were removed from the airplane and subjected to bench tests at the UAL maintenance facility in San Francisco, California. No significant anomalies were discovered and both valves performed within specified tolerances.

1.16.4 General Inspection of Other UAL Airplanes

During the on-scene phase of the investigation, the Safety Board investigators examined six other B-747 airplanes while they were on the ground at HNL (four UAL airplanes and two operated by other carriers) to observe routine cargo door operations and to assess the condition of latching components. Generally, the door operations were normal. During the examination of latch pins on these airplanes, it was noted that most had a smooth wear ridge at the 9:00 position (looking forward) or were undamaged. All wear areas on the pins were smooth.

During electrical operation of the aft cargo door on one of the other UAL B-747 airplanes (N4718U), the pull-in hooks did not pull the door fully closed and the latch cams completed the closure. During operation of the latch cams, the bottom of the door moved, first circumferentially downward and then inboard. This additional movement was approximately 1/4 inch. A definite "thunking" noise was discernible as the door moved to its closed position at the end of cam rotation. On one occasion, the door would not open under electrical power. The door was "kicked" by a UAL mechanic, power was reapplied, and the door opened properly. Examination of the door by UAL mechanics, disclosed that the riveted plate holding the aft pull-in hook switch striker was loose.

All eight lower latch pins for the forward cargo door on N4718U exhibited a smooth ridge near the 9:00 position. Pins No. 1 and 2 also showed a smooth ridge at the 6:30 position with a smooth wear area between the 6:30 and 9:00 position. The forward and aft midspan cams of both forward and aft cargo doors had a heavy gouge mark corresponding to the end of the midspan latch pin. N4718U was subsequently removed from service for repair of the aft cargo door latching mechanisms.

1.17 Additional Information

1.17.1 Previous Cargo Door Incident

On March 10, 1987, a Pan American Airways B-747-122, N740PA, operating as flight 125 from London to New York, experienced an incident involving the forward cargo door. According to Pan Am and Boeing officials who investigated this incident, the flightcrew experienced pressurization problems as the airplane was climbing through about 20,000 feet. The crew began a descent and the pressurization problem ceased about 15,000 feet. The crew began to climb again, but about 20,000 feet, the cabin altitude began to rise rapidly again. The flight returned to London.

When the airplane was examined on the ground, the forward cargo door was found open about 1 1/2 inches along the bottom with the latch cams unlatched and the master latch lock handle closed. The cockpit cargo door warning light was off.

According to the persons who examined the airplane, the cargo door had been closed manually and the manual master latch lock handle was stowed, in turn closing the pressure relief doors and extinguishing the cockpit cargo door warning light. Subsequent investigation on N740PA revealed that the latch lock sectors had been damaged and would not restrain the latch cams from being driven open electrically or manually. It was concluded by Boeing and Pan Am that the ground service person who closed the cargo door apparently had back-driven (opened) the latches manually after the door had been closed and locked. The damage to the sectors, and the absence of other mechanical or electrical failures supported this conclusion.

Further testing of the door components from N740PA and attempts to recreate the events that led to the door opening in flight revealed that the lock sectors, even in their damaged condition, prevented the master latch lock handle from being stowed, until the latch cams had been rotated to within 20 turns (using the manual 1/2 inch socket drive) of being fully closed. A full cycle, from closed to open, is about 95 turns with the manual drive system.

1.17.2 FAA Surveillance of UAL Maintenance

The Denver, Colorado, FAA Flight Standards District Office (FSDO) holds the operating certificate for United Airlines, Inc. The FAA FSDO in San
 Francisco, California, has the primary surveillance and oversight responsibility for UAL maintenance.

The FAA's PMI has the responsibility to oversee an airline's compliance with Federal Regulations with respect to maintenance, preventive maintenance, and alteration programs. The PMI determines the need for, and then establishes work programs for, surveillance and inspection of the airline to assure adherence to the applicable regulations. A portion of the PMIs position description reads as follows:

Provides guidance to the assigned air carrier in the development of required maintenance manuals and recordkeeping systems. Reviews and determines adequacy of manuals associated with the air carrier's maintenance programs and revisions thereto. Assures that manuals and revisions comply with regulatory requirements, prescribe safe practices, and furnish clear and specific instructions governing maintenance programs. Approves operations specifications and amendments thereto.

Determines if overhaul and inspection time limitations warrant revision.

Determines if the air carrier's training program meets the requirements of the FARs, is compatible with the maintenance program, is properly organized and effectively conducted, and results in trained and competent personnel.

Directs the inspection and surveillance of the air carrier's continuous airworthiness maintenance program. Monitors all phases of the air carrier's maintenance operation, including the following: maintenance, engineering, quality control, production control, training, and reliability programs.

At the Safety Board's public hearing on this accident, the PMI for United Airlines at the time of the flight 811 accident stated that he was trained as an FAA air carrier inspector and had been assigned to United Airlines since November 25, 1985. In addition to attending the normal FAA indoctrination course, he had received training in accident investigation, compliance enforcement, nondestructive testing, enforcement, and composite materials. To qualify for the position of PMI, he had completed a 3-week management training course at Lawton, Oklahoma. This was supplemented by a 2-week course on management training systems.

According to the PMI, FAA surveillance of UAL B-747 maintenance activities was organized around the daily work schedule of the FAA air safety inspector, specifically assigned to the UAL B-747 fleet by the PMI. The schedule for surveillance is normally prepared a year in advance by the FAA computerized Work Planning Management System (WPMS). Each FAA inspector is assigned specific responsibilities in the surveillance and monitoring of the airplane fleet to which he is assigned.

The PMI stated that assigned inspectors conducted surveillance of the UAL airplanes while they were in light or heavy maintenance and when they were released to service or in the process of preparing for a flight. Postflight surveillance was also performed. He said, as a routine, the inspectors visually inspected the airplanes and reviewed the airplane log records either during en route checks, while in flight, or upon termination of various flights. He said that inspectors conduct spot ramp inspections;

however, they do not routinely observe ramp service operations as part of the surveillance program.

He said that FAA inspectors are not required to inspect the airplanes, but merely are to observe ramp service activities. Deficiencies or malfunctions were to be noted. The assigned inspector or the PMI would then report these observations to the UAL quality assurance liaison person or directly to UAL management.

The PMI stated that the FAA had conducted five special surveillance inspections of UAL in the previous 3 years and 5 months. The last special inspection, an MEL Survey Inspection, was completed in 1988. That inspection primarily addressed how many deferred maintenance items were being carried or deferred on each aircraft during a specified time period.

The PMI stated that his office does not approve the method by which the carrier complies with an AD, unless specified in the AD. However, a scheduled surveillance method was in place to review the carrier's AD compliance process and the ADs applicable to certain fleets. Each assigned inspector had a schedule for performing this oversight in his work program. The PMI or his staff review a monthly report from the carrier listing ADs applicable to a particular fleet and their compliance. The FAA's surveillance of the carrier's AD compliance process involved a review of this list, not actual shop visits to verify compliance.

The inspector assigned to the UAL B-747 fleet stated that approximately 30 percent of his time was spent on actual ramp maintenance surveillance. Other activities included: en route inspections, station inspections, meetings, classes and administrative paper work. Spot ramp inspections were scheduled as a normal routine, as well as by mandate in a particular AD.

The PMI stated that foreign contract maintenance bases were inspected once a year at a minimum. The PMI had the prerogative to use geographical surveillance inspectors (inspectors from other FAA offices), or inspectors from his office more familiar with UAL maintenance procedures to conduct inspections or investigations.

The PMI and the B-747 maintenance inspector assigned to UAL testified that, prior to this accident, they were not aware of any problems involving the operation of B-747 cargo doors, including the problems reported with N4713U during December 1988. The PMI testified that he could always use more inspectors to "conduct more in-depth surveillance and monitor UAL's fleet more adequately."

The extensive documentation of maintenance performed on UAL B-747 airplanes was forwarded to the PMI's official library by US mail. The data were ultimately channeled to the B-747 maintenance inspector. The PMI and maintenance inspector testified that the voluminous paperwork and work schedules precluded their monitoring the information to determine trends on problem areas.

1.17.3 Corrective Actions

On March 31, 1989, the FAA issued telegraphic (AD) ADT 89-05-54. This AD superseded AD 88-12-04 and required certain procedures to be accomplished when operating the cargo doors. These included: confidence checks of the door mechanical and electrical systems, inspections of the door locking mechanisms, and repairs if necessary. The AD also accelerated the schedule for terminating action to place steel doublers on the latch lock sectors, and it reinstituted the procedures for using the eight view ports to verify the position of the latch cams, after the door is latched and locked.

The FAA, in conjunction with the Air Transport Association, the manufacturers, and other interested parties, are collectively working to address the human factor issues in the readability and understandability of ADs and SBs by line maintenance personnel. They are also reviewing the entire range of design, maintenance, and operation of outward opening doors to develop advisory information for pertinent parties.

FAA representatives stated at the Safety Board's public hearing that the FAA is increasing their operations and airworthiness inspector staffing by approximately 1,000 new hires in the next 3 fiscal years.

The PMI for UAL at the time of the accident stated at the Safety Board's public hearing that, as a result of the accident, "we have intensified our surveillance on the cargo door activities to the point where the assigned inspectors and inspectors who are not assigned to that particular fleet, 747s, are doing night surveillance, early morning surveillance, and we have intensified our surveillance on the cargo door in watching the operation of the cargo door to comply with the Airworthiness Directive."

On August 23, 1989, the Safety Board issued three safety recommendations (A-89-92 through -94) to the FAA. The recommendations urged the FAA to:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams.

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently.

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions.

Section 4.0 contains the FAA's response to the recommendations and the status of the followup actions.

On October 12, 1989, the FAA issued NPRM 89-NM-148-AD, which proposed the amendment of ADT-89-05-54. The proposed revisions would require modification of the warning systems for the forward and aft cargo door, and the main deck cargo door, if installed. The modifications would provide visual warnings to flightcrew and ground crew when the doors are not fully closed, the latch cams are not rotated to the closed position, or the lock sectors are not in the locked position. Further, the source for the warning signal would monitor the position of the latch cams. Public comments for the NPRM were due by December 27, 1989.

Boeing has completed tests that have verified the integrity of the upgraded latch lock sectors to prove that the latch cams cannot be back-driven through the lock sectors mechanically or electrically. Boeing also has been conducting tests on the B-747 cargo door to evaluate the effects of unrepaired damage and abuse on the latch/lock system. The tests, which determined the allowable damage limits on the latch lock system and mechanism support structures, were completed in March 1990. Additionally, Boeing conducted tests to evaluate any unlatching tendencies under cabin pressure loads. These tests were completed in November 1990 and included the measurement of loads in the latch system as the latch cams are rotated incrementally from the fully latched position to the unlatched position under pressurization loads.

The first series of tests included electrical backdriving of the latch cams into the lock sectors (both steel and steel reinforced were tested) with a modified latch actuator (the maximum output torque of the modified latch actuator was roughly twice that of a normal, torque-limiting latch actuator.) During these tests, the maximum cam rotation was 22.2 degrees against steel reinforced lock sectors and 18.8 degrees against the all-steel lock sectors.

During the second set of tests, which measured the effects of internal pressure loads on partially unlatched cams, it was discovered that pressurization did not create any significant loads in the latch mechanism with the door fully closed and the latch cams positioned up to 45 degrees from the fully latched position. Both series of tests show that if the latch cams were somehow electrically backdriven by a latch actuator that had no torque-limiting ability, the steel or steel-reinforced lock sectors would limit the amount of cam rotation such that the partially unlatched cams would still prevent pressure loads from forcing the door open.

1.17.4 Boeing 747 Cargo Door Certification

Title 14 CFR 25.783, Amendment 25-15, effective October 24, 1967, was the original certification basis for Boeing 747 cargo doors. Specifically, Part 25.783(e) and (f) applied to doors for which the initial opening movement is outward (non-plug type doors). Those rules specified that:

(e) There must be a provision for direct visual inspection of the locking mechanism by crewmembers to determine whether external doors, for which the initial opening movement is outward (including passenger, crew, service, and cargo doors), are fully locked. In addition, there must be a visual means to signal to appropriate crewmembers when normally used external doors are closed and fully locked.

(f) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure.

Amendment 25-23, effective May 8, 1970, added the following text to paragraph (f): "...or failure of a single structural element." Amendment 25-23 did not apply to the initial certification basis for the B-747.

Amendment 25-54, effective October 14, 1980, expanded Part

25.783 (e), (f), and (g) to read:
(e) There must be a provision for direct visual inspection of the locking mechanism to determine if external doors, for which the initial opening movement is not inward (including passenger, crew, service and cargo doors), are fully closed and locked. The provision must be discernible under operational lighting conditions by appropriate crewmembers using a flashlight or equivalent lighting source. In addition, there must be a visual warning means to signal the appropriate flight crewmembers if any external door is not fully closed and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed and locked indication is improbable for doors for which the initial opening movement is not inward.
(f) External doors must have provisions to prevent the initiation of pressurization of the airplane to an unsafe level if the door is not fully closed and locked. In addition, it must be shown by safety analysis that inadvertent opening is extremely improbable.
(g) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure or failure of a single structural element.
At the Safety Board's public hearing, the FAA and the Boeing representatives acknowledged that during certification of the Boeing 747 the loss of a lower lobe cargo door was not considered to be an "acceptable event." Therefore, redundant mechanical devices and operational procedures were incorporated to protect against loss of the door in flight. Initial FAA certification approval of the Boeing cargo door design and operation included the installation and use of eight view ports on the door for ground personnel to observe the alignment of paint stripes on the latch cams with arrows on the latch pin support fitting, thereby complying with the requirements of 14 CFR 25.783(e), which

require a ". . . provision for direct visual inspection of the door locking mechanism ...," to determine if the door is closed and locked.

In correspondence dated November 24, 1969, and May 15, 1970, Boeing requested that the FAA approve the use of a visual inspection of the pressure relief doors of the cargo doors as an alternate method for determining the locked condition of the door. This design also provided a visual indication to the flightcrew via the cargo door warning light on the flight engineer's warning light annunciator panel. Boeing's request stated that this means of compliance "... provides a simpler check whereby only the pressure relief doors need to be checked ...," by the ground crew, in lieu of actually observing the latch cams and alignment stripes through the eight view ports. Boeing also provided a Failure Analysis to support its request. The conclusion of the Failure Analysis reads: "Any failure, mechanical or electrical, within the latching system which results in open latches will always be indicated by open pressure relief doors." The FAA approved their alternate method on June 8, 1970. Subsequently, the procedures for maintaining the view ports and the alignment stripes in a serviceable condition,

which had been included in the UAL MM were removed. Also, the provision for observing the alignment stripes as part of the door closing procedure were not required for B-747 airline operators.

At the Safety Board's public hearing, a Boeing witness, in answer to a question relative to Boeing's possible consideration of modifications or design changes to the B-747 cargo door indication system to install a position switch directly on the latch cams, stated, "We are looking into the best possible designs that would provide indication on the cams and door closed, both exterior to the aircraft and in the flight deck. We are going to look into that.... However, we want to achieve the required indication in the most reliable method and we have not yet determined what that will be, or any changes (that) are necessary, or would make it more reliable than the way the system operates currently."

1.17.5 Advisory Circular AC 25.783-1

Advisory Circular (AC) 25.783-1 was issued December 10, 1986, on the subject, "Fuselage Doors, Hatches, and Exits." AC 25.783-1 set forth the acceptable means of compliance with the provisions of Part 25 of the FAR's dealing with the certification of fuselage doors. Specifically, it provides for an acceptable method for showing compliance with the provisions of Part 25.783, Amendment 25-54.

Neither the provisions of Part 25.783, Amendment 25-54, nor the guidelines of AC 25.783-1 were part of the certification basis of the Boeing 747.

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.

The airplane was being prepared for flight at the UAL maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.

The aft cargo door was cranked open manually, the C-288 circuit

breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident. With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage.
UAL personnel notified the Safety Board of the occurrence, and the airplane was examined at JFK by representatives of the Safety Board, United Airlines, and Boeing. After the wires in the damaged area were electrically isolated, electrical operation of the door was normal when the door was unlocked. When the door was locked (master latch lock handle closed), activation of the door control switches had no effect on the door. This indicated that the S2 master latch lock switch was operating as expected (removing power from the door when it was locked). After the on-site examinations, the wiring bundle was cut from the airplane and taken to the Safety Board's materials laboratory for further examination.
The wiring bundle with the damaged wires contained all electric control wires (28 volt DC) and power wires (115 volt AC) that pass between the fuselage and the aft cargo door. From the forward side of the J-4 junction box, the bundle progresses in the

forward direction, just above the forward pressure relief door, then upward, following the forward lift actuator arms. The bundle then enters an empty space between two floor beams, where the bundle has an approximate 180-degree bend when the door is closed. From this location, the wiring bundle progresses inboard, through a fore-to-aft intercostal between two floor beams. The wiring bundle then splits, with wires going in several directions.

The bundle is covered by the flexible conduit approximately from the lower end of the lift actuator arms to the fore-to-aft intercostal between the floor beams.

The conduit covering the wiring bundle is intended to prevent the wire bundle from being damaged during opening and closing of the door and during cargo handling operations. The conduit is a sealed flexible interconnector consisting of a convoluted helical brass innercore covered by a bronze braid. The innercore is soldered at every other convolute, and should be capable of withstanding pressures exceeding 1,000 pounds per square inch (psi). Boeing has indicated that the conduit is an evolutionary improvement and that it has been installed on all B-747 airplanes produced since 1981 (from line number 489 on). Airplane N152UA was delivered in April 1987.

Airplanes produced prior to 1981, including N4713U, used a bungee retraction system, to retract the cargo door wire bundle. Guidelines for the replacement of the bungee sys tem with the flexible conduit were covered in Boeing Service Bulletin 747-752-2170, dated August 1981. The service bulletin was prompted by reports that the wire bundle bungee retraction system had not retracted the wire bundle sufficiently to prevent trapping the bundle between the cargo door and the door frame. UAL did not perform the retrofit on N4713U, which was line number 89, nor was the company required to do so.

Examination of the wires in the damaged area on the wiring bundle revealed that four of the wires were similar in appearance, with insulation breaches that progressed through to the underlying conductor. Adjacent to the breach on these four wires, the insulation was blackened, as if it had been burned. Another wire contained an extensive breach but no evidence of burned insulation. The damaged area was located on the bundle at a position approximately corresponding to a conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism. This support bracket was found bent in the forward direction. In addition, mechanical damage was noted on adjacent components in this area.

A second damaged area was noted on the wiring bundle at a position approximately corresponding to the conduit swivel clamp at the elbow between the two arms of the forward lift actuator mechanism. Wires in this area were missing portions of their exterior coating, but no breaches to the underlying conductors were noted.

The exterior braid on the conduit contained minor rub marks and was slightly kinked at a position corresponding to the area on the wires with breached insulation. Additional examinations revealed that the innercore of the conduit contained multiple circumferential cracks in the areas corresponding to the damage areas on the wires. The cracks were in the convoluted innercore directly adjacent to the inside diameter of the conduit.

The lock sectors, latch cams, and latch pins from the aft cargo door were examined on the incident airplane and were generally in excellent condition. There was no evidence to suggest that the cams had ever been electrically (or manually) driven into or through the lock sectors.

Boeing also informed the Safety Board that, in May of 1991, a B-747 operated by Quantas was found to have chafing of the wires in the wire bundle to the aft cargo door. This airplane also had a flexible conduit protecting the wires, and the chafing was located approximately at the standoff pin on the bracket at the upper arm of the forward lift actuator.

The Safety Board determined that the chafing of the wires on the airplane involved in the JFK occurrence was caused by, or was greatly accelerated by, the circumferential cracks in the conduit and that the cracks in the conduit were caused either by repeated flexing of the conduit as the cargo door opens and shuts or by unusual stresses on the conduit generated concurrently with damage to the conduit guide bracket and attached standoff pin on the upper end of the forward lift actuator upper arm.

A portion of the wire bundle for the forward cargo door on many B-747 airplanes is also covered by a flexible conduit that is very similar to the conduit for the aft cargo door. However, there are substantial differences between the orientation of the flexible conduits for the two doors, and the Safety Board has not become aware of problems associated with the flexible conduit for the forward door.

Nevertheless, because of the concerns about the chafed wires and possible electrical short circuits, on August 28, 1991, the Safety Board recommended that the FAA:

Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between the fuselage and aft cargo door to require an expedited inspection of:

(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test method or visual examination);

(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;

(3) the flexible conduit for the presence of cracking in the convoluted innercore.

Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an appropriate cyclic interval. (Class II, Priority Action) (A-91-83)

Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in A-91-83. (Class II, Priority Action) (A-91-84)

The FAA responded to these safety recommendations on November 1, 1991, stating that it agreed with the intent of the recommendations and that the issuance of an NPRM was being considered to address the issues in the safety recommendations. The Safety Board replied on November 27, 1991, classifying each of the recommendations as "Open--Acceptable Response," pending the completion of the rulemaking process. Since that exchange of correspondence, the FAA has published an NPRM which is now being reviewed by the Safety Board. Safety Recommendations A-91-83 and -84 will continue to be classified as "Open--Acceptable Response" until an acceptable final rule is published.

2. ANALYSIS

2.1 General

This analysis is based on the facts gathered during the initial investigation phase, without the benefit of the evidence from the cargo door, updated to include the findings from the subsequent examinations of the door after it was recovered.

The flightcrew and flight attendants were trained and qualified in accordance with the applicable Federal regulations and UAL standards and requirements. There were no air traffic control or weather factors related to the cause of this accident.

The airplane had been properly maintained, with the exception of certain requirements pertaining to the cargo doors. Those discrepancies will be discussed in detail in this analysis.

The evidence examined by the Safety Board during its investigation revealed conclusively that this accident was precipitated by the sudden loss of the forward lower lobe cargo door, which led to an explosive decompression. There was no evidence of preexisting metal fatigue or corrosion in the structure surrounding the cargo door. All breaks were the result of overload at the time of the loss of the door. There was no evidence of a bomb or similar device that caused an explosion on the airplane.

The explosive decompression of the cabin when the cargo door separated caused the nine fatalities. The floor structure and seats where the nine fatally injured passengers had been seated were subjected to the destructive forces of the decompression and the passengers were lost through the hole in the fuselage. Their remains were not recovered. Most of the injuries sustained by the survivors were caused by the events associated with the decompression, such as baro-trauma to ears, and cuts and abrasions from the flying debris in the cabin. Other injuries were incurred during the emergency evacuation.

The loss of power to the Nos. 3 and 4 engines was caused by foreign object damage when debris were ejected from the cargo compartment and cabin during the explosive decompression. The debris also caused damage to the right wing leading edge flap pneumatic ducting, and other areas along the right side and empennage of the airplane.

During the approach to HNL, all of the leading edge flaps had extended, except the outboard sections 22 through 26 on the right wing. The reason that they failed to extend probably was the damage to the pneumatic duct caused by the ejected debris. The pneumatic pressure probably was too low to actuate the most outboard flaps to the extended position.

The failure of the flightcrew and passenger oxygen systems was caused by structural deformation and damage to the supply lines in the area adjacent to the cargo door and failed fuselage structure.

The Safety Board's analysis of this accident concentrated on the reasons for the loss of the cargo door and the events that led to its loss in flight. The analysis included an evaluation of the design, certification, and approval processes for the B-747 cargo doors, and the operational, maintenance, and inspection processes for the doors. Also, the analysis included an evaluation of the historical events that had occurred over the past months and years that eventually led to this accident.

2.2 Loss of the Cargo Door

The calculated pressure differential at the time of the loss was about 6.5 psi, which would have exerted a load on a properly closed and locked door that was substantial, but well within design limits.

There was no evidence of a structural problem with the cargo door that could have caused it to fail from metal fatigue or corrosion. Although the cargo door was recovered in two pieces on the floor of the ocean, there was no evidence of a preseparation structural failure of the door. All fractures and damage found on the door were determined to be the result of the sudden opening of the door rather than the cause. The evidence showed that the door was intact when it flew open violently and that its integrity was compromised when it struck the upper fuselage structure and most likely when it struck the water. The fracture in the cargo door occurred just below the midspan latch cams. Paint marks on the outer surface of the door that matched upper fuselage structure paint pattern, damage to the latch pins, pull-in hooks and hook pins, as well as damage to the floor structure near the upper door hinge area were consistent evidence that the door was intact when it flew open.

The evidence was also conclusive that the failure of the door did not result from the failure of the structure surrounding the door. The damage to the cabin floor beam structure, adjacent to the cargo door hinge area, showed that decompression loads in the cabin broke the beams downward when pressure was released from the cargo compartment. The fuselage skin above the door was torn away during the decompression as the door separated violently from the airplane. Unfortunately, the upper skin structure was not recovered from the sea.

There are no reasonable means by which the door could open in flight with the cams properly closed and locked. If the lock sectors were in proper condition, and were properly situated over the closed latch cams, the lock sectors had sufficient strength to prevent the cams from vibrating to the open position during ground operation and flight. Thus, the only ways in which the cargo door could open while in flight involve the placement of the cams in a partially latched or unlatched position. Either the latching mechanisms were forced open electrically through the lock sectors after the door was secured, or the door was not properly latched and locked before departure. Then the door opened when the pressurization loads reached a point at which the latches could not hold.

2.3 Partially Closed Door

Examination of the eight latch pins that had been removed from the lower sill of the forward cargo door revealed smooth wear patterns where the latch cams had normally rotated around the pins. These wear patterns indicate that interference had existed during normal operation between the cams and the pins over an extended period of time. All eight pins also had roughened areas from approximately the 6:15 position to the 7:30 position (clock references are as looking forward, 9:00 being directly inboard). The 7:30 position corresponds closely to the area where the lower surface of the cam first contacts the pin as the door reaches the nearly closed position, before the cams are rotated to the latched position.

The hoop stresses generated by pressurization of the airplane create a bearing load against the cam/pin contacting points. Even if the cams are in the unlatched position, and the airplane is pressurized, this bearing load could act as a frictional latch between the cams and the pins and would tend to keep the door in the closed position.

Transferred cam material and heat tinting of the pin surface was found to extend from the point where the cam-to-pin interface at the near fully open position of the latch cams (7:30 position) to a position corresponding to the bottom of the pin (6:15 position). This evidence was found on the roughened areas on all of the pins. The heat tinting and metal transfer are indicative of the high stress and rapid movement of the cam across the pin when the door separation occurred. Therefore, the location of this evidence indicates the probable location of the cams just before, and at the time of, separation of the door. The Safety Board concludes that these markings and their location on the pins resulted from a very fast, high bearing stress, separation of the cams across the pins, when the cams were in or very close to the unlatched position. Further, examination of the recovered cargo door confirmed that the latch cams were in a nearly unlatched position at the time the separation occurred. The lock sectors were found in the locked position jammed against the cams. Therefore, the cargo door latch cams had been closed, the master latch lock handle had been closed, and the lock sectors had moved to the locked position. Subsequently, the cams had been back-driven to the near-open position, deforming the lock sectors.

The pull-in hooks and pull-in hook pins would also counteract the pressurization loads in the outward direction, providing that the latch cams were not engaged on the latch pins and carrying the pressurization loads. However, Boeing studies showed that the pull-in hooks would fail at a pressure differential of about 3.5 psi, assuming that the cams are in the unlatched position and that there is no bearing load on the pins. Therefore, based on the probable pressure differential of about 6.5 psi just before the door separated, it is concluded that forces other than the pull-in hooks/pins were holding the door closed. Since the flightcrew and passengers reported no pressurization difficulties until the explosive decompression, it is reasonable to conclude that the door was being held closed by the bearing stresses of the cam-to-pin interfaces as well as by the pull-in hooks.

The Safety Board believes that the approximate 1.5 to 2.0 seconds between the first sound (a thump) and the second very loud noise recorded on the CVR at the time of the door separation was probably the time difference between the initial failure of the latches at the bottom of the door, and the subsequent separation of the door, explosive decompression, and destruction of the cabin floor and fuselage structure. The door did not fail and separate instantaneously; rather, it first opened at the bottom and then flew open violently. As the door separated, it tore away the hinge and surrounding structure as the pressure in the cabin forced the floor beams downward in the area of the door to equalize with the loss of pressure in the cargo compartment.

Three possible theories to explain why the latch cams could have been in a partially latched condition during flight are examined: (1) they were never closed fully before the door was "locked" before takeoff. (2) they were backdriven manually after the door had been fully latched and locked or (3) they were back-driven electrically after the door had been fully latched and locked.

2.4 Incomplete Latching of the Door During Closure

The Safety Board considered the possibility that the master latch lock handle had not been closed before the airplane departed the gate, and the possibility that the shrouds recommended by SB-747-52-2097 for the cargo door pressure relief doors were not installed on the forward door. If this were the case, it is possible that this condition allowed the pressure relief doors to be rotated closed when the airplane pressurized.

The Safety Board believes that these events were very unlikely based on the statements of the ramp personnel, line maintenance personnel, and the flightcrew. The ramp and maintenance personnel would have to have missed seeing the master latch lock handle in the unstowed position and the pressure relief doors open before departure. Also, the flightcrew would have to have missed seeing the cockpit cargo door warning light indication.

The examination of the recovered forward cargo door did not provide confirmation that the pressure relief door shrouds were actually installed on the forward door, although UAL records showed that they had been installed on both cargo doors of N4713U, in accordance with SB-747-52-2097. However, the shrouds were found not to be installed on the aft door, contrary to UAL records, and therefore may not have been installed on the forward door. Without the shrouds, the pressure relief doors could have rotated shut during the pressurization cycle. Because the closure of the pressure relief doors would back-drive the lock sectors, this scenario would presume previous damage to the sectors, which would permit the sectors to move over the unlatched cams.

Before recovery of the cargo door, the Safety Board believed that the lock sectors might have been damaged some time prior to the accident flight to the extent that they could have been moved to the locked position even though the latching cams were not fully closed.

During closure of the door, the latch actuator may not be able to rotate the cams to the fully closed position because of excessive binding forces between the latch cams and pins. This could occur if the cargo door is misaligned (out of rig) or if the pull-in hooks do not pull the door in far enough to properly engage the cams around the pins. There is sufficient evidence of wear on the pins and from the previous discrepancies with the door to indicate that the door was misaligned and not properly rigged.

The smooth wear areas found on the pins from N4713U are signs of heavy contact (interference) between the cams and pins during numerous past closings and openings of the door. This wear, other evidence from the door, and the maintenance history of the door, suggest strongly that the door was out of rig during the weeks and months before the accident.

The wear pattern damage to the pull-in hook pins also showed interference during the normal ground operations prior to the accident. This is further evidence of an out-of-rig door. It is also possible that the excessive binding force acting over a period of time precipitated a failure of the latch actuator. Regardless of the reason(s), the conditions of the latch pins and pull-in hook pins showed prolonged out-of-rig operation.

Most of the previous discrepancies with the forward cargo door on N4713U during December 1988 involved problems with closing the door electrically. These problems always occurred when the airplane was fully or nearly fully loaded, just before departure. The trouble-shooting and corrective actions by UAL maintenance, which on some occasions only involved cycling the door and finding it functional, were performed when the airplane was not fully loaded, during overnight maintenance inspections. The flexing of the fuselage with a full load of fuel, cargo, and passengers could have caused distortion of the door frame and resulted in misalignment between the cams and pins. In this case, the pull-in hooks may not have pulled the door fully in before the cam actuator attempted to latch the door. The wear evidence on the latch pins from N4713U suggests that this event had been occurring before the accident.

Safety Board investigators also witnessed this event during inspection and operation of the aft door on another UAL B-747, N4718U, in HNL. It was noted that the door on N4718U was not being pulled in fully by the pull-in hooks, so the latch cams completed the closing cycle with significant interference and "thunking" sounds. In fact, the out-of-rig door on N4718U failed to operate electrically at one point during its examination.

By design, any attempt to close the master latch lock handle and move undamaged lock sectors into place would not be successful unless the cams were rotated to near the fully latched position. This condition was substantiated by Boeing tests. Even with severely damaged lock sectors, as found on the Pan Am B-747, if the cams were more than 20 turns from the fully closed position on the Pan Am airplane, the master latch lock handle could not be stowed. Examination of the recovered N4713U door indicated that the door lock sectors were generally intact and jammed against the cams that had been back-driven into the lock sectors. Consequently, if the latch cams had been in the nearly unlatched position as found on the recovered door at the time the cargo handler attempted to move the master latch lock handle, the interference between the cams and the lock sectors would have prevented the master latch lock handle from moving to the closed position. Furthermore, this interference would have prevented the closure of the pressure relief doors as the airplane pressurized, irrespective of the possible absence of the pressure relief door shrouds. This conclusion is supported by extensive testing of the latch/lock mechanisms following the recovery of the door.

Therefore, based upon the examination of the lock sectors and the tests that were conducted, the Safety Board concludes that the latches were fully closed and that the locking handle was placed in the stowed position after the cargo was loaded.

2.5 Manual Unlatching of the Door Following Closure

It is possible that the cams could have been manually back-driven (about 95 turns) after the door had been secured; however, the UAL ramp personnel involved with dispatching the flight stated that the door was operated electrically. Furthermore, it seems unlikely that the ramp personnel would have driven the manual latch actuator 95 turns toward the open position after the door was fully latched.

The placard/seal located over the latch actuator manual drive on the recovered door was found with damage that initially suggested it had been previously compromised. If this were the case, it would indicate that someone may have used the manual drive to operate the door latches on an earlier flight or possibly immediately before the accident flight. However, the Safety Board believes that an insertion of a screw driver and rotation of the plate retaining screw would have caused rotational tearing around the circumference of the screw head. There was no such tear. Rather, the damage to the placard/seal was more consistent with that which would occur from impact and underwater pressure forces. Therefore, the evidence strongly suggests that manual operation of the latch actuator by ground service personnel after the door was properly closed is unlikely.

2.6 Electrical Unlatching of the Door Following Closure

2.6.1 Conditions or Malfunctions Required to Support Hypothesis

It was determined in 1987, after the Pan Am incident, that the locking sectors for B-747's, including those installed on N4713U, could be overcome by the force of the latch cam actuator, electrically or mechanically. If the latch cam actuator had been energized for some reason with the originally designed unstrengthened lock sectors installed, the latch actuator motor was capable of driving the latch cams open through properly positioned lock sectors, whether they were damaged or undamaged. Therefore, the locking sectors installed as original equipment for B-747's, and those installed on N4713U, would not perform the locking function as intended by the design. They would not "lock" the latches in place as implied by the name "lock sectors."

The investigation has shown that there are several conditions that must be met before the latch actuator will electrically drive the latch cams to the unlatched position on the B-747 after the door has been properly closed and locked. First, the ground handling power bus must be energized by having external power connected, or the APU must be operating and the APU generator field switch in the cockpit must be set to power the bus via the No. 2 ground handling power relay. Second, the air/ground relay must be in the "airplane on the ground" position. These two conditions are normally present when the airplane is on the ground before engine startup. Third, there must be a signal to the door open position in one of the two door open/close switches. Fourth, the S2 master latch lock switch, which cuts off power to the door actuators when the handle is stowed, must sense "not locked."

Therefore, it would take several independent conditions and some failures to provide for electrical power to be available to drive the door open electrically once it is closed and locked. The number of conditions and combinations depend upon the phase of operation of the airplane.

While the airplane was on the ground, before engine startup, with the master latch lock handle stowed, the external power connected (or with the APU running), and the ground handling bus powered, an "open" signal to the cargo door latch actuator would have occurred if any of the following combinations of conditions had been met: (1) a malfunction of the S2 master latch lock switch and the placement by someone of one of the door control switches to the "open" position; (2) a malfunction of the S2 master latch lock switch and certain short circuits; or (3) a two-wire short circuit path consisting of wire 101-20 shorting with any of the following wires: 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

While the airplane was on the ground, after engine startup, and with the cargo door master latch lock handle stowed and the APU running, an "open" signal to the door latch actuator would have occurred if the following conditions had been met: (1) an energized ground handling bus resulting from the flightcrew reenergizing the APU generator field or failure of the No. 2 ground handling power relay; (2) a malfunction of the S2 master latch lock switch; (3) a malfunction of either of the door open/close switches or the placement of the switch in the "open" position by someone. An "open" signal would have also occurred had certain wire short circuits been present with condition (1) alone, or with conditions (1) and (2).

Regardless of the cause, electrical power to the latch actuator would have had to persist for the time necessary to rotate the cams to the nearly open position. If the electrical power had been applied for a longer time, the latch cams could have opened fully and caused the pull-in hooks to rotate open, a situation that would have prevented the airplane from pressurizing after takeoff. However, it is also possible that the latch actuator stalled before they opened fully because of the forces of the interference between the lock sectors and the cams as they were back-driven.

After takeoff, electrical operation of the door latch actuator would have required: (1) the APU to be running; (2) malfunction of the air/ground relay, (3) malfunction of the No. 2 ground handling power relay; and (4) malfunction of the S2 master latch lock switch and one of the cargo door open/close switches or a short circuit of the aforementioned wire pairs. Although the flightcrew could conceivably energize the ground handling bus from the APU by actuating the APU generator "field" switch, there was no evidence that they did so.

Thus, regardless of the phase of operation, either a wiring short circuit or a failure of the S2 master latch lock switch combined with some other anomaly or action would be required to cause the latches to move toward the open position. Before the recovery of the door, the Safety Board was able to examine two of the electrical relays and the door open/close switches from N4713U that would have to have failed to allow electrical operation of the cargo door in flight, with the APU running. These were the No. 2 ground handling power relay, the air/ground relay, and the internal and external door open/close switches. The examination of the relays and switches revealed no evidence of a single fault or conditions that might have caused an intermittent failure mode. The arcing noted on the No. 5 terminal of the outside door control switch was on the door "close" circuit and could not have been related to a short to the open mode. Further, because the flightcrew did not note a cargo door warning light, and the fact that the airplane was able to be pressurized, confirms that the master latch lock handle was in the closed position before takeoff. This position would actuate the master latch lock switch to disconnect power to the door opening actuators.

According to the flightcrew testimony and the pilots' comments recorded on the CVR during the flight, the APU was shut down shortly after takeoff and remained in that condition. Engine generators cannot power the ground handling bus from which the cargo door actuating mechanisms are powered. Once the APU was shut down, there was no power available to any of the cargo door electrical components. Therefore, an electrical actuation of the latch cam actuator at the time of the door loss was not possible.

The Safety Board believes that there is another reason why the opening of the door could not have been caused by electrical actuation shortly before the explosive decompression. Because the door carries the structural loads (hoop stresses) through its hinge and latches, the latch cams would be heavily loaded against the latch pins when the airplane was pressurized to the 6.5 psi differential pressure that was calculated to have been present at the time of the decompression. In that case, the torque limiter within the actuator would probably slip well before the actuator could achieve the torque necessary to drive the cams open against the frictional lock produced by the high bearing stresses resulting from pressurization.

2.6.2 Electrical Switches and Wiring Examinations--Recovered Door

All cargo door position sensing switches (S2 through S9) were found installed in their proper position. The cargo door recovery team found the S2 master latch lock switch in the "not-locked" position immediately after the door was aboard the recovery ship. This position would be consistent with the master latch lock handle being open. Further tests of the S2 switch revealed damage that probably resulted from the pressures under the sea. The only notable exception was a broken internal bracket that may have affected the operation of the switch prior to the accident. Other similar switches did not exhibit this failure. It is therefore possible that the S2 master latch lock switch failed prior to the accident, allowing more possibilities for electrical short circuits to power the latch actuator. Nevertheless, despite extensive testing, it could not be determined whether the S2 switch was functional before the accident.

The examination of 35 wires that remained with the recovered cargo door revealed several areas of damaged insulation that could have permitted an electrical short circuit to power the latch actuator. However, no evidence was noted of arcing that was indicative of short circuits. Furthermore, a significant number of the wires that had the potential for allowing for short circuits to power the latch actuator were not recovered. Testing conducted by Boeing and by UAL was inconclusive regarding whether a short circuit would have left detectable evidence of arcing. Therefore, the Safety Board was unable to determine whether the latch actuator was inadvertently powered by a short circuit in the cargo door wires.

The incident involving a UAL Boeing 747 at JFK Airport on June 13, 1991, confirmed that electrical short circuits in the cargo door wiring could cause the door to open. In this case, the short circuits were in the fuselage-to-cargo door wiring bundle where the bundle was covered by a flexible conduit. Although N4713U did not have a flexible conduit installed at the forward door position, its wiring was routed over the top of the door hinge where exposure to damage could occur. That portion of the wiring from N4713U was not recovered from the sea. The wires located at the door hinge area are more susceptible to in-service damage from movement during the open/close cycle, as compared with the wires mounted on the door that are normally static.

Following the incident at JFK, UAL directed that the circuit breaker that terminates power to the cargo doors be pulled after the door is closed and before departure of every B-747 flight. UAL obtained approval for this practice from the FAA and requested Boeing and the FAA to make such a practice part of the approved manual for the airplane. Neither Boeing nor the FAA acted on UAL's request.

Nevertheless, the Safety Board believes that the FAA should initiate rulemaking to include design considerations for nonplug transport category aircraft cargo doors that would deactivate the electrical circuitry to the door actuators after the doors are closed and locked. The catastrophic nature of the loss of a cargo door dictates the need to provide additional redundancies and fail-safe features in the door mechanisms to supplement the hardware safety features.

2.6.3 Possibility of Electrical Malfunction

Due to the lack of physical evidence, the Safety Board was unable to conclude that an electrical short caused the cargo door actuator to move the latch cams to the nearly open position, allowing the door to separate when the cabin pressure exceeded the load-carrying capability of the door latches. Neither could this possibility be eliminated. A momentary actuation of the door open switch by someone on the ground in the presence of a faulty S2 switch could also have caused the latches to open through the closed lock sectors. However, no evidence has been found that someone actuated the switch after the door was initially closed and locked.

The Safety Board concludes that it was not possible for the cargo door to have opened electrically at the time of the loss of the door. There was no power to the ground handling bus to power the actuator, even if there had been an electrical short. Further, the Safety Board concludes that it is highly improbable that an electrical short could have caused the latches to open after the airplane was airborne. Although the ground handling bus could conceivably have been powered, failures of other components that were tested as functional would also have been necessary.

The Safety Board believes that the electrical operation of the latch actuators from the fully closed and locked position most likely occurred before the engines were started when the ground handling bus was powered. The precise source of the electrical actuation could not be determined. Once the engines were started, the possibility of an electrical short decreases significantly because the ground handling bus is disengaged from the APU when the engines start. There was no evidence that the flightcrew reengaged the ground handling bus.

Because the preaccident condition of the S2 master latch lock switch could not be determined, it could also not be determined whether its proper functioning would have prevented the accident. The Safety Board did not determine whether damaged cargo door wires or a malfunctioning S2 switch could have been found by UAL maintenance had they been more aggressive in troubleshooting the cargo door problem in the weeks prior to the accident.

2.7 Design, Certification, and Continuing Airworthiness Issues

The Safety Board's analysis of this accident went beyond the conclusions about how the door failed. The Safety Board also examined the initial design and certification of the B-747 cargo door, and the continuing airworthiness system that should have prevented this accident, to identify the breakdowns in this system that led to the accident. As is the case with most aviation accidents, there are many factors that led up to the actual failure of the door on flight 811.

The Safety Board found that there were multiple opportunities during the design, certification, operation, and maintenance of the forward cargo door for N4713U for persons to have taken actions that could have precluded the accident involving flight 811. The circumstances that led to this accident exemplify the need for human factors considerations in the promulgation of regulations, the application of regulatory policies, the design of airplane systems, and the quality of airline operational and maintenance practices.

The first opportunity to prevent this accident occurred during the design and certification of the B-747 cargo door mechanical systems, when the design was chosen and approved, which allowed for the overriding of the lock sectors by either mechanical or electrical actuation. It is apparent that the original design was not tested sufficiently to verify that the locking sectors in fact "locked" the latch cams in the closed position. This shortcoming should have become apparent during the initial certification testing and approval process. Later, it should have become apparent when Boeing applied for, and the FAA granted, an alternative method of compliance with the certification regulations (25.783 [e]) that permitted the elimination of operational practices that included a visual verification of the cargo door latch positions via view ports in the doors.

The failure mode analysis performed by Boeing, and the FAA's acceptance of its content in granting the exemption, probably were based on the assumption that the lock sectors would always prevent the master latch lock handle from being in a stowed position when the latch cams were not fully closed. This assumption was not valid, as evidenced by the findings in 1987 following the Pan Am incident that the lock sectors could not prevent the latch cams from being driven from the fully latched position with the master latch lock handle stowed, while a false indication was provided to the flightcrew that the cargo door was properly latched and locked. At the time that Boeing sought approval of the alternative compliance, Boeing and the FAA should have reviewed the design and required testing of the door latch/lock mechanisms to verify their integrity. Thus, the procedure for direct viewing of the latches via the view ports before the airplane could be dispatched should not have been eliminated without adequate verification that the lock sectors were totally effective.

The next opportunity for the FAA and Boeing to have reexamined the original assumptions and conclusions about the B-747 cargo door design and certification was after the findings of the Turkish Airline DC-10 accident in 1974 near Paris, France. The concerns for the DC-10 cargo door latch/lock mechanisms and the human and mechanical failures, singularly and in combination, that led to that accident, should have prompted a review of the B-747 cargo door's continuing airworthiness. In the Turkish Airlines case, a single failure by a ramp service agent, who closed the door, in combination with a poorly designed

latch/lock system, led to a catastrophic accident. The revisions to the DC-10 cargo door mechanisms mandated after that accident apparently were not examined and carried over to the design of the B-747 cargo doors.
Specifically, the mechanical retrofit of more positive locking mechanisms on the DC-10 cargo door to preclude an erroneous locked indication to the flightcrew, and the incorporation of redundant sensors to show the position of the latches/locks, were not required to be retrofitted at that time for the B-747. Of similar concern is the fact that the cargo doors for the L-1011 required redundant latch/lock indication sensors at initial certification, during the approximate same time frame the DC-10 and B-747 were certificated.
More recently, when Boeing and the FAA learned about the circumstances of the Pan Am cargo door opening incident in March 1987, more timely and positive corrective actions should have been taken. The Safety Board believes that the findings of that incident investigation should have called into question the assumptions and conclusions about the original design and certification of the B-747 cargo door, especially the alternative method for verifying that the door was latched and locked that was sought by Boeing and was granted by the FAA. Since a B-747 cargo door opening in flight was considered to be an "unacceptable event", once a door did come open in flight, the FAA and Boeing should have acted much quicker to prevent another failure.
It took nearly 16 months from the date of the Pan Am Incident (March 10, 1987) until the FAA issued AD-88-12-04 (July 1, 1988). And then, the AD allowed 18 or 24 months, depending on the model B-747, from the date of its issuance for compliance with the terminating actions of the AD. The fact that Boeing had issued an Alert SB as a result of the Pan Am incident is an indication of the apparent urgency with which Boeing treated this issue. Alert SB's

are issued for "safety of flight" reasons, while regular SB's deal with "reliability" and not necessarily safety of flight items. Despite this, the terminating action, issued as revision 3 to the Alert SB, on August 27, 1987, was not mandated by the FAA for 11 months.

The Safety Board found no evidence that the FAA or Boeing reassessed the original design and certification conclusions regarding the safety of the B-747 cargo door during this period. Several opportunities for preventive action were also missed by UAL during this period. First, UAL delayed the completion of the terminating actions of Alert SB 52A2206 (Rev 3 and AD-88-12-04. In fact, there was no evidence that UAL had intended to comply with the terminating action of the Alert SB, until it was mandated by the FAA.

It is understandable that an airline would not take its aircraft out of service to incorporate revisions that do not appear to be safety critical. Although by definition an Alert SB is safety related, there was no implication from Boeing's and FAA's actions regarding this matter that urgency was required. The airlines rely on the airframe manufacturers and the FAA to evaluate the need for urgent airworthiness actions that might take airplanes out of revenue service. In this case, UAL had scheduled completion of its B-747 fleet modifications in accordance with the terminating actions for AD-88-12-04 before the final allowable date; however, the schedule was based on other heavy maintenance schedules to prevent unnecessary down-time of its airplanes.

UAL personnel stated after the UAL 811 accident that its personnel did not fully appreciate the importance, or safety implications, of the terminating actions, or they would have incorporated the improvements much earlier. The usual difficulties in setting short suspense dates for performing terminating actions in AD's, such as parts availability, did not seem to exist in this case, because the parts were not complex components and probably could have been fabricated fairly quickly in-house by most airlines.

Human performance certainly contributed to UAL's failure to incorporate an important inspection step into its maintenance program as mandated by AD-88-12-04. When UAL obtained an advance draft copy of the forthcoming NPRM that eventually led to the AD, the airline began preparing its work orders to implement the forthcoming the AD requirements into its B-747 fleet (30 airplanes at the time). UAL developed its maintenance work sheets from the text of the draft NPRM, which was virtually identical to the text of the final rule. As a result of a clerical error, one of the important inspection steps required by the AD was omitted.

Apparently, UAL maintenance personnel never compared the work sheets they received with the actual requirements of the AD, or if they did, the omission was not detected. FAA inspectors responsible for oversight of UAL's maintenance program also did not detect this error because normal surveillance of AD compliance merely involved verifying the correctness of UAL's paperwork that listed the applicable AD's and compliance dates. The inspectors did not actually verify UAL's compliance action by shop visits, or by comparison of work sheets with AD provisions. These omissions by the UAL maintenance and quality assurance personnel, and the limitations of the FAA surveillance procedures were probably significant in setting the stage for the events that led to the actual cause of the door separation from N4713U.

Another matter of concern is the quality of UAL's trend analysis program. There was no indication that the repeated discrepancies with the forward cargo door on N4713U "raised a flag" within the UAL maintenance department. A quality assurance or trend analysis program should have detected an adverse trend and should have prompted efforts to resolve the repeated problems. If it had, any faults in the door electrical system or damage to mechanical components might have been detected.

In summary, the Safety Board concludes that there were several opportunities wherein Boeing, the FAA, and UAL could have taken action during the initial design and certification of the B-747 cargo door, as well as during the operation and maintenance of the cargo door installed on N4713U, to ensure the continuing airworthiness of the cargo door. The Safety Board further concludes that these deficiencies and oversights contributed to the cause of this accident.

2.8 Survival Aspects

The Hickam ARFF units and the airport's ARFF units operated on separate radio networks and thus they could not communicate directly on-scene by radio. This situation required them to communicate by voice. Although the two ARFF services had a common radio frequency (as per the Airport Emergency Plan), procedures for its use had not yet been developed. The Safety Board believes that such communication procedures should be expeditiously developed.

The use of camouflage paint schemes on military ARFF vehicles may be appropriate for military purposes; however, the Safety Board believes that camouflage is not appropriate for ARFF vehicles that are operated at a joint- use airport. It is obvious that these vehicles must be conspicuous to be seen by other responding vehicles and by persons who are involved in the accident, such as airport and airline personnel, crew and passengers, and off-airport firefighting and rescue vehicles.

The National Fire Protection Association Standards recommend for primary firefighting, rapid intervention and combined agent vehicles, that, "Paint finish shall be selected for maximum visibility and shall be resistant to damage from firefighting agents."4 Furthermore, Federal Aviation Regulation 14 CFR 139.319 (f) (2) requires emergency vehicles, "Be painted or marked in colors to enhance contrast with the background environment and optimize daytime and nighttime visibility and identification." Further guidance for the high visibility color of ARFF vehicles is provided in a Federal Aviation Administration Advisory Circular where the vehicle paint color is specified as, "lime yellow" Dupont No. 7744 UH or its equivalent.5

Because flight attendants are vital to the safety and survival of the passengers following a decompression, measures should be taken to prevent flight attendants from being incapacitated by hypoxia. The Safety Board believes that oxygen masks should be attached to the emergency oxygen bottles to avoid any delay in their use in order to be in compliance with the intent of 14 CFR 25.1447 (c)(4). Therefore, the FAA should direct its inspector staff to survey B-747 airplanes for compliance with 14 CFR 25.1447(c)(4), and correct deficiencies found.

In this accident, the use of megaphones was vital because of the inability to be heard over the public address (PA) system. Title 14CFR 121.309 (f)(1) requires one megaphone on each airplane with a seating capacity of more that 60 and less that 100 passengers; 14 CFR 121.309 (f)(2) requires two megaphones in the cabins on each airplane with a seating capacity of more than 99 passengers. As this decompression demonstrated, additional megaphones are necessary on wide-body and large narrow-body airplanes to ensure communication in the cabin during emergencies when the PA system is inoperative.

Had there been a need for an immediate evacuation, or a water ditching, rapid egress would not have been possible at doors 2-left and 2-right because they were blocked by open storage compartments and spilled contents. The possibility also exists that a compartment door could release during a hard landing or turbulence and swing down and injure a flight attendant. Thus, the Safety Board believes that improved latches should be installed and the downward movement of stowage compartments doors should be restricted to prevent the doors from striking a seated flight attendant or block the exit door.

The Safety Board believes that the problems with life preserver donning and adjustment demonstrated in this accident should be addressed by the FAA. The straps and fittings on life preservers need to be evaluated to determine where improvements can be made, and clearer donning instructions should be developed.

TSO-C13d, Life Preservers 1/3/83 prescribes the minimum performance standards for life preservers. With regard to donning, the TSO requires:

Donning. It must be demonstrated that an adult, after receiving only the customary preflight briefing on the use of life preservers, can don the life preserver within 15 seconds unassisted while seated. It must be demonstrated that an adult can install the life preserver on another adult, a child, or an infant within 30 seconds unassisted. The donning demonstration is begun with the unpackaged life preserver in hand.

Based on flight attendant interviews and information obtained from passengers these donning times were exceeded in many instances.

The Safety Board has made numerous recommendations to the FAA in the past regarding needed improvements in life preserver donning instructions, donning procedures, and timing of donning.6 The FAA has adopted most of the Safety Board's recommendations in its April 23, 1986, revision to TSO-C13e, Life Preservers, which now requires the wearer to be able to secure the preserver with no more than one attachment and make no more than one adjustment for fit. Also, donning tests are required for age groups of users starting with 20-29 years and ending with 60-69 years. At least 60% of the test subjects in each age group must be able to don then life preserver within 25 seconds unassisted with their seatbelts fastened starting with the life preserver in its storage package. TSO-C13e contains requirements that would have eliminated some of the problems that passengers had in this accident in correctly donning and adjusting their life preservers.

The Safety Board has recommended (A-85-35 through-37) to the FAA to amend 14 CFR 121, 125, and 135 to require air carriers to install life preservers that meet TSO-C13e within a reasonable time. The FAA adopted TSO-C13e on April 23, 1986, and originally had specified an effective date of April 23, 1988, after which all newly manufactured life preservers approved under the TSO system would have to meet the requirements of TSO-C13e. The objective of the cut off date was to introduce life preservers into the fleets with the higher performance level as specified in TSO-C13e by assuring that replacement articles met the higher standards. On March 3, 1988, the FAA rescinded the cut off date to seek further public comments of fleet retrofit in accord with the proposed rulemaking. See Section 4.0 for FAA action and status of the recommendations.

3. CONCLUSIONS

3.1 Findings

1. There were no flightcrew or cabincrew factors in the cause of the accident or injuries.
2. There were no air traffic control or weather factors in the cause of the accident.
3. The airplane had not been maintained in accordance with the provisions of AD-88-12-04 that required an inspection of the cargo door locking mechanisms after each time the door was operated manually and restored to electrical operation. However, this circumstance was determined not to be a factor in the accident.
4. All but one of the electrical components remaining with the airplane or found with the cargo door that were necessary to have malfunctioned in order to cause an inadvertent electrical opening of the cargo door after dispatch were found to function properly.
5. The forward cargo door lock sectors were found in the

locked position (actually in an "over-locked" position) and jammed against the latch cams. The latch cams were found in the nearly open position.

6. The latch actuator manual drive port seal was found damaged from the forces involved in the separation of the door and did not indicate that the drive port had been used to open the door latches manually before the accident.

7. Electrical continuity tests indicated that the S2 master latch lock switch was in the "not locked" position when it was recovered with the cargo door. Because it had sustained damage from being submerged in the sea, its preaccident condition could not be determined.

8. An S2 switch functioning as found after recovery would permit electrical power to the door during ground operation so that additional failure modes or activation of the door control switch could result in movement of the latching cams.

9. All other switches associated with operation of the cargo door were found damaged from being submerged in the sea; however, they were determined to be properly installed and probably functional.

10. Short circuit paths in the cargo door circuit were identified that could have led to an uncommanded electrical actuation of the latch actuator; this situation occurred most likely before engine start, although limited possibilities for an uncommanded electrical actuation exist after engine start while an airplane is on the ground with the APU running.

11. It was not possible for electrical short circuits to command the cargo door to open at the time of the loss of the door, and it is highly improbable that such an event occurred when the airplane was airborne during the short period while the APU was running.

12. Insulation breaches were found on recovered portions of the cargo door wires that could have allowed short circuiting and

power to the latch actuator, although no evidence of arcing was noted. All of the wires were not recovered, and tests showed that arcing evidence may not be detectable.

13. An uncommanded movement of cargo door latches that occurred on another UAL B-747 on June 13, 1991, was attributed to insulation damage and a consequent short between wires in the wiring bundle between the fuselage and the moveable door. Because the S2 switch functioned properly on that airplane, movement of the latches would not have occurred after the door was locked.

14. UAL's maintenance trend analysis program was inadequate to detect an adverse trend involving the cargo door on N4713U. This circumstance was determined not to be a factor in the accident.

15. FAA oversight of the UAL maintenance and inspection program did not ensure adequate trend analysis and adherence to the provisions of airworthiness directives. This circumstance was determined not to be a factor in the accident.

16. The smooth wear patterns on the latch pins of the forward cargo door installed on N4713U were signs that the door was not properly aligned (out of rig) for an extended period of time, causing significant interference during the normal open/close cycle.

17. The rough heat-tinted wear areas on the latch pins of the forward cargo door installed on N4713U marked the positions of the cams at the time the door opened in flight.

18. The design of the B-747 cargo door locking mechanisms did not provide for the intended "fail-safe" provisions of the locking and indicating systems for the door.

19. Boeing's Failure Analysis, which was the basis upon which the FAA granted an alternative method of compliance with the provisions of 14 CFR 25.783(e), was not valid as evidenced by the findings of the Pan Am incident in 1987, and the accident

involving flight 811.

20. Boeing and the FAA did not take immediate action to require the use of the cam position view ports following the Pan Am incident, and did not include this requirement in the provisions of the Alert Service Bulletins or AD-88-12-04.

21. There were several opportunities for the manufacturer and the FAA to have taken action during the service life of the Boeing 747 that might have prevented this accident.

22. The fact that the crash fire rescue vehicles responding to this accident did not use a common radio frequency led to problems in communication among the responding vehicles.

23. The camouflage paint scheme of the military fire rescue units led to reduced visibility of these units and resulted in at least one near-collision.

24. Megaphones were used in flight to communicate with passengers because of the high ambient noise level. However, more megaphones would have afforded better communication in all parts of the cabin.

25. Some flight attendants and passengers had difficulties tightening straps of their life preservers around their waists because of the fabric used, the design of the adjustment fittings, and the angle the straps were pulled.

26. Articles that fell to the floor from stowage bins above the L-2 and R-2 exits and galley service items had to be cleared away from the exits before the emergency evacuation could be initiated.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff.

Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

4. RECOMMENDATIONS

As a result of the investigation, including evidence from the recovered cargo door and a June 13, 1991, incident involving the uncommanded electrical operation of a cargo door on a UAL Boeing 747 at JFK Airport, the National Transportation Safety Board recommends that the FAA:

Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits. (Class II, Priority Action) (A-92-21)

As a result of this investigation, on August 23, 1989, the Safety Board issued the following safety recommendations to the FAA:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams. (Class II, Priority Action)(A-89-92)

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks,

independently. (Class II, Priority Action)(A-89-93)
Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions. (Class II, Priority Action)(A-89-94)
The FAA responded to Safety Recommendations A-89-92 through -94 on November 3, 1989. During its evaluation of Safety Recommendation A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with AD 88-12-04, cannot be overridden during mechanical or
least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this, Safety Recommendation A-89-92 has been classified as "Closed--Reconsidered."
The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all jetpowered transport-category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight. The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100 certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as "Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for

any pressurized aircraft using nonplug doors and that the FAA should not be limiting this review to only those transports which are jetpowered.

On November 29, 1990, Boeing issued service bulletin number 747-52-2224 applicable to all 747-100, 747-200, and 747-300 airplanes to add a new "door latch" switch to all 747 cargo doors. In addition to the door warning switch that monitors the position of the pressure relief doors, the new door latch switch is activated by the latch cam bellcrank to separately sense the position of the latch cams. The existing "door closed" switch is also replaced with a double pole switch. The additional pole is used to separately sense the position of the door. Another single pole switch is also added to redundantly sense the position of the door. If any of these switches are not actuated, the warning light on the flight engineer's panel and a new light added to pilot's glareshield panel will be illuminated. The modification also requires installation of new cargo door control panels on the forward and aft lower cargo doors. The new panel incorporates an additional light to indicate proper door locking.

The FAA mandated the incorporation of this service bulletin within 18 months by AD 90-09-06, Amendment 39-6581, effective May 29, 1990.

Also, as a result of this accident, on May 4, 1990, the National Transportation Safety Board issued the following safety recommendations to the FAA:

Amend 14 CFR 25.1447(c)(4) to require that face masks be attached to the regulators of portable emergency oxygen bottles. (Class II, Priority Action) (A-90-54)

Require, in accordance with the requirements of 14 CFR 25.1447 (c)(4), that a portable oxygen bottle be located at the flight attendant stations at exit door 5 right and at exit door 5 left in B-747 airplanes. (Class II, Priority Action) (A-90-55)

Require that no articles be placed in storage compartments that are located over emergency exit doors. (Class II, Priority Action) (A-90-56)

Amend 14 CFR 121.309(f) to require a readily accessible megaphone at each seat row at which a flight attendant is stationed. (Class II, Priority Action) (A-90-57)

Take corrective action to improve direct visibility to passengers from the upper level flight attendant jumpseat in the B-747 airplanes using eye reference data contained in Federal Aviation Administration report FAA-AM-75-2 "Anthropometry of Airline Stewardesses." (Class II, Priority Action) (A-90-58)

Issue an Airworthiness Directive to require that stronger latches be installed in oversized storage compartments that formerly held liferafts on all B-747 airplanes and also limit the distance that these compartments can be opened. (Class II, Priority Action) (A-90-59)

Demonstrate for each make and model of life preserver that it can be donned, adjusted, and tightened within the elapsed time required by TSO-C13d. Direct particular attention to the ease with which straps pass through adjustment fittings when the straps are pulled at all possible angles. (Class II, Priority Action) (A-90-60)

Establish a cutoff date of [within 1 year of this recommendation letter] after which all life preservers manufactured for passengercarrying aircraft would be required to meet the specifications of TSO-C13e. (Class II, Priority Action) (A-90-61)

The FAA first responded to these safety recommendations in a July 26, 1990, letter. Further responses to various safety recommendations in the group came in letters dated October 26, 1990 (A-90-59); May 13, 1991 (A-90-58); September 23, 1991 (A-90-55, -56, and -59); and March 9, 1992 (A-90-59). The current status of each safety recommendation is:

A-90-54: "Open--Acceptable Response," pending outcome of potential rulemaking initiative by the FAA.

A-90-55: "Open--Unacceptable Response," pending a review by

the FAA of B-747 airplanes for compliance with portable oxygen bottle placement and securement requirements and for modifications that do not meet the intent of the type certification.
A-90-56: "Open--Unacceptable Response," pending a reexamination by the FAA of the potential for contents of compartments spilling out during an emergency and obstructing passengers.
A-90-57: "Open--Unacceptable Response," pending the FAA's review of its position regarding a requirement for multiple megaphones on passenger airplanes.
A-90-58: "Closed--Reconsidered" as a result of the Safety Board's acceptance of the FAA position that the cabin jumpseat design on B-747's does not constitute an unsafe condition.
A-90-59: "Open--Acceptable Response," pending the issuance of an Airworthiness Directive to require stronger latches on oversized storage compartments on B-747 airplanes.
A-90-60: "Open--Acceptable Response," pending the implementation of the latest iteration of TSO-C13.
A-90-61: "Open--Unacceptable Response," pending inclusion in TSO-C13 (latest iteration) of a cutoff date after which all life preservers manufactured for passenger-carrying aircraft would be required to meet the specifications of the TSO.
The FAA's March 9, 1992, response to Safety Recommendation A-90-59 included the final AD addressing this issue. The AD does meet the intent of the recommendation, which is now classified as "Closed--Acceptable Action."
Also as a result of this accident, on May 4, 1990, the Safety Board reiterated the following recommendations to the FAA:
A-85-35
Amend 14 CFR 121 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the

adoption of the current revision of the TSO; ensure that 14 CFR 25 is consistent with the amendments to Part 121.

A-85-36

Amend 14 CFR 125 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; amend Part 125 to require approved flotation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR 25 is consistent with the amendments of Part 125.

A-85-37

Amend 14 CFR 135 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; Amend Part 135 to require approved floatation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR SFAR No. 23 is consistent with the amendments to Part 135.

In a November 28, 1988, letter to the FAA, the Safety Board recommended that a cutoff date January 1, 1989, be reestablished. Based on this accident, the Safety Board's again urges the FAA to establish a cutoff date by which life preservers meeting TSO-C13e would be introduced into the fleets within a reasonable time (A-85-36). The Safety Board recognizes that the FAA has complied with the part of this recommendation pertaining to the flotation-type seat cushions.

Safety Recommendations A-85-35 and -37 are being held in an "Open--Acceptable Action" status pending the publication of the final rule. Safety Recommendation A-85-36 is being held in an "Open--Unacceptable Action" status because Part 125 operations were not included in the FAA rulemaking action.

As a result of its investigation, on May 4, 1990, the Safety Board also recommended that the State of Hawaii, Department of Transportation, Airports Division:

Develop, in cooperation with the Department of Defense, procedures for direct radio communication between aircraft rescue and fire fighting vehicles operated by the State of Hawaii and Hickam Air Force Base that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-62)

Additionally, as a result of its investigation, on May 4, 1990, the Safety Board recommended that the Department of Defense:

Develop, in cooperation with the State of Hawaii Department of Transportation, procedures for direct radio communication between aircraft rescue and firefighting vehicles operated by Hickam Air Force Base and the State of Hawaii that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-63)

Comply with Federal Regulation 14 CFR 139.319(f)(2) and the guidance contained in Federal Aviation Administration Advisory Circular 150/5220-14 by using high visibility color for aircraft rescue and firefighting vehicles that operate at Honolulu International Airport. (Class II, Priority Action) (A-90-64)

The Department of Defense responded to Safety Recommendations A-90-63 and -64 on August 17, 1990, citing the establishment of emergency radio communication ability between ARFF vehicles operated by Hickam Air Force Base and the State of Hawaii at Honolulu International Airport. Based on this action, Safety Recommendation A-90-63 was classified as "Closed--Acceptable Action" on December 12, 1990. With the establishment of the communications system as recommended, the Safety Board now classifies Safety Recommendation A-90-62 as "Closed--Acceptable Action."

Also, with regard to Safety Recommendation A-90-64, the

Department of Defense pointed out that the Air Force has initiated a program to rep™ aint the vehicles over a 3-year period to spread out funding concerns. This safety recommendation is being held as "Open--Acceptable Response," pending the completion of the repainting program in 1993.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

SUSAN COUGHLIN
Acting Chairman

JOHN K. LAUBER
Member

CHRISTOPHER A. HART
Member

JOHN HAMMERSCHMIDT
Member

JAMES L. KOLSTAD
Member

March 18, 1992

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Washington Headquarters of the National Transportation Safety Board was notified of the United Airlines accident within a short time after the occurrence. A full investigation team departed Washington, D.C. at 1400 eastern daylight time on the same day and arrived in Honolulu at 0030 Hawaiian standard time the next day.

The team was composed of the following investigation groups: Operations, Structures/Systems, Maintenance Records, Metallurgy, and Survival Factors. In addition, specialist reports were prepared relevant to the CVR, FDR and radar plots.

Parties to the field investigation were United Airlines, the FAA, the Boeing Commercial Airplane Company, the Air Line Pilots

Association, the International Association of Machinists, and the Association of Flight Attendants.

2. Public Hearing

A 3-day public hearing was held in Seattle, Washington, beginning on April 25, 1989. Parties represented at the hearing were the FAA, United Airlines, the Boeing Commercial Airplanes Company, the Air Line Pilots Association, and the International Association of Machinists.

APPENDIX B

PERSONNEL INFORMATION

Captain David Cronin

Captain David Cronin, 59, was hired by UAL on December 10, 1954. The captain holds Airline Transport Pilot (ATP) Certificate No. 1268493 with airplane multiengine land ratings and commercial privileges in airplane single-engine land, sea and gliders. The captain is type rated in the B747, DC10, DC8, B727, Convair (CV) 440, CV340, CV240 and the learjet. The captain was issued a first class medical certificate on November 1, 1988, with no limitations.

The captain's initial operating experience (IOE) check out in the B747 occurred in December, 1985. The captain's latest line and proficiency checks in the B747 were completed in August and December, 1988, respectively. Training in ditching and evacuation was included with the proficiency check. The captain had flown a total of about 28,000 hours, 1,600 to 1,700 hours of which were in the B747. During the 24-hour, 72-hour and 30-day periods, prior to the accident, the captain had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 76 hours, 18 minutes, respectively.

First Officer Gregory Slader

First Officer Gregory Slader, 48, was hired by UAL on June 15, 1964. The first officer holds ATP Certificate No. 1528630 with airplane multiengine land ratings and commercial privileges in airplane single-engine land. The first officer is type rated in B747, DC10, B727, and B737. The first officer was issued a first class medical certificate on February 14, 1989, with no limitations. The first officer's initial operating experience (IOE) check out in the B747 occurred in August, 1987. The first officer's latest proficiency check in the B747 was completed in October, 1988. Training on ditching and evacuation was included with the proficiency check. The first officer had flown a total of about 14,500 hours, 300 hours of which were in the B747. During the 24-hours, 72-hour and 30-day periods prior to the accident, the first officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Second Officer Randal Thomas

Second Officer Randal Thomas, 46, was hired by UAL on May 22, 1969. The second officer holds Flight Engineer Certificate No. 1947041 for turbo jet powered airplanes, issued July 18, 1969. The second officer holds commercial pilot certificate No. 1585899 with ratings and limitations of airplane single and multiengine land with instrument privileges. The second officer was issued a first class medical certificate on December 6, 1988, with no limitations. The second officer's IOE check out in the B747 occurred in March, 1987. The second officer's latest proficiency check in the B747 was completed in October, 1988. Training in ditching and evacuation was included with the proficiency check. He had flown a total of about 20,000 hours, about 1,200 hours of which were as second officer on the B747. During his 24-hour, 72-hour and 30 day-periods, prior to the accident, the second officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Flight Attendant and Chief Purser Laura Brentlinger

Flight attendant Laura Brentlinger, 38, was employed by UAL in May 1982; and had completed B747 recurrent training on September 19, 1988.

Flight Attendant and AFT Purser Sarah Shanahan

Flight attendant Sarah Shanahan, 42, was employed by UAL in August 1967; and had completed B747 recurrent training on October 10, 1988.

Flight Attendant Richard Lam

Flight attendant Richard Lam, 41, was employed by UAL on April 1970; and had completed B747 recurrent training on September 16, 1988.

Flight Attendant John Horita

Flight attendant John Horita, 44, was employed by UAL in June 1970; and had completed B747 recurrent training on November 1, 1988.

Flight Attendant Curtis Christensen

Flight attendant Curtis Christensen, 34, was initially employed by PAA in May 1978. He was subsequently employed by UAL in February 1986 when UAL purchased PAA Pacific Division. Flight attendant Chrisensen had completed B747 recurrent training on December 12, 1988.

Flight Attendant Tina Blundy

Flight attendant Tina Blundy, 36, was employed by UAL in May 1973; and had completed B747 recurrent training on October 28, 1988.

Flight Attendant Jean Nakayama

Flight attendant Jane Nakayama, 37, was employed by UAL in August 1973; and had completed B747 recurrent training on December 6, 1988.

Flight Attendant Mae Sapolu

Flight attendant Mae Sapolu, 38, was initially employed by Pan American Airlines (PAA) in March 1973. She was subsequently employed by UAL in February 1986; when UAL purchased PAA Pacific Division. Flight attendant Sapolu completed B747 recurrent training on October 13, 1988.

Flight Attendant Robyn Nakamoto

Flight attendant Robyn Nakamoto, 26, was employed by UAL in

April, 1986, and transferred to the Inflight Service Division in May, 1988. She was initially trained on the B747 in May 1988; and had not attended recurrent training.

Flight Attendant Edward Lythgoe

Flight attendant Edward Lythgoe, 37, was employed by UAL in December 1978; and had completed B747 recurrent training on October 21, 1988.

Flight Attendant Sharol Preston

Flight attendant Sharol Preston, 39, was employed by UAL in July 1970; and had completed B747 recurrent training on July 29, 1988.

Flight Attendant Ricky Umehira

Flight attendant Ricky Umehira, 35, was employed by UAL in November 1983; and had completed B747 recurrent training on November 15, 1988.

Flight Attendant Darrell Blankenship

Flight attendant Darrell Blankenship, 28, was employed by UAL in February 1984; and had completed B747 recurrent training on February 10, 1988.

Flight Attendant Linda Shirley

Flight attendant Linda Shirley, 30, was employed by UAL in March 1979; and had completed B747 recurrent training on November 3, 1989.

Flight Attendant Ilona Benoit

Flight attendant Ilona Benoit, 48, was initially employed by PAA in November 1969. She was subsequently employed by UAL in February 1986; and had completed B747 recurrent training on November 17, 1988.

Lead Ramp Serviceman Paul Engalla

Lead ramp serviceman Paul Engalla was employed by UAL in 1959. Because of his extensive ramp service experience, Mr. Engalla was selected as a ramp service trainer in 1986.

Ramp Serviceman Daniel Sato

Ramp serviceman Daniel Sato was employed by UAL in May

1987. Company records indicate that his proficiency in the opening and closing of B747 cargo doors and the operation of container loads was attained in September 1988.

Ramp Serviceman Brian Kitaoka

Ramp serviceman Brian Kitaoka was employed by UAL in November 1986. Company records indicate that his proficiency in the operation of container loaders was attained in November 1987. His proficiency in the opening and closing of B747 cargo doors was attained in October 1988.

Dispatch Mechanic Steve Hajanos

Dispatch mechanic Steve Hajanos was employed as an airplane mechanic by UAL on October 30, 1986. He holds FAA Airplane and Powerplants Certificate No. 362583850, issued November 14, 1981. He was formerly employed by Aloha Airlines as a maintenance supervisor and by World Airways as a mechanic and maintenance supervisor. He began his aviation career as an airplane mechanic in the United States Air Force.

APPENDIX C

AIRPLANE INFORMATION

Type of Date of Maximum Inspection Inspection Cycles Interval Service No. 1 Current 02/23/89 58,814:24 15,027 Note 1 Previous 02/23/89 58,809:02 15,026 Service No. 2 Current 02/22/89 58,802:35 15,024 65 Hours Previous 02/18/89 58,747:12 15,016 Note 2 A Check Current 02/14/89 58,710:14 15,009 350 Hours Previous 01/16/89 58,368:57 14,947 B Check Current 11/28/88 57,751:44 14,839 131 Days Previous 07/28/88 56,635:36 14,632 C Check Current 11/28/88 57,751:44 14,839 393 Days Previous 11/19/87 53,789:00 14,146 MPV Check Current 04/30/84 43,731:0 11,857 5 Years Previous 01/30/80 30,906:0

D Check Current 04/30/84 43,731 19,237 9 Years Previous 09/09/76 19,237 Note 1: Service No. 1 to be accomplished on through flights or at trip termination whenever time is less than

12 hours per Maintenance Manual Procedures BX 12-0-1-1.
Note 2: Aircraft with layover of 12 hours or more will receive a Service No. 2 not to exceed 65 flight hours between checks.

APPENDIX D

INJURY INFORMATION

Flight Crewmember.--The second officer sustained minor superficial brush burns to both elbows and forearms, during the evacuation.

Cabin Crewmembers.--The cabin crewmembers sustained the following injuries during the evacuation:

Flight attendant No. 1 sustained a strained left shoulder;
Flight attendant No. 2 sustained acute thoracic and lumbosacral strain;
Flight attendant No. 3 sustained a mild right bicep strain;
Flight attendant No. 4 sustained a left elbow contusion, left shoulder dislocation, and mild lumbosacral strain;
Flight attendant No. 5 sustained a left calf contusion;
Flight attendant No. 6 sustained a mild left elbow bruise;
Flight attendant No. 7 sustained mild left arm and lower back strain;
Flight attendant No. 8 sustained a soft tissue injury to the back;
Flight attendant No. 9 sustained abrasions to both palms and the left knee;
Flight attendant No. 10 sustained a fracture of the left tenth rib;
Flight attendant No. 11 sustained a minimal injury to the right middle finger PIP joint and left first MP joint;
Flight attendant No. 12 sustained a pulled muscle on the left side of the neck;
Flight attendant No. 13 sustained a comminuted fracture of the right ulna and radius;
Flight attendant No. 14 sustained a mild thoracic back strain;
Flight attendant No. 15 sustained a non-displaced fracture of C-6, a cerebral concussion, a fracture of the proximal right humerus,

and multiple lacerations;
A flight attendant, flying as a passenger, sustained mild lumbosacral strain, a laceration of the right little finger, and a left elbow abrasion.
Passengers.--Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH, and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally injured in the accident.
Passengers seated in the indicated seats sustained the following injuries:
Seat
7C - Barotrauma to both ears
9C - Half-inch laceration to the upper left arm, superficial abrasions to left arm and hand, barotrauma to both ears
9E - Superficial abrasions and contusions to the left hand, mild barotrauma to both ears
10B - Superficial abrasions to the left elbow and left middle finger
10E - Superficial abrasions to the torso and left forearm, bruising of the left hand and fingers
11E - Laceration on the right ankle tendon, multiple bruises
11F - Slight contusion of the right shoulder
13D - Barotrauma to both ears
13E - Bleeding in both ears
13H - Contusion to the left periorbital area
14A - Laceration in the parietal occipital area, barotrauma to both ears
15J - Comminuted fracture of the lateral epicondyle of the left distal humerus (about 5mm separation)
16B - Superficial abrasions to the right arm
16J - Barotrauma to both ears
16K - Right temporal abrasions
26A - Barotrauma to both ears

26B - barotrauma to both ears
26H - Barotitis to both ears, low back pain, irritation to the right eye due to foreign bodies
27A - Barotrauma to the right ear
28J - Superficial abrasions and a contusion to the left hand, mild barotrauma to both ears
1The flap track canoe fairings are numbered 1 through 8, from left outboard to right outboard.
2For ease in reference, the following numbering was used to relate forward cargo door frames to fuselage body stations (BS): frame 1--BS 567.10, frame 2--BS 580.95, frame 3--BS 596.75, frame 4--BS 608.15, frame 5--BS 623.96, frame 6--BS 636.02, frame 7--BS 651.50, frame 8--BS 662.90.
3 The "used" switch is the switch through which electricity passes; the "unused" switch does not have electricity pass through it.
4NFPA 414 - Aircraft Rescue and Fire Fighting Vehicles, National Fire Protection Association, 1984, Batterymarch Park, Quincy, MA 02269.
5Airport Fire and Rescue Vehicle Specification Guide, AC 150/5220-14, March 15, 1979, Federal Aviation Administration, Washington, D.C. 20591.
6 Air Carrier Overwater Emergency Equipment and Procedures" (NTSB/SS-85/02)

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "aniljit singh uppal" <aniljitsingh@hotmail.com>
Subject: **Obtaining evidence**

Thank you for your call. This email confirms we have two way communication. I will send the electronic version of AAR 92.02 for UAL 811 in separate email.

May I conclude by saying that I know that your clients did not bomb AI 182 because nobody bombed AI 182. I can prove that conclusion beyound most doubt with facts, data, evidence, and official documents.

In addition you have access to the video tapes of the actual wreckage to match that damage to the confirmed wiring/cargo door event of UAL 811; you can get the wreckage database to match against the databases of PA 103, TWA 800; we can plot the actual debris pattern on the surface to deduce the destruction sequence and area of first damage; you can get the photographs of the actual wreckage that they retrieved. They may have photographs of the forward cargo door area before it slipped back into the ocean.

All of the above contain actual irrefutable facts and will avoid the conspiracy nonsense which plagues the four Boeing 747 fatal accidents, AI 182, PA 103, TWA 800 and UAL 811. I shall inform you of other evidence that may be relevant that you may obtain through discovery.

I am a little concerned that an attorney, Keith Hamilton, paid for by the Crown is 'helping' the defense. Regardless I shall explain everything to him if you say so.

The extradition of Mr. Reyat is wrong also and a hearing in Britain is the appropriate time to broach the concept of no bomb but mechanical cause.

Feel free to call me anytime for voice contact and email is always available. Here are some backup email addresses, corazonsmith@msn.com, CEO@internetpagepublishing.com and of course, barry@corazon.com

May I address you as Aniljit? I am Barry.

The defense must know the complete details of AI 182, PA 103, UAL 811, and TWA 800, they are all caused by the same probable cause, wiring shorting on the forward cargo door unlatch motor allowing the midspan latches to rupture causing explosive decompression and the structural failure of the fuselage. AI 182 is an airplane crash and not a bank robbery. The similar crashes and causes to AI 182 must be completely evaluated. The three match UAL 811, the only confirmed mechanical electrical caused open cargo door event.

To know the accidents is to read the Aircraft Accident Reports for each.

I shall send you the ones for AI 182, PA 103, and UAl 811, the one for TWA 800 is available at their website for download.

Looking forward to talking with you again, Aniljit.

Cheers,
Barry
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.

US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

Thank you for your assistance. My number is 604-834-8888. I have noted the following three items to request from the crown.

1. All video tapes
2. Complete wreckage database.
3. All photographs.

I have also noted the name of the person to contact on the Transport Safety Board - John Garstaign.

I will share this information with you as soon as I receive it.

Thank you and I look forward to seeing you in March

Aniljit Singh

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: aniljit singh uppal <aniljitsingh@hotmail.com>
Subject: **TWA 800 link for report**

Dear Aniljit, below is link to NTSB for large TWA 800 electronic version of AAR 00/03. It's about 350 pages not including the appendices.

Additional information which is relevant but omitted from the AI 182 report is the complete CVR, cockpit voice recorder, evaluation, the complete Flight Data Recorder, FDR, evaluation, the interview notes with the ticket person who took the phone calls from the 'Sikhs,' and something that is very very important but will be difficult to obtain, the complete evaluation of the 'bombing' of the baggage cart at Narita airport Japan, which killed two. That event is very important and has sketchy evidence. The Japanese may have the report.

Cheers,
Barry

http://www.ntsb.gov/publictn/A_Acc1.htm

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Recent publications are available online in the Adobe Portable Document Format (PDF), which requires the free Acrobat Reader from Adobe for viewing. IMPORTANT: Some PDF publications are quite large - see the Abstract description for *each document to obtain file size*. (Questions/Problems/Tips)

Title: Aviation Accident Report: In-flight Breakup Over the Atlantic Ocean Trans World Airlines (TWA) Flight 800 Boeing 747-141, N93119 near East Moriches, New York July 17, 1996
NTSB Report Number: AAR-00-03, adopted on 08/23/2000 [Abstract | PDF document]
NTIS Report Number: PB2000-910403

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: aniljit singh uppal <aniljitsingh@hotmail.com>
Subject: **Evidence exists:**

Dear Aniljit,

Here is more information you may obtain as defense which is relevant to the wiring/cargo door explanation and mostly omitted from the Indian and Canadian AAR.

Complete maintenance logs of AI 182 long before and just before the fatal flight.

The maintenance report on the aft cargo door removal to include what was done and why.

To summarize discovery evidence which exists and will support the wiring/cargo door explanation:

1.Videotapes of wreckage.
2. Photographs of wreckage.
3. Wreckage database.
4. Narita Airport baggage explosion report.
5. Interview notes with ticket taker.
6. Maintenance logs of the aircraft for a period before the accident.
7. Maintenance report on the aft cargo door removal and reinstallation.
8. CVR evaluation report.
9. FDR evaluation report.

I also strongly recommend contacting the PA 103 defense team now in the midst of an appeal. They have access and you will too, to the hangar at Farnborough to examine the actual wreckage and in particular the forward cargo door area about which the AAIB AAR is strangely silent.

adlaw@planet.nl, rskeenqc@compuserve.com, adlaw@callnetuk.com are the emails of the defense team:
Kamal Maghur,
Mr. Alistair Duff,
Mr. Stephen Mitchell,
Mr. Richard Keen,
Murdo Macleod,
Eddie MacKechnie,
McGRIGOR DONALD,
Alex Prentice,
William Taylor,
John Beckett
The evidence exists which will free your clients. It may be

difficult to obtain, observe, or evaluate, but it is there. Below is what happens to a Boeing 747 when the forward cargo door ruptures in flight. This is what happened to AI 182. It was not caused by a bomb.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "aniljit singh uppal" <aniljitsingh@hotmail.com>
Subject: **Re: Obtaining evidence**

Dear Aniljit, thank you for reassuring me about Mr. Hamilton. I was beginning to feel as if he might be a 'mole' for the Crown. Normally there would not be suspicions about motives but with these plane crashes I have realized that 'bomb' conspiracy guys are unscrupulous and have no honor. I am a scientist and would prefer to stay out of the political aspects of these crashes but it is inevitable that I will be drawn in somehow; therefore I'm trying to identify the cast of characters so I know how to respond to questions from them.

In that regard, I found your questions and comments to me to be plainly spoken, direct, and professional.

I shall treat Mr. Hamilton as an open minded attorney with the goal of representing Mr. Malik to the best of his ability by examining and evaluating all the available real evidence.

The below list of things to do demonstrates the degree of science and detail required to conclusively match AI 182 to UAL 811 and other similar crashes to persuade beyond a reasonable doubt that AI 182 was caused by a wiring/cargo door event and not a bomb. It will not be possible to complete all of the below because of the location of the wreckage at the bottom of the ocean, but some can be evaluated.

I understand that the Defence effort at cargo door cause may be to sow reasonable doubt in the minds of jury, muddy the 'bomb' waters, and thus insert some reason for the jury to come to 'not guilty' verdict by providing a plausible, reasonable, mechanical alternative explanation with precedent, UAL 811. From my point of view, the probable cause of wiring/cargo door must be proven conclusively so that safety can be achieved by removing or isolating the offending Poly X wires so that the fatal events will not happen again.

The sooner we get started on obtaining evidence on AI 182 from the RCMP, TSB, and other Canadian and Indian authorities, the better.

This will truly be an international effort. The Crown has already travelled all over the world, at taxpayer expense, to obtain prosecution evidence but now is the time for the Crown to allow and fund the Defence to do the same. Mr. Hamilton, as an honorable man, can gain access to those sites that hold the evidence that has been held in storage for these many years for this very purpose; to be examined by objective investigators. I am in contact with professional persons who are capable of doing those very evaluations and I may be able to persuade them to assist, if asked.

I am eager to begin.

PS: Another piece of relevant evidence to obtain, although gruesome, is the complete medical forensic report on all the recovered victims. The type of fatal injuries they incurred is very important. By the way, none of the victims showed any type of 'bomb blast type' injury but the complete autopsy reports are needed.

Cheers,
Barry

At 9:02 AM -0800 2/21/01, John Barry Smith wrote:
What was the condition of the cargo door hinges?
Bent upward/equally/unequally etc.
What was the condition of the torque-limiting devices?

>show that door has had "uncommanded door opening."
>If these are in direct contact with latch sectors, we can reasonably
conclude that fcd tried to open itself.
What was the condition of the fcd frame and the locking pin holes?
Do these holes show the locking pin being pulled across the frame in
different directions?

Was the bottom of the cargo door frame worn away prior to crash?
What was the condition of the floor beams immediately inboard from fcd?
What was the condition of the bulkhead immediately aft of the fcd?
Do the floor and bulk head beam's cross sections indicate
that slow (seconds) high energy tortional twisting or fast (<sec) fracture
fatigue damage?
Detailed paint mark analysis of any "foreign" paint marks on fcd?
Detailed analysis of the "grease" on fcd parts for wear indicator materials?
What was the condition (failure mechanism) of the RH Inboard powerplant
plyon bolts?
Were all recovered engine pylon bolts of the correct type?
What was the condition of the front stages of the RH inboard engine?
Was baggage related debris found in this engine?
Were any of the silicone/organic materials in the RH wing burned?
Is there evidence of complete or incomplete combustion of these
materials?
What was the failure type of all of the different powerplant main bearings?
Do all post failure analysis of these bearings indicate a normal
"spindown"?
What was the spectrometric metal content of the powerplant

oil in the
filters and in the main bearings?
Does any of the Baggage from the FCH have indications of high temperature
(<1,500F) burning?
This would indicate a self oxygenating fire or (plastic) Explosive.
Does any of the Baggage from the FCH have indications of lower temperature
(<750F) burning?
This would indicate fuel related burning.
If not burned then baggage was lost prior to major fuel explosion(s).
Were there any cell phones in use on the plane?
Were any conversations recovered from AT&T or MCI switching computers?
Has the position of any transmission(s) been calculated?
2. Radar tracking..
3. Satellite Tracking..
(No body reporting on this!).
5. Coroner's forensic reports and victim damage computer model.
6. Physical Condition of items ejected from aircraft prior to explosion.
7. Physical Conditions of Engines and recovery locations.
8. Physical Condition of other aircraft material / sections and recovery
locations.
9. Explosive and trace elemental analysis of recovered materials.
10. Fast/slow strain analysis model of aircraft skin fasteners.
11. Oxidation sampling modeling of aircraft metallic components for
explosion temperature zone modeling. Shows high temperature combustion areas..

12. Oxidation Sampling modeling of aircraft organic components for
explosion temperature zone modeling. Shows lower temperature combustion areas.
and items 13 - 200+ etc.
1) Position of the latch sectors?
> 2) Condition of the latch pins?
> 3) Position and condition of the lock sectors?
> 4) Condition of fuselage-to-door cable bundle?
> 5) Condition of all cargo door switches, especially S2 master latch
>lock handle switch?
> 8) Condition of the torque-limiting devices?
> 9) Condition of floor beams immediately inboard from fcd?
>10) Condition of the oxygen lines passing immediately adjacent to floor
>beams?
>11) Condition of the cargo door hinges?
>12) Detailed paint mark analysis of any "foreign" paint marks on fcd?
2. examine cargo door for status of cam latches, unlocked or locked.
3. examine cargo door lock sectors, unlocked or locked.
4. examine cargo door lock sectors and cam sectors for wear and gouging.
5. examine cargo door manual locking bar for locking position.
6. examine all door electrical switches for proper operation.
8. note condition of cargo door, in how many pieces to match UAL 811.
9. note position of cargo door when found, close to event site or far away
indicating time it left aircraft.
9. detect frayed wiring in door control system.

10. examine direction of buckled floor beams, up or down indicating
decompression or explosion.
12. check for presence or non presence of evidence of fire/ explosion on
separated nose.
13. match sudden on loud sound on CVR to sound library of in flight
aircraft explosions and decompressions.
14. match abrupt end of tape signals on FDR to two other abrupt end of tape
Boeing 747 crashes, PA 103, and AI 182.
15. confirm by computer simulation that 300 knot wind blowing into nine
foot by 15 foot hole in right side of weakened nose will tear nose of in an
second.
16. examine wreckage for more severe in flight debris damage on right side
of aircraft to include wing fillet, leading edges of wing and horizontal
stabilizer and vertical stabilizer, engine cowls and pylons.
>1) If the latch sectors aren't within 18-22 degrees of fully-closed
>position, it could mean that door
>wasn't fully latched, or door tried to unlatch itself after closing and
>locking.
>
>2) If the latch pins have a "smooth" part from 6:30 position to 8:30
>position, this could be
>indication of "out-of-rig" door. If there is a discolored (blued)
>roughened (gouged) section from

>6:30 to 7:30 position, it would mean that latch sectors were
violently
>pulled past latch pins,
>indicating a blown/torn-out fcd.
>
>3) if the lock sectors aren't completely "over-center" and show
>deformation on the surface closest
>to latch sectors, it could show that door has had "uncommanded
door
>opening." If these are in
>direct contact with latch sectors, we can reasonably conclude
that fcd
>tried to open itself.
>
>4) Mostly this will show whether these cables are chaffed. The
critical
>wire here is 101-20, which
>NTSB has shown that it can short with many other sources to
cause
>"uncommanded door
>opening," especially if detail number 5 is true.
>
>5) If these switches show concave deformation, it could be an
indication
>of door that has been
>"out-of-rig" for some time. If S2 master latch lock handle
switch has
>broken bracket inside, the
>operation should be tested to verifiy whether "door-open"
circuit was
>being jumped "closed"
>allowing current to pass even though master latch lock handle is
stowed

>and locked.

>
>9) If the floor beams are buckled downward, it is an indication
that
>explosive decompression has
>taken place.
>
>10) If the floor beams have been buckled downward, there is a
very good
>chance that all flight
>deck and cabin oxygen lines will have been "pinched-off"
preventing
>anyone from getting oxygen
>from on-board oxygen generators. At higher altitudes, this
would
>adversely affect flight and
>cabin crew effectiveness when dealing with an emergency of
this
>magnitude, even if the nose
>section hasn't been torn off.
>
>11) If the cargo door hinges are bent backwards, it is an
indication
>that cargo door opened past
>it's full "open" position, and probably struck fuselage
immediately
>above it.
>
>12) This detail should be performed with detail 11 to show if
door
>violently opened in flight. Any
>"foreign" paint marks found should be checked with portion of

fuselage
>immediately above fcd
>through detailed paint mark analysis.
>

Thank you for your e-mails.

It is quite common for the crown to fund a defence lawyer. In this case Keith Hamilton will be working solely for the defence. In order to insulate him from the crown, his legal invoices will be reviewed by an independent lawyer.

There is no doubt about his integrity and I believe Mr. Smart and Mr. Peck have known Mr. Hamilton for over 15 years.

I look forward to contacting you.

Aniljit Singh

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: aniljit singh uppal <aniljitsingh@hotmail.com>
Subject: **747 retired Sikh pilot**

Dear Aniljit,

Mr. Santokh Singh is a retired Boeing 747 pilot who has been following the wiring/cargo door explanation for AI 182 for the past few months, as well as Ms. Shyrone Kaur, an active airline ticket agent.

They have expressed interest in contacting you and have technical knowledge about AI 182 related items.

Cheers,
Barry

At 11:28 PM +0100 2/21/01, Santokh Singh wrote:
X-From_: maan100@worldonline.nl Wed Feb 21 22:40:24 2001
X-Sender: maan100/pop3.worldonline.nl@pop3.norton.antivirus
Date: Wed, 21 Feb 2001 23:28:59 +0100
To: John Barry Smith <barry@corazon.com>
From: Santokh Singh <maan100@worldonline.nl>
Subject: lawyer

Can you confirm that "aniljit singh uppal"
<aniljitsingh@hotmail.com>
is defending the 2 accused in Canada?
This could be our voice.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: aniljit singh uppal <aniljitsingh@hotmail.com>
Subject: **Examination of the Narita incident**

Dear Aniljit, I just sent the below to Santokh. Note terrorist attack in 1988 and tower destruction of 1978. The bombing of

June 1985 could have been the same people.

Barry

Santokh, Narita was no sleepy airport. There was planning to expand airport before 1986 when construction started. It is very possible that the violent group went to violence again in 1985 to protest expansion. Need more data. But....there was a motive for a 'bombing' at Narita that was independent of AI 182. And there was a terrorist attack in 1988. See, the whole Narita thing against AI 182 stinks. And destroy the Narita connection to AI 182 and the whole case falls apart.

Cheers,
Barry

1971, Sep. Second compulsory execution of the land expropriation by proxy
Three policemen killed in conflict during expropriation.

1977, May. Removal of the obstructing steel tower. The death of one the supporters of the opposition group during the protest rally.

1978, Mar. The extremists attack on the control tower and subsequent destruction of most of the equipment resulting in the opening of the airport being postponed.

1978, May. Opening of Narita Airport (on 20 May)

1986, Nov. Start of land development work on second phase site.

1988, Sep. Chairman of the Chiba Pref. Land Expropriation Committee seriously injured in an attack of terrorism. All members of the committee,thereby, resigned.

The solution to this problem was the second-phase zone, as originally planned. The construction work was begun in 1986.

Narita Airport (NRT) is the largest airport in Japan, used by fifty airline companies from thirty-eight countries. Proof that it's the major sky-gateway of Japan. From early morning until midnight the 4,000 meter runway is busy. A daily average of 335 planes arrive and depart carrying passengers and cargo.

Narita Airport is the sky-gate of Japan. Since its opening in 1978, its reputation has spread worldwide. 50 airline companies from 38 countries connect Narita Airport to 98 cities, handling on average 65,000 passengers and 4,200 tons of cargo daily, making it the fifth largest transporter of people in the world and the number one concerning its cargo transport. Because of increased demand for Terminal building 2 was opened in December 1992.

Overviews of the Narita Airport Disputes

1966, Jul. The Cabinet decision of the construction of
Narita Airport

1966, Jul. Organization of the Opposition group against the
airport (on 10 July)

1966, Jul. Establishment of the Airport Authority (on 30 July)

1969, Apr. Start of construction work of A runway and other facilities

1969, Dec. Authorization of the construction of Narita Airport according
to the Land Expropriation Law

1971, Feb. First compulsory execution of the land expropriation by proxy

1971, Sep. Second compulsory execution of the land expropriation by proxy
Three policemen killed in conflict during expropriation.

1977, May. Removal of the obstructing steel tower. The death of one the
supporters of the opposition group during the protest rally.

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1986, Nov. Start of land development work on second phase site.

1988, Sep. Chairman of the Chiba Pref. Land Expropriation Committee seriously injured in an attack of terrorism. All members of the committee,thereby, resigned.

1990, Jan. Talk was held with Eto, the current Minister of Transport and the opposition group.

1990, Nov. Organization of the Regional Promotion and Liaison Conference

1991, Feb. Regional Promotion and Liaison Conference proposed the open symposium.

1991, Nov. Start of Narita Airport Issues Symposium

1992, Dec. Opening of Passenger Terminal 2

1993, May Final session of the Symposium

- To withdraw the authorization of the construction of Narita airport
- lanning of B,C runways should begin all over

again.
- Organization of a new conference for talking regarding
the airport issues All members agreed to the above
decisions.

1993, Sep. Start of Narita Airport Issues Round Table Conference

1994, Apr. Opening of a Community Consultation Center of the
Airport Authority

1994, Oct. Final session of the Round Table Conference
- Break the conflicting relations
- Establishment of a new committee for Symbiosis between
the Local Community and Narita Airport
- Establishment of a new committee for creating an
Experimental Park Village regarding Global issues

Construction of parallel runway and cross runway should
be constructed apart from each other

Improvement of the noise countermeasures

Regional promotion
All members agreed to the above decisions.

1994, Nov. The Airport Authority establishment of new

organizations,
Symbiosis Office(Planning office for building partnerships
with the local community) and Environment Management
Office, to implement the agreement at the Round Table Conference.

1995, Jan. Establishment of the Committee for Symbiosis between the
Local Community and Narita Airport Ogawa group, one of the
opposite groups, declared termination of opposition movements.

1995, Mar. Opening of Airport Information Center

1995, Dec. Issue of "Umenoki Common owned Land" solved, now in service
as an apron.

1996, May Agreement of one of the farmers of the Ogawa group to trade
with the Airport Authority for his land.

1996, May The holding of the 6th ACI(Airports Council International)
Pacific Region Assembly and Conference at Narita with the
theme "Airports and the Community Building Partnerships"

1996,July Relocation of the Airport Authority head office to Narita Airport.

+ Opposition Movement Gathers Strength

Chiba Prefecture took a resistant attitude to this decision, stating that there had not been sufficient communication in advance before the selection of Tomisato. It requested postponement of a decision on the airport's location at a Cabinet session. Local residents had shown signs of growing opposition to the new airport since the time when the selection of candidate sites was narrowed to either Tomisato or Kasumigaura, but after the unofficial decision for Tomisato, the opposition movement in the Tomisato area grew increasingly strong. Thereafter, in response to a request from the Ministry of Transport, Chiba Prefecture sought to improve the situation with thorough measures for local residents by the national government. However, government arrangements for those measures dragged on over some time, while local opposition continued to intensify. Ultimately it was decided that the government would postpone action on the Tomisato site for the time being.

+ Polarization of Conditional Acceptance vs. Opposition, - Formation of Airport Opposition Alliance -

The Chiba Prefecture Assembly had passed a resolution to promote construction of the airport as early as July 4, 1966. However, in the same month, the Narita City Assembly and Shibayama Town Assembly both passed resolutions opposing the airport, causing a complex situation. Still, enthusiastic efforts at persuasion by Chiba Prefecture and parties related to the airport bore fruit, and the Narita City Assembly overturned its resolution opposing the airport on August 2. As a result, there was a shift in controversy over the airport toward a focus on the conditions of its establishment. On August 25, the Community Association on Measures Relating to Narita Airport was formed. On December 27, Shibayama Town Assembly also overturned its resolution opposing the airport. Meanwhile, residents taking the stance of opposition to establishment of the airport formed the Sanrizuka Airport Opposition Alliance and the Shibayama District Sanrizuka Airport Opposition Alliance. On July 10, these groups were combined as the Sanrizuka-Shibayama Airport Opposition Alliance.

+ Tension Mounts on Night Before Opening

The year had finally arrived for the long-delayed opening of the new airport. Enormous losses had resulted from the delay in the airport's opening, not only to the Airport Authority but also to airport-related enterprises. This delay was also a critical problem for the persons who had provided land and now would make their living in a new way related to the airport. The opening date of the new airport was awaited impatiently by the government and Airport Authority, as well as by the city of Narita and other local governments, airline companies, related enterprises, and persons who had provided land. In November 1977, inspection of the airport's facilities was completed, and it remained only for governmental agencies and airline companies to relocate to Narita. It was decided that the airport would open on March 30, 1978. The Airport Authority notified the Minister of Transport of the opening date for the new airport on November 26, and the Minister of Transport announced this date on November 28. On December 3, the Ministry of Transport issued a notice to airmen, or NOTAM, to the International Civil Aviation Organization (ICAO) and 50 related nations concerning the opening of the new airport, and announced the planned opening to the world. As the opening date drew near, preparatory work in the airport approached fever pitch. The atmosphere was charged with anticipation as boarding information announced by a computer-synthesized voice began to be broadcast for testing purposes. Meanwhile, tension was growing day by day around the airport. Opposition groups had mobilized protesters from around the country to carry on continuous protests. To prevent entry by the most violent faction, nine gates around the airport were kept under tight security, and the airport was enclosed by a chain-link fence three meters in height. Over 10,000 riot police were stationed all around the airport.

+ Control Tower Sabotaged on March 26

In spite of all this, a nightmarish incident took place. On the afternoon of March 26, some members of the most violent faction gained access to the control tower. They entered the sixteenth-floor control room and the fourteenth-floor micro-communications room, destroying control equipment and other property. This crippled communications for the transmission of air traffic control instructions, flight plans, and so on. It was not possible to conduct thorough repairs by the opening date, March 30. On March 28, the New Tokyo International Airport ministerial council officially decided to postpone the opening of the airport. The Ministry of Transport immediately dispatched a NOTAM concerning the delayed opening of the new airport to air travel related institutions all over the world.

+ Airport Opened Under Guard on May 20

The work of restoring the destroyed facilities was executed at a rapid pace, until it was judged that safety was assured. On April 4, the New Tokyo International Airport ministerial council again sent a NOTAM around the world stating that the new opening date would be May 20. The airline companies, which had already completed their preparations, began relocating to Narita on May 10, and this was completed on May 26. During this relocation, a total of 1,790 vehicles were use, and strict guard was maintained. The relocation was completed smoothly and without confusion. Finally, at midnight on May 20, Narita Airport was opened under tight security. The opening ceremony was held at 10:30 a.m. at the departure lobby in the north wing of the passenger terminal.

It was attended by 58 persons, including the Minister of Transport and the president of the Airport Authority. Although simple, the ceremony was conducted with solemnity and included a prayer for safety. In a congratulatory speech, Minister of Transport Mr. Tominaga expressed his expectations for the future of Narita Airport with the proverb, "A child whose birth is difficult will grow smoothly to adulthood."

+ Second Passenger Terminal Opened on December 4, 1992

Following the airport's opening, it was operated with the facilities corresponding to the first-phase plan, which included Runway A, the first passenger terminal, and cargo handling facilities. This amounted to about half, or 550 hectares, of the total planned area. Compared to other major international airports, this was definitely not a large size. The airport was reaching its limits of handling capacity with regard to passenger demand, which was growing year by year. The solution to this problem was the second-phase zone, as originally planned. The construction work was begun in 1986. The second terminal was the first of the second-phase facilities to be completed, and opened on December 6, 1992. The new terminal housed 32 of the airline companies serving the airport. Since two terminals are now used in the operation of Narita Airport, customs and immigration procedures and boarding now occur smoothly even at peak times. The second passenger terminal is spacious, with 280,000 square meters of floor space, or about 1.6 times that of the first passenger terminal. In addition, the paths of passenger flow are divided clearly in a structure that allows for easy use, with the first and second floors used for arrivals and the third floor for departures. New services and facilities befitting a modern airport are found throughout the building, including a business travel center, refreshment room, game room, and audio-visual room. The world's first automatic shuttle system without a human operator provides access between the main building and the satellites.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **Re: Evidence exists to confirm cargo door cause for AI 182**

Dear Mr. Campbell, 14 Nov 00

I have provided your e-mails to lead counsel and we will be in touch down
the road, when we have given the materials their due consideration.

Great, thank you, 'due consideration' is all one can ask.

"Down the road" I hope is within sight.

The PA 103 defense team is defending against similar charges and might be interested, attorney to attorney, in the wiring/cargo door explanation because the evidence supports that cause for their accident also. The parallels are many. They can get into Farnborough to examine the actual wreckage with the forward cargo door of that Boeing 747 to confirm it opened in flight; whereas, AI 182 forward cargo door is on the bottom of the ocean and only videotape exists of the wreckage. AI 182 and PA 103 are always shown together in the media as a pair of bombings so it might be reasonable to request evidence examination of the PA 103 wreckage to prepare a defense for AI 182. The confirmation of your client's innocence lies in a hangar in England. It's in the latches and latch pins and cams of the forward cargo door of PA 103 which will match the evidence of UAL 811, the Boeing 747 whose nose did not come off after the forward cargo door opened in flight. NTSB reports on UAL 811 available on request.

Call or email anytime with questions; I never forget this is a life and death matter and that the probable cause of the faulty wiring causing the door to rupture/open is still out there.

Good luck with bail.

Cheers,

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Mr. Smith:

Thank you for your messages. We are presently undertaking to apply for the
release of our client on bail, and we have yet to receive/review the huge
volume of evidence which is involved in this case. As we have just recently
been retained, it is unknown yet how the tasks will be divided; undoubtedly
there will be a number of counsel working full time on it for many months.
I have provided your e-mails to lead counsel and we will be in touch down
the road, when we have given the materials their due consideration.
Jeff Campbell

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **Bail easier if possibly not a crime committed, but an accident**

Dear Mr. Campbell, 16 Nov 00

Thank you for your recent email.

expert evidence that the deaths due to the Air India disaster were not the
result of a bomb may be placed before the judge on the bail application, and
it may very well improve the prospects of our client being released on bail.

Yes, if no crime, no culprits. There must be some Latin phrase that means first a crime, then criminals, and not call a person a criminal, then make up the crime.

I am currently working on another case, but I am passing hard copies of your
emails along to lead counsel.

Thank you, I assume the lead counsel is Mr. Peck.

Thank you for your ongoing interest.

Well, it's been twelve years and counting.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **No bomb on AI 182**

Mr. Corazon,

I am an associate with Peck and Company, which has been retained to represent Mr. Bagri in the Air India prosecution. I understand that you have authored a study in which you concluded that the cause of the crash of Flight 182 may not have been a bomb.

We would be very interested in taking a look at your study. Could you please advise how we might obtain a copy?

Thank you for your assistance.

Yours truly,

PECK and COMPANY

Jeff Campbell

Dear Mr. Campbell, 8 Nov 00

Thank you for your interest.

I understand that you have authored a study in which you concluded that the cause of the crash of Flight 182 may not have been a bomb.

Yes, I concluded that AI 182 was not a bomb. For twelve years I have researched and analyzed Boeing 747s that suffered fatal explosive decompression inflight. There are four, one of which is AI 182. The supporting facts, data, and evidence are on website http://www.corazon.com/crashcontentspagelinks.html (home page below).

I know your client did not put a bomb on AI 182 because nobody did. It was the inadvertent opening of the cargo door in flight, probably caused by wiring fault. It happened again in 1988, and 1989, and 1996. Each time it was 'bomb' that did it. For two of the accidents, UAL 811, and TWA 800, the bomb explanation was later discounted; for two accidents, AI 182 and PA 103, the 'bomb' explanation is still active although much disputed and about to enter the legal arena.

I do not believe in all this conspiracy talk: The RCMP and Indians blame the Sikh conspiracy, and the Sikhs blame the RCMP and Indian conspiracy. It's an airplane crash, not a bank robbery. I invite discussion that is aviation based and relies on facts, data, and evidence.

Yes, I understand the enormity of saying PA 103 was not a bomb, but that's what the evidence says and, as an experienced aviator, I always defer to reality. I hope that the unjustly accused will take the time to actually look at the evidence from a nonbomb point of view.

I have no legal, manufacturer, airline, government, religious or police affiliation. I am a retired military officer who once was in a sudden fiery fatal jet plane crash and does not want that to happen again.

If you put your legal mind to the facts of AI 182 from reading the Canadian and Indian report (on website http://www.corazon.com/AirIndiareportcontents.html) I think you will find how flimsy the 'bomb' evidence is, and how strong the wiring/cargo door evidence is, especially since hindsight allows the examination of several other very similar events supported by more similar evidence.

I can send you the electronic version of the AI 182 Canadian and Indian accident report if you request, It's quite large.

As it turns out, my weekly statistics show much interest in AI 182 and have for the previous several months as shown below and you can click on the links to go there.

I consider myself an independent aviation accident investigator specializing in Boeing 747 explosive decompressions in flight.

I invite factual discussion, preferably with someone who has knowledge of basic aerodynamics. Are you a pilot, perchance?

Cheers,

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

The other accused in the Air India case, Ajaib Singh Bagri, will be represented by Richard Peck.

High-profile Vancouver lawyers to represent Air India bombing suspects*Updated 1:35 PM ET November 7, 2000*VANCOUVER (CP) - Two high-profile lawyers will take the lead roles in defending the men charged with the Air India bombing.
Bill Smart said Tuesday he will act on behalf of millionaire Ripudaman Singh Malik. Smart's name has been in the news regularly lately. He defended NHL tough guy Marty McSorley, who was convicted of assault with a weapon last month for clubbing an opponent over the head with his hockey stick. Smart

is also the special prosecutor heading up the case against former premier Glen Clark, who has been charged with breach of trust and fraud.
The other accused in the Air India case, Ajaib Singh Bagri, will be represented by Richard Peck.
Peck is best known for representing Robin Sharpe, who successfully challenged laws against pornography possession.
The case has gone to the Supreme Court of Canada.
Smart said Tuesday it will be weeks before he applies for bail for Malik.
"There is no date set for the bail hearing," he said.
"I won't do that until (there's been) a chance to prepare the material and it could be several weeks."
Malik will remain in jail until then.
Smart said the case will be complex and lengthy. He has asked the Crown to provide him with the evidence, about 100 volumes of material.
"I can't address the strength of the case until I've had a chance to consider it."
The two Sikh fundamentalists are charged with murder and conspiracy to commit murder in the 1985 airliner blast that killed 329 people.

Boeing 747

Rupture at Midspan Latches of Forward Cargo Door in Flight Probably Caused by Wiring/Electrical Fault

Accidents
TWA 800, UAL 811, PA 103, AI 182
Similar Crash Pattern:
The Type Airplane
The Damage Start Location
The Radar Blips

The Sudden Loud Sounds on CVR
The Abrupt Power Cuts to FDR
The Fodded Engines
The Inflight Damage
The Missing Bodies
Same Cut Point Torn Off Noses
The Wreckage Plots
More Similarities
The Red Herring: Bomb!
Similar Crash Cause:
Mechanical Malfunction:
Inadvertent Rupture/Opening of the Forward Cargo Door in Flight
Probably Caused by Wiring/Electrical Fault

Additional Details on Accidents includes AARs, photos, text, drawings, and related accidents, Air India 182, PA 103, UAL 811, and TWA 800

Background and Reference

Newer Page Reasoning behind hull rupture door opening
Introduction
Introduction Photograph
Introduction Page
reconstructmatches.html Reconstruction pictures/drawings of AI 182, PA 103, UAL 811, and TWA 800
reasoning.html Reasoning behind cargo door hypothesis
Boeing 747.html Basic Boeing 747 information.

747historycontents.html Illustrated history of Boeing 747, problems, construction pictures, and stretching.
747-121dimensions.html Drawing of Boeing 747-121
747cargo door and nose Pictures and drawings of cargo door and nose of Boeing 747
747specsheet.html Boeing 747 Specifications and history
747seating.html Boeing 747-100 series and-200 series seating.
747crashes.html List of Boeing 747 crashes.
cargodoorfaraway.html Forward cargo door far, medium and close up photo.
pressurization1.html Aircraft pressurization theory.
aerodynamics.html Boundary layer aerodynamics.
crashchart0.html Chart of three Boeing 747 crashes and similarities presenting a pattern.
crashchart1.html Chart of three different Boeing 747 crashes/ incidents and similarities.
Airworthiness Directive 79-17-02.html First Airworthiness Directive against forward cargo door.
Airworthiness Directive 88-12-04 Original AD to prevent inadvertent opening of forward cargo door, later amended by AD 89-05-54, not available, later amended by AD 90-09-06 below.
Airworthiness Directive 90-09-06 Current AD to try again to stop doors from opening when they shouldn't.
800summary TWA Flight 800 ,UAL Flight 811, Pan Am Flight 103, Air India Flight 182 Summaries and explanations.
variousdooraccidents.html Accounts of various cargo door accidents/incidents.
forwardcargodoorpict.html Contents of links to door on site to show latch pins, openings, hinge, seal, and lock sectors.
747passdoor.html 747 plug type passenger door failed
Why Does Door Rupture/Open?
Door Goes; Nose Goes? When door ruptures, how and why nose comes off.

Bibliography: Official government accident board reports, news sources, textbooks and documentary books.

Cargo Door Opening/Rupture Event 1985
Boeing 747-237B, Air India Flight 182
AI182essentials.html Extracts from Canadian report, Boeing 747-237B. Explanations of sudden sound, decompression damage, wreckage plot, and inflight damage.
182summary.html Description of Air India Flight 182 crash with cargo door similarities.
Debriefing
AirIndiareportcontents.html To Canadian and Indian Air India Flight 182 accident report

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Cargo Door Opening/Rupture Event 1988
Boeing 747-121, Pan Am Flight 103

103drawrightleftani.html Computer moving simulation of sequence of destruction on left and right side of fuselage, cargo door side more severe.
103blipsani.html Computer moving simulation of radar blips showing disintegration of aircraft. Door is shown as diamond.
PA103essentials.html Extracts from AAIB accident report. Descriptions of sudden loud sound, damage location, wreckage plot, and abrupt power cut.
103radarblip1.html Pan Am Flight 103 cargo door caught on radar. Fig C-14, Boeing 747. This image matches radar plot of TWA 800.
103cvrtext1.html CVR short loud sound interpretation as break up of aircraft structure. Page C-6
103scancvr1.html Abrupt loss of signal indicates severe event

occurred. Fig C-8
103scandraw0.html First reconstruction drawing showing cargo door coming apart on 103. Fig. B-10
Debriefing
Pan Am 103 Not a Bomb? Flimsy evidence for bomb now even weaker with subsequent similar accidents.
103reportcontents.html To UK Pan Am Flight 103 accident report

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Cargo Door Opening Event 1989
Boeing 747-122, United Airlines Flight 811

UAL811essentials.html Extracts from NTSB accident report. Descriptions of sudden loud sound, radar tracking, missing bodies, FOD engines, and sequence of destruction once door opens.
811bigholephotobetter.html Better picture of big hole that 300 knot wind enters and blows off nose of UAL 811, Boeing 747.
811page92conclusions3cause.html Revised probable cause of door opening, faulty switch.
811PS.html Popular Mechanics cover picture and story.
811picture UAL 811 cargo door hole picture
More pictures of UAL 811 cargo door hole
Debriefing
811reportcontentpage.html To UAL Flight 811 NTSB accident report

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Cargo Door Opening/Rupture Event 1996
Boeing 747-131, Trans World Airways Flight 800

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Contents Cargo Door Website
Page 2 Details on Accidents

Boeing Manufacturer of 747
http://www.ntsb.gov/ NTSB
http://www.faa.gov/avr/aai/aaihome.htm FAA
barry@corazon.com Email author here.

Referrer Report

Listing referring URLs with at least 1 request, sorted by the number of
requests.

#reqs: URL
-----: ---
5509: http://www.corazon.com/AirIndiareportcontents.html
2748: http://www.corazon.com/
1873: http://www.corazon.com/Boeing 747.html
1020: http://www.corazon.com/nosepicts.html
672: http://www.corazon.com/crashcontentspagelinks.html
655: http://www.ntsb.org/
430: http://www.corazon.com/Page2.html
328: http://www.corazon.com/811holesofftv.html
308: http://www.corazon.com/AI182pagecancoverCan.html
286: http://www.corazon.com/DC-10crashcontents.html
258: http://www.corazon.com/Missingbodies.html
246: http://www.corazon.com/Damagelocation.html
245: http://www.corazon.com/747specsheet.html
244: http://google.yahoo.com/bin/query
230: http://www.corazon.com/mountain.html
226: http://www.corazon.com/Skiescargodoor0pict.html
221: http://www.google.com/search
208: http://www.corazon.com/Suddenloudsound.html
207: http://www.corazon.com/UAL811essentials.html
202: http://www.corazon.com/AI182pagecan19.html

201: http://www.corazon.com/747historycontents.html
183: http://www.corazon.com/Radarblips.html
183: http://www.corazon.com/TWA800PA103UA811.html
182: http://www.corazon.com/forwardcargodoorpicts.html
181: http://www.corazon.com/AI182essentials.html
173: http://www.geocities.com/CapitolHill/5260/crash.html
159: http://www.altavista.com/cgi-bin/query
157: http://www.corazon.com/AI182pagecan20.html
154: http://www.corazon.com/103reportcontents.html
149: http://www.corazon.com/cargodoorfaraway.html
148: http://www.corazon.com/AI182pagecancoverCan1.html
147: http://www.corazon.com/AI182pagecan5.html
139: http://www.corazon.com/AI182pagecan1.html
136: http://aviation-safety.net/database/1985/850623-2.htm
134: http://www.corazon.com/wreckageplots.html
133: http://www.corazon.com/Inflightdamage.html
128: http://www.corazon.com/aftmidspanlatch.html
126: http://www.corazon.com/AI182pagecan9.html
122: http://www.corazon.com/800wxradar.html
118: http://www.corazon.com/AI182pagecan21.html
116: http://www.corazon.com/314accidentreport.html
115: http://www.airdisaster.com/news/1000/29/news.html
113: http://www.corazon.com/Tornoffnose.html
111: http://www.corazon.com/Redherrings.html
110: http://www.corazon.com/Foddedengines.html
106: http://www.geocities.com/CapitolHill/5260/teknik.html
102: http://www.corazon.com/AI182pagecan2.html
93: http://www.corazon.com/reconstructmatches.html
89: http://www.corazon.com/AI182pagecan58.html
89: http://www.corazon.com/AI182pagecan33.html

Request Report

Listing files with at least 1 request, sorted by the number of requests.

#reqs: %bytes: last time: file
-----: ------: ---------------: ----
4744: 0.20%: Nov/ 4/00 23:55: www.corazon.com/cgi-bin/Count23.cgi
1886: 1.90%: Nov/ 4/00 23:55: www.corazon.com/
1092: 1.88%: Nov/ 4/00 23:11: www.corazon.com/AirIndiareportcontents.html
373: 0.43%: Nov/ 4/00 22:58: www.corazon.com/Boeing 747.html
291: 0.32%: Nov/ 4/00 18:59: www.corazon.com/crashcontentspagelinks.html
282: 0.01%: Nov/ 4/00 19:20: www.corazon.com/AI182pagecancoverCan.html
266: 0.87%: Nov/ 4/00 23:30: www.corazon.com/747specsheet.html
194: 0.01%: Nov/ 4/00 14:07: www.corazon.com/AI182pagecan19.html
186: 0.58%: Nov/ 4/00 21:58: www.corazon.com/747crashes.html
185: 0.41%: Nov/ 4/00 23:24: www.corazon.com/Page2.html
170: 0.05%: Nov/ 4/00 20:54: www.corazon.com/nosepicts.html
168: 0.09%: Nov/ 4/00 23:04: www.corazon.com/Missingbodies.html
164: 0.01%: Nov/ 3/00 23:23: www.corazon.com/AI182pagecan20.html
160: 0.01%: Nov/ 4/00 19:27: www.corazon.com/AI182pagecan5.html
159: 0.03%: Nov/ 4/00 20:52: www.corazon.com/Skiescargodoor0pict.html

145: 0.07%: Nov/ 4/00 20:19: www.corazon.com/Damagelocation.html
144: 0.01%: Nov/ 4/00 12:58: www.corazon.com/AI182pagecancoverCan1.html
143: : Nov/ 4/00 19:20: www.corazon.com/AI182pagecan1.html
136: 0.03%: Nov/ 4/00 20:37: www.corazon.com/forwardcargodoorpicts.html
132: 0.01%: Nov/ 4/00 18:11: www.corazon.com/AI182pagecan9.html
131: 0.01%: Nov/ 4/00 19:21: www.corazon.com/AI182pagecan21.html

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From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **Re: Reporter called me**

Mr. Smith:

Lead counsel for Mr. Bagri is Richard Peck, Q.C.

-Jeff Campbell

Dear Mr. Campbell,
OK, I'll tell him. He says he has been writing about AI 182 for fifteen years. That's good. He asked me if I would testify in court as to my assertions. I said that since this is an aviation safety item and I espouse no political cause, I probably would.

He said he relied on experts for opinions about plane crashes and I told him that all he needed to know to understand AI 182 is why balloons pop and when he puts his hand outside a moving car and moves his hand, he could feel the resistance change.

Good luck with the bail hearing; I've been checking the Canadian news every day but have read nothing.

Cheers,
Barry
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **Check it out, please**

Dear Gentlemen,

14 Feb 01 Valentine's Day

Gentlemen Kamal Maghur,
Mr. Alistair Duff,
Mr. Stephen Mitchell,
Mr. Richard Keen,
Murdo Macleod,
Eddie MacKechnie,

McGRIGOR DONALD,
Alex Prentice,
William Taylor,
John Beckett

Jeffrey Campbell

James Hall
Bernard Loeb
James Wildey
Al Dickinson

Ronald Wojnar
Johm Dimtroff
Neil Schalekamp
Bob Breneman
Tom McSweeney
Lyle Streeter

Russell Young

David Evans,

John Sampson

Above is the hole in UAL 811 made by the fuselage skin that gets torn off when the forward cargo door ruptures/open in flight and blows out and upward taking skin with it. (The missing cargo door is behind the people.) The paint smears of this door on the fuselage match TWA 800 paint smears, the shape of this hole matches the PA 103 shape although this hole is smaller and the nose stayed on, the broken floor beams of this fuselage match PA 103 and AI 182, the split door wreckage of this door matches PA 103 split door, the missing midspan latches of this door matches TWA 800 missing latches, the noise this hole makes on the CVR matches TWA 800, PA 103, and AI 182 sudden loud sounds, the nine never recovered bodies who used to sit in the missing seats match the at least nine never recovered bodies of AI 182, PA 103, and TWA 800, the type of plane, the type of door, the size of door, the function of door of this door above matches AI 182, PA 103, and TWA 800, the abrupt power cut to the FDR that occurred when this door ruptured matches AI 182, PA 103, and TWA 800 FDR, the damage that the ejected material from this hole which caused nearby engine number three to catch on fire matches PA 103 and TWA 800 number three engines, the exposed ribs above the door match PA 103 exposed ribs, the right wing fillet damage just aft of this door matches PA 103 TWA 800 and AI 182 fillet damage, and the first explanation for this above hole was a bomb, which matches AI 182, PA 103, and TWA 800 explanations which were and still are for two- 'bombs'.

Above is the port side of PA 103 at event time. The 20 inch blue rectangle is the 'Shatter Zone' damage caused by the 'relatively mild blast' of the 'rather large shotgun' type discharge which gave a 'directed' force which resulted in no sound on the CVR at event time. (Quotes from AAIB report.) That small damage was not caused by a bomb which gives a 'powerful' 'spherical' and 'loud' sound on the CVR, all of which are missing in PA 103. Quotes are mine.

To deny all of the above facts, data, and evidence which leads the conclusion that the damage on the port side and later the nose coming off was not caused by a 'bomb' giving a small hole (but possibly by a huge hole on the starboard side) is do deny reality, experience, and common sense. If a 747 can land with the big hole, then it can certainly turn around and land after a small hole.

Dear government officials with the responsibility for aviation public safety, attorneys defending innocent accused, media who have the responsibility to present plausible explanations of public interest, manufacturers who have the responsibility to built safe aircraft, airlines with the responsibility to keep the airplanes flying safely, and politicians entrusted with the welfare of their constituents: You all have the duty to do the one thing you said you would do, the one thing you went to school to do, the one thing you are sworn to do, the one thing you are paid to do, say the three words, "Check it out."

Check it out. That's all. Do your duty to investigate a reasonable, plausible, mechanical explanation with precedent for accidents which may occur again if the fault, after being checked out and proven correct, happens again.

Check it out. Attorneys hire an aviation expert in these matters who has no vested interest in maintaining the 'bomb' explanation because of prior statements. And contact me.

Manufacturer order the engineers to determine if a 20 inch hole can cause the nose of 747 to come off and why a thirty foot hole did not. And contact me.

Airlines check the wiring in the cargo door area for cracks, arcing, and water. And contact me.

Media check sources for the evaluation of the wiring/cargo door explanation. And contact me.

Government oversight agencies such as FAA and NTSB order investigators to check out the possible probable cause. And contact me.

Wiring/cargo door explanation for AI 182, PA 103, TWA 800 has not been checked out. It has been ignored or brushed aside with a misleading statement for TWA 800 about 'all' the latches being latched when in fact two midspan latches have not been recovered and photographs show two large ruptures at those precise locations, for PA 103, the status and latches of the forward cargo door are omitted, and the status of the the AI 182 door is lost at the bottom of the ocean.

The status of the UAL 811 door is now known because the NTSB at the time decided to 'check it out' and retrieved the door and determined the first explanation of improperly latched was incorrect as the door was properly latched but the electrical system/wiring was at true fault and thus issued another AAR, 92/02.

Why have not the responsible agencies checked out the wiring/ cargo door explanation for AI 182, PA 103, and TWA 800?

The best place to start to check out a plausible cause for an accident which has not been confirmed officially is by contacting the discoverer, proponent, and presenter, me.

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,

Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Over the past twelve years researching and investigating the four explosive decompressions of AI 182, PA 103, UAL 811 and TWA 800, I have had lots of contact with various people and I have learned how to tell the true from the false. The false use swear words, are rude, make many misspellings and grammatical errors, use a lot of capitals and exclamation points, factually wrong, never document sources, refer to vague rumors, make statements in the guise of questions, present inconsistencies, give up quickly, and are usually anonymous.

The true identify themselves and their credentials, are polite, used correct grammar and spelling, articulate, give sources, use official data and photographs,
ask questions to find out the answer, are persistent and consistent over years, and invite interaction.

The persons in the middle are the indifferent to the accuracy, the validity, the truth of a probable cause of a fatal event. They want to keep things the way they are and attempt to prevent any change.

The indifferent react to change suggestions by me such as the wiring/cargo door explanation for three Boeing 747 accidents by the following sequence:

1. No.
2. You are wrong.
3. You are crazy.
4. Go away.

5. I'm ignoring you.
6. Attack.
7. Ask a real question to check it out.

I'm trying very very hard to get the attorneys, the manufacturer, the government agencies, the airline, the media, the passengers, and other parties to get to stage seven, to ask a question to check out the wiring/cargo door explanation.

I'm doing that in this letter by using photographs and drawings and the other ways the true use for persuasion.

There are two men about to go on trial for for their lifetime freedom, another charged in Britain to be extradited, one in prison to spend the rest of his life, ten of thousands of men women and children flying now, and billions of dollars to be exchanged in insurance and purchases of aircraft based upon the probable cause of three accidents.

All will be affected, one way or the other, by checking out the wiring/cargo door explanation for AI 182, PA 103, and TWA 800.

To check out a story is to contact the source, me. Here is my phone, my address, my email and my identity.

Please do not be indifferent.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,

Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **Are these names of real people?**

Dear Mr. Campbell,

Can you confirm for me if the names below are genuine and if the email is legitimate?

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Date: Sat, 17 Feb 2001 11:59:06 -0800 (PST)
From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: Shyrone Kaur
To: kaursingh@webtv.net
MIME-Version: 1.0
Content-Type: text/plain; charset=us-ascii

WJKK, WJKF!!!

Shyrone Kaur,

Hi, my name is Sundeep Kaur. I am working on the Air India file for Mr. Malik. Aniljit Singh (Mr. Malik's legal assistant) is inviting Mr. Barry Smith to Vancouver so that we can discuss his findings with Mr. Smart. I was wondering if you could write back and

let me know you availability.
Thank you

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **Four teams with same goal**

Mr. Smith:

I believe that the people named in the email are people working on this
matter.

-Jeff Campbell

Dear Mr. Campbell, thank you, sir. Just this morning Mr. Aniljit Singh Uppal from the Malik team called me and we had a nice long chat. So the email was on the up and up.

Mr. Uppal informed me that his defense team has invited me up to Vancouver in a few weeks to meet with a Mr. Keith Hamilton, a defense attorney paid for by the Crown, to present my wiring/cargo door explanation for AI 182 and others. I hope to meet with you then, I'll be driving up from California.

I've written a few emails this morning to Mr. Uppal after our call, the content of which will be of interest to you, so let me include the information here. You can obtain these documents and can be granted access to the following:

To summarize discovery evidence which exists and will support the wiring/cargo door explanation:

1.Videotapes of wreckage.
2. Photographs of wreckage.
3. Wreckage database.
4. Narita Airport baggage explosion report.
5. Interview notes with ticket taker.
6. Maintenance logs of the aircraft for a period before the accident.
7. Maintenance report on the aft cargo door removal and reinstallation.
8. CVR evaluation report.
9. FDR evaluation report.

I also strongly recommend contacting the PA 103 defense team now in the midst of an appeal. They have access and you will too, to the hangar at Farnborough to examine the actual wreckage and in particular the forward cargo door area about which the AAIB AAR is strangely silent.

adlaw@planet.nl, rskeenqc@compuserve.com, adlaw@callnetuk.com are the emails of the defense team:
Kamal Maghur,
Mr. Alistair Duff,
Mr. Stephen Mitchell,
Mr. Richard Keen,
Murdo Macleod,
Eddie MacKechnie,
McGRIGOR DONALD,
Alex Prentice,
William Taylor,
John Beckett
The evidence exists which will free your clients. It may be difficult to obtain, observe, or evaluate, but it is there.

There are three defense teams working on the crash of two Boeing 747s that suffered an explosive decompression in flight, one team in Scotland and two in Vancouver. In addition, there may be attorneys in Britain trying to stop the extradition of Mr. Reyat. That's four groups of attorneys working on what I believe is the same probable cause, a mechanical problem in which no crime is involved. Somehow, the four teams need to be coordinated and able to compare notes and news. It's several countries and different languages and religions and cultures. But the left hand has to know what the right hand is doing....as well as the feet.

Please consider at least touching base with your fellow attorneys defending innocent men against common charges.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
Subject: **Narita thing stinks**

Dear Mr. Campbell,

Below was sent to Mr. Aniljit Singh Uppal of the Malik Defence team. Santokh is a retired Boeing 747 pilot who concurs with the wiring/cargo door explanation for AI 182.

The whole Narita bombing event needs to be carefully examined. It has many flaws. The case file on Mr. Reyat, convicted of the bombing, needs to be obtained. Can you get it for me for my evaluation?

Cheers,
Barry

To: aniljit singh uppal <aniljitsingh@hotmail.com>
From: John Barry Smith <barry@corazon.com>
Subject: Examination of the Narita incident
Cc:
Bcc:
X-Attachments:
Dear Aniljit, I just sent the below to Santokh. Note terrorist attack in 1988 and tower destruction of 1978. The bombing of June 1985 could have been the same people.

Barry

Santokh, Narita was no sleepy airport. There was planning to expand airport before 1986 when construction started. It is very possible that the violent group went to violence again in 1985 to protest expansion. Need more data. But....there was a motive for a 'bombing' at Narita that was independent of AI 182. And there was a terrorist attack in 1988. See, the whole Narita thing against AI 182 stinks. And destroy the Narita connection to AI 182 and the whole case falls apart.

Cheers,
Barry

1971, Sep. Second compulsory execution of the land expropriation by proxy
Three policemen killed in conflict during expropriation.

1977, May. Removal of the obstructing steel tower. The death of one the
supporters of the opposition group during the protest rally.

1978, Mar. The extremists attack on the control tower and subsequent
destruction of most of the equipment resulting in
the opening of the airport being postponed.

1978, May. Opening of Narita Airport (on 20 May)

1986, Nov. Start of land development work on second phase site.

1988, Sep. Chairman of the Chiba Pref. Land Expropriation Committee
seriously injured in an attack of terrorism. All members
of the committee,thereby, resigned.

The solution to this problem was the second-phase zone, as originally planned. The construction work was begun in 1986.

Narita Airport (NRT) is the largest airport in Japan, used by fifty airline companies from thirty-eight countries. Proof that it's the major sky-gateway of Japan. From early morning until midnight the 4,000 meter runway is busy. A daily average of 335 planes arrive and depart carrying passengers and cargo.

Narita Airport is the sky-gate of Japan. Since its opening in 1978, its reputation has spread worldwide. 50 airline companies from 38 countries connect Narita Airport to 98 cities, handling on average 65,000 passengers and 4,200 tons of cargo daily, making it the fifth largest transporter of people in the world and the number one concerning its cargo transport. Because of increased demand for Terminal building 2 was opened in December 1992.

Overviews of the Narita Airport Disputes

1966, Jul. The Cabinet decision of the construction of Narita Airport

1966, Jul. Organization of the Opposition group against the
airport (on 10 July)

1966, Jul. Establishment of the Airport Authority (on 30 July)

1969, Apr. Start of construction work of A runway and other facilities

1969, Dec. Authorization of the construction of Narita Airport according
to the Land Expropriation Law

1971, Feb. First compulsory execution of the land expropriation by proxy
1971, Sep. Second compulsory execution of the land expropriation by proxy
Three policemen killed in conflict during expropriation.

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1986, Nov. Start of land development work on second phase site.

1988, Sep. Chairman of the Chiba Pref. Land Expropriation Committee
seriously injured in an attack of terrorism. All members
of the committee,thereby, resigned.

1990, Jan. Talk was held with Eto, the current Minister of Transport and the opposition group.

1990, Nov. Organization of the Regional Promotion and Liaison Conference

1991, Feb. Regional Promotion and Liaison Conference proposed the open symposium.

1991, Nov. Start of Narita Airport Issues Symposium

1992, Dec. Opening of Passenger Terminal 2

1993, May Final session of the Symposium

- To withdraw the authorization of the construction of Narita airport
- lanning of B,C runways should begin all over again.
- Organization of a new conference for talking regarding the airport issues All members agreed to the above decisions.

1993, Sep. Start of Narita Airport Issues Round Table Conference

1994, Apr. Opening of a Community Consultation Center of the

Airport Authority

1994, Oct. Final session of the Round Table Conference
- Break the conflicting relations
- Establishment of a new committee for Symbiosis between
the Local Community and Narita Airport
- Establishment of a new committee for creating an Experimental Park Village regarding Global issues

Construction of parallel runway and cross runway should
be constructed apart from each other

Improvement of the noise countermeasures

Regional promotion
All members agreed to the above decisions.

1994, Nov. The Airport Authority establishment of new organizations,
Symbiosis Office(Planning office for building partnerships
with the local community) and Environment Management
Office, to implement the agreement at the Round Table Conference.

1995, Jan. Establishment of the Committee for Symbiosis between the
Local Community and Narita Airport Ogawa group, one of the

opposite groups, declared termination of opposition movements.

1995, Mar. Opening of Airport Information Center

1995, Dec. Issue of "Umenoki Common owned Land" solved, now in service as an apron.

1996, May Agreement of one of the farmers of the Ogawa group to trade with the Airport Authority for his land.

1996, May The holding of the 6th ACI(Airports Council International) Pacific Region Assembly and Conference at Narita with the theme "Airports and the Community Building Partnerships"

1996,July Relocation of the Airport Authority head office to Narita Airport.

+ Opposition Movement Gathers Strength

Chiba Prefecture took a resistant attitude to this decision, stating that there had not been sufficient communication in advance before the selection of Tomisato. It requested postponement of a decision on the airport's location at a Cabinet session. Local residents had shown signs of growing opposition to the new airport since the time when the selection of candidate sites was narrowed to either Tomisato or Kasumigaura, but after the unofficial decision for Tomisato, the opposition movement in the Tomisato area grew increasingly strong. Thereafter, in response to a request from the Ministry of Transport, Chiba Prefecture sought to improve the situation with thorough measures for local residents by the national government. However, government arrangements for those measures dragged on over some time, while local opposition continued to intensify. Ultimately it was decided that the government would postpone action on the Tomisato site for the time being.

+ Polarization of Conditional Acceptance vs. Opposition, - Formation of Airport Opposition Alliance -

The Chiba Prefecture Assembly had passed a resolution to promote construction of the airport as early as July 4, 1966. However, in the same month, the Narita City Assembly and Shibayama Town Assembly both passed resolutions opposing the airport, causing a complex situation. Still, enthusiastic efforts at persuasion by Chiba Prefecture and parties related to the airport bore fruit, and the Narita City Assembly overturned its resolution opposing the airport on August 2. As a result, there was a shift in controversy over the airport toward a focus on the conditions of its establishment. On August 25, the Community Association on Measures Relating to Narita Airport was formed. On December 27, Shibayama Town Assembly also overturned its resolution opposing the airport. Meanwhile, residents taking the stance of opposition to establishment of the airport formed the Sanrizuka Airport Opposition Alliance and the Shibayama District Sanrizuka Airport Opposition Alliance. On July 10, these groups were combined as the Sanrizuka-Shibayama Airport Opposition Alliance.

+ Tension Mounts on Night Before Opening

The year had finally arrived for the long-delayed opening of the new airport. Enormous losses had resulted from the delay in the airport's opening, not only to the Airport Authority but also to airport-related enterprises. This delay was also a critical problem for the persons who had provided land and now would make their living in a new way related to the airport. The opening date of the new airport was awaited impatiently by the government and Airport Authority, as well as by the city of Narita and other local governments, airline companies, related enterprises, and persons who had provided land. In November 1977, inspection of the airport's facilities was completed, and it remained only for governmental agencies and airline companies to relocate to Narita. It was decided that the airport would open on March 30, 1978. The Airport Authority notified the Minister of Transport of the opening date for the new airport on November 26, and the Minister of Transport announced this date on November 28. On December 3, the Ministry of Transport issued a notice to airmen, or NOTAM, to the International Civil Aviation Organization (ICAO) and 50 related nations concerning the opening of the new airport, and announced the planned opening to the world. As the opening date drew near, preparatory work in the airport approached fever pitch. The atmosphere was charged with anticipation as boarding information announced by a computer-synthesized voice began to be broadcast for testing purposes. Meanwhile, tension was growing day by day around the airport. Opposition groups had mobilized protesters from around the country to carry on continuous protests. To prevent entry by the most violent faction, nine gates around the airport were kept under tight security, and the airport was enclosed by a chain-link fence three meters in height. Over 10,000 riot police were stationed all around the airport.

+ Control Tower Sabotaged on March 26

In spite of all this, a nightmarish incident took place. On the afternoon of March 26, some members of the most violent faction gained access to the control tower. They entered the sixteenth-floor control room and the fourteenth-floor micro-communications room, destroying control equipment and other property. This crippled communications for the transmission of air traffic control instructions, flight plans, and so on. It was not possible to conduct thorough repairs by the opening date, March 30. On March 28, the New Tokyo International Airport ministerial council officially decided to postpone the opening of the airport. The Ministry of Transport immediately dispatched a NOTAM concerning the delayed opening of the new airport to air travel related institutions all over the world.

+ Airport Opened Under Guard on May 20

The work of restoring the destroyed facilities was executed at a rapid pace, until it was judged that safety was assured. On April 4, the New Tokyo International Airport ministerial council again sent a NOTAM around the world stating that the new opening date would be May 20. The airline companies, which had already completed their preparations, began relocating to Narita on May 10, and this was completed on May 26. During this relocation, a total of 1,790 vehicles were use, and strict guard was maintained. The relocation was completed smoothly and without confusion. Finally, at midnight on May 20, Narita Airport was opened under tight security. The opening ceremony was held at 10:30 a.m. at the departure lobby in the north wing of the passenger terminal. It was attended by 58 persons, including the Minister of Transport and the president of the Airport Authority. Although simple, the ceremony was conducted with solemnity and included a prayer for safety. In a congratulatory speech, Minister of Transport Mr. Tominaga expressed his expectations for the future of Narita Airport with the proverb, "A child whose birth is difficult will grow smoothly to adulthood."

+ Second Passenger Terminal Opened on December 4, 1992

Following the airport's opening, it was operated with the facilities corresponding to the first-phase plan, which included Runway A, the first passenger terminal, and cargo handling facilities. This amounted to about half, or 550 hectares, of the total planned area. Compared to other major international airports, this was definitely not a large size. The airport was reaching its limits of handling capacity with regard to passenger demand, which was growing year by year. The solution to this problem was the second-phase zone, as originally planned. The construction work was begun in 1986. The second terminal was the first of the second-phase facilities to be completed, and opened on December 6, 1992. The new terminal housed 32 of the airline companies serving the airport. Since two terminals are now used in the operation of Narita Airport, customs and immigration procedures and boarding now occur smoothly even at peak times. The second passenger terminal is spacious, with 280,000 square meters of floor space, or about 1.6 times that of the first passenger terminal. In addition, the paths of passenger flow are divided clearly in a structure that allows for easy use, with the first and second floors used for arrivals and the third floor for departures. New services and facilities befitting a modern airport are found throughout the building, including a business travel center, refreshment room, game room, and audio-visual room. The world's first automatic shuttle system without a human operator provides access between the main building and the satellites.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: jeffreytcampbell@home.com
Subject: **Evidence exists to confirm cargo door cause for AI 182**

Dear Mr. Campbell, 11 Nov 00

I have not heard back from you so I assume you are evaluating the data and analysis at www.corazon.com and would question me if there are any doubts.

There is enough wreckage and videotapes of the wreckage on the ocean bottom to accurately determine the cause of AI 182. Seen from the perspective of an open cargo door in flight, and not a bomb, the wreckage and video can be reexamined to match subsequent events and wreckage evidence such as PA 103 and UAL 811 and TWA 800. RCMP and TSB have access to those videotapes and must be evaluated as evidence at trial. I believe you have the authority to release those tapes for independent expert evaluation. John Garstaing of TSB has viewed those tapes personally and talked to me about it.

It's not only the door area that is important but the right wing fillet, the starboard engines, and right horizontal stabilizer. The investigators did not thoroughly check those areas because they were looking for proof of bomb, not open cargo door in flight. I would be willing to view and evaluate those video tapes for you, should you get access, to match with wreckage of other 747s.

The forest is four 747s and the trees are AI 182, PA 103, UAL 811, and TWA 800. Each tree has its own group explaining why it fell, but only through the analysis of all four does the pattern become clear; inadvertent opening of the cargo door in flight, probably caused by known faulty Poly X wiring.

I leave all this conspiracy talk to others, it's counterproductive to an airplane crash investigation. Machines don't conspire. I understand the political implications about India and independent homelands and temples and assassinations all wrapped up into accusations of mass murder but, really, this is an airplane crash that matches other airplane crashes that were mechanical events and not bombs.

I am non religious, non political, and not associated with any airline or manufacturer or government. I believe that that is the reason why I can be so objective and look at the evidence unemotionally to reach the cargo door conclusion which is rejected by authorities. It is an unpleasant truth and most reject that.

As a air crash survivor I have a strong interest in preventing the next crash of a 747 caused by explosive decompression when that cargo door opens in flight again. The same fault that caused AI 182 and others is still there.

Here's the patterns of the trees that make up the forest derived from close analysis of the official accident reports.

103 to 811 were both
aged
high flight time
poly x wired
early model Boeing 747
which took off in no sun
running late
and after takeoff
experienced a sudden initial event in the forward cargo hold
which left a
short
sudden

loud
sound on the cockpit voice recorder, an
abrupt data loss to the flight data recorder,
foreign object damage to starboard engines number 3
fire on engine number 3
enginge three fodded number four
more severe inflight damage on starboard side,
at least nine never recovered bodies,
torn off skin in forward cargo door area on starboard side,
fracture at forward cargo door at aft midspan latch,
outward peeled skin on upper forward fuselage,
downward bent floor beams in cargo door area,
vertical fuselage tear lines forward of the wing and aft of forward cargo door,
shattered fuselage shape on right side forward of the wing is
vertical large rectangle around forward cargo door.
door in two big halves split at longitudinal midline.
radar reflection from aircraft at event time

103 and 182 were both:
early model
poly x wired
Boeing 747
suffers hull rupture in forward cargo hold
engine three falls apart from other engines
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
sound does not match bomb sound
outward peeled skin in cargo door area
midspan latch status not determined

took off in no sun
running late
more severe inflight damage on starboard side
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
inadvertent opening of the forward cargo door in flight offered as explanation during official inquiry
bomb in forward cargo hold initially suspected

Pan Am 103 and TWA 800 were both:
aged
high time
early model
poly x wired
Boeing 747
shortly after take off
suffers hull rupture forward of the wing
fodded number three engine
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
outward peeled skin in cargo door area
midspan latch status not determined
took off in no sun
running late
more severe inflight damage on starboard side
downward bent floor beams in cargo door area
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door

bomb in forward cargo hold initially suspected
bomb in forward cargo hold placed two flights previous to final fatal flight exploding in flight and nose coming off explanation is still believed to be the correct probable cause at least for the last nine years.
Non bomb structural failure offered as explanation for sudden loud short sound on the CVR.
Non bomb structural failure rejected.
Bomb planters are terrorists of foreign countries.
Bomb planters not tried in court.
Bomb planters deny they planted bomb.

800 to 182
Forward Cargo door frayed
Door Skin shattered outward.
Bottom eight latches latched.
Midspan latch status undetermined.
early model
poly x wired
Boeing 747
suffers hull rupture forward of the wing on the right side in cargo door area
damaged number three engine
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
took off in no sun
running late
more severe inflight damage on starboard side
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo

door
bomb in forward cargo hold initially suspected
bomb in forward cargo hold placed at least one flight previous to final fatal flight exploding in flight and nose coming off
explanation was thought to be explantion for at least seventeen months.
Forward cargo door opening in flight considered as explanation for sudden loud short sound on the CVR.
Forward cargo door opening in flight rejected.
Bomb planters would have been terrorists of foreign countries.
Bomb planters not charged.
Bomb planters deny they planted bomb.
Conspiracy explanations considered seriously.

TWA 800 leads to UAL 811 which were both:
aged
high flight time
poly x wired
early model Boeing 747
which took off in no sun
running late
and shortly after takeoff
while climbing
experienced a sudden initial event in the forward cargo hold
which left a
short
sudden
loud
sound on the cockpit voice recorder, an
abrupt data loss to the flight data recorder,
foreign object damage to starboard engine #3

more severe inflight damage on starboard side,
smooth port side forward of the wing
at least nine never recovered bodies,
torn off skin in forward cargo door area on starboard side,
rupture at forward cargo door at aft midspan latch,
outward peeled skin on upper forward fuselage,
downward bent floor beams in cargo door area,
vertical fuselage tear lines forward of the wing and aft of forward cargo door,
inadvertent opening of forward cargo door considered as probable cause.
bare wires found in cargo door area.
destruction initially thought to be have been caused by a bomb.

And UAL 811 leads to Air India 182.

UAL 811 and AI 182 were both:
early model
poly x wired
Boeing 747
had previous problems with cargo doors.
experienced hull rupture forward of the wing on right side in cargo door area
fodded number three engine
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt data loss to FDR
outward peeled skin in cargo door area
took off in no sun
running late
more severe inflight damage on starboard side

at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
inadvertent opening of the forward cargo door in flight offered as explanation during official inquiry
bomb in forward cargo hold initially suspected

UAL 811
aged
non Section 41 retrofit
high flight time
early model
poly x wired
Boeing 747
had previous problems with forward cargo door.
experienced hull rupture forward of the wing on right side in cargo door area
fodded number three engine
on fire number three engine.
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
hoop stress found in cargo door area
outward peeled skin in cargo door area
longitudinal break at midline of the forward cargo door at midspan latch,
midspan latch status not determined
took off in no sun
running late
more severe inflight damage on starboard side
at least nine never recovered bodies

vertical fuselage tear lines forward of the wing and aft of cargo door
inadvertent opening of the forward cargo door in flight offered as explanation during official inquiry
more severe inflight damage on starboard side,
port side smooth forward of the wing
torn off skin in forward cargo door area on starboard side,
rupture of forward cargo door at aft midspan latch,
outward peeled skin on upper forward fuselage,
downward bent floor beams in cargo door area,
destruction initially thought to be have been caused by a bomb.

PA 103
aged
non Section 41 retrofit
high time
early model
poly x wired
Boeing 747
experienced hull rupture forward of the wing in forward cargo hold
nose came off
fodded number three engine
engine 3 falls apart from other three engines
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
sound does not match bomb sounds
abrupt power cut to FDR
outward peeled skin in cargo door area
longitudinal break at midline of the forward cargo door at

midspan latch,
midspan latch status not determined
took off in no sun
running late
more severe inflight damage on starboard side
downward bent floor beams in cargo door area
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
bomb in forward cargo hold initially suspected
bomb in forward cargo hold placed two flights previous to final fatal flight exploding in flight and nose coming off explanation is still believed to be the correct probable cause for at least for the last nine years.
Non bomb structural failure offered as explanation for sudden loud short sound on the CVR.
Non bomb structural failure rejected.
Bomb planters are terrorists of foreign countries.
Bomb planters not tried in court.
Bomb planters deny they planted bomb.

TWA 800
aged
high flight time
non Section 41 retrofit
poly x wired
early model Boeing 747
which took off in no sun
running late
and shortly after takeoff
experienced hull rupture forward of the wing
nose came off
foreign object damage to starboard engines #3

more severe inflight damage on starboard side,
at least nine never recovered bodies,
torn off skin in forward cargo door area on starboard side,
post side smooth forward of the wing.
rupture at forward cargo door at aft midspan latch,
outward peeled skin on upper forward fuselage,
downward bent floor beams in cargo door area,
bare wire found in cargo door area.
vertical fuselage tear lines forward of the wing and aft of forward cargo door, and
destruction initially thought to be have been caused by a bomb.
parts initially shed from just forward of the wing.
first pieces of structure to leave aircraft in flight from forward cargo bay.
Forward Cargo door frayed
hoop stress found in cargo door area
Door Skin shattered outward.
Bottom eight latches latched.
Midspan latch status undetermined.
fodded number three engine
fire in number three engine
missing blades from number three engine.
stator blade in right horizontal stabilizer
red paint mark in right horizontal stabilizer
glitter in right horizontal stabilizer.
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
took off in no sun
running late
more severe inflight damage on starboard side
at least nine never recovered bodies

vertical fuselage tear lines forward of the wing and aft of cargo door
bomb in forward cargo hold initially suspected
bomb in forward cargo hold placed at least one flight previous to final fatal flight exploding in flight and nose coming off explanation was thought to be explantion for at least seventeen months.
Forward cargo door opening in flight considered as explanation for sudden loud short sound on the CVR.
Forward cargo door opening in flight rejected.
Bomb planters would have been terrorists of foreign countries.
Bomb planters not charged.
Bomb planters deny they planted bomb.
Conspiracy explanations considered seriously.
downward bent floor beams in cargo door area
bomb in forward cargo hold initially suspected
bomb in forward cargo hold placed one flight previous to final fatal flight exploding in flight and nose coming off explanation considered probable cause for seventeen months
Cargo door failure offered as explanation for sudden loud short sound on the CVR.
Cargo door failure explanation rejected.
Bomb planters are terrorists of foreign countries.
Bomb planters are not identified

AI 182
non Section 41 retrofit
early model
poly x wired
Boeing 747
had previous problems with cargo door.
experienced hull rupture forward of the wing

damaged number three engine
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
nose came off
outward peeled skin in cargo door area
took off in no sun
running late
more severe inflight damage on starboard side
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
inadvertent opening of the forward cargo door in flight offered as explanation during official inquiry
bomb in forward cargo hold initially suspected
Forward Cargo door frayed
Door Skin shattered outward.
Bottom eight latches latched.
Midspan latch status undetermined.
bomb in forward cargo hold initially suspected
bomb in forward cargo hold placed at least two flights previous to final fatal flight; exploding in flight and nose coming off explanation was thought to be explanation for at least fifteen years.
Forward cargo door opening in flight considered as explanation for sudden loud short sound on the CVR.
Forward cargo door opening in flight rejected.
Bomb planters are terrorists of foreign countries.
Bomb planters deny they planted bomb.
Conspiracy explanations considered seriously.
sound does not match bomb

More evidence:

From Report:
2.4.3.6 A question arose whether removal of the door stop fittings could have caused some difficulty in flight. From the video films of the wreckage it was found that the complete aft cargo door was intact and in its position except that it had come adrift slightly. The door was found latched at the bottom. The door was found lying along with the wreckage of the aft portion of the aircraft. This indicates that the door remained in position and did not cause any problem in flight.

2.11.4.6 All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

3.4.1 Aircraft Break-up
The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer

before water impact. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.
The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile to the west indicating that there was some break-up of the number 3 engine before water impact.
The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction.

Note that floor panels separating in an upward direction gives same evidence as floor beams going in down direction, which is what happens to explosive decompression when floor beams, not panels, get sucked down, whereas, a bomb makes floor beams go up, which did not happen.

Note that the above description of the forward cargo door matches the photo of TWA 800 wreckage:

As an attorney, Mr. Campbell, I hope you trust in my faith in the evidence and less on the hearsay of biased authorities.

Cheers,
Barry
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net
Subject: **Overview**

Dear Mr. Jeffrey Campbell,
Mr. Aniljit Singh Uppal,
Ms. Sundeep Kaur Dhaliwal,
Captain Santokh Singh,

Ms. Shyrone Kaur Singh,

25 February 2001

We have corresponded in the past individually so I thought it would be good for me to address all at once. My name is John Barry Smith. I am a retired US military officer living with my wife and daughter in Carmel Valley, California. I have extensive experience in aviation and have survived a sudden night fiery fatal jet airplane crash.

I am the discoverer and messenger about the wiring/cargo door explanation for four Boeing 747 fatal accidents. As the person explaining the probable cause I am unimportant. The message is everything.

Much of the details and supporting documents for the wiring/cargo door explanation can be found at www.corazon.com. There is literally thousands of other pages of my analysis that exist which were written over the past twelve years and can be retrieved when necessary.

I do not have much faith in my persuasive power as persons like me that discover and report truths which are contrary to the conventional wisdom are seldom charming guys. Of course I are abrasive, I go against the grain. So, please, when I irritate you, as I will, just ignore and focus on the facts, data, evidence.

I do have faith in the evidence, in the hard realities of molecules, physical laws of drag, thrust, lift, pounds per square inch, and electrons in wires. Forty years of aviation have taught me to always defer to reality. The engine quits when there is no fuel, even though there is supposed to be fuel in the tank, although you checked and there was fuel in the tank earlier, they told you there was fuel in the tank, and if there is no fuel in the tank, you are in a lot of trouble. If no fuel, the engine quits, period. It will not keep going for a few more minutes to make the field because there are good people on board, or quit a few minutes earlier because there are bad. Reality is the engine quits when no fuel.

Reality is a sudden loud sound on the cockpit voice recorder of four cockpit voice recorders of early model Boeing 747s that suffered fatal accidents in flight. The sound is not the sound of a bomb going off because there are low frequencies missing and the rise time is too slow in the spectrum. Bomb sounds give a certain real sound signature just as explosive decompression does. The sounds do not match bomb sounds but do match explosive decompression sounds.

Reality is an abrupt power cut to the flight data recorder of four flight data recorders just after a sudden loud sound on the cockpit voice recorders. It's very difficult to inadvertently and abruptly cut off the power to a Boeing 747 and it's only happened four times.

Reality is that a huge hole appeared on the starboard side of four airplanes just forward of the wing as the same time as the sudden loud sounds and abrupt power cuts. The forward cargo door is just forward of the wing on the starboard side.

Reality is that a type of wire called Poly X with a polyimide insulation is now known to degrade in the presence of moisture, easily chafes and cracks to the bare metal wire. All four aircraft had that faulty wire installed and forward cargo holds have water in them from condensation.

Reality is that all four of the aircraft with the above realities were involved in fatal accidents which were initially thought by authorities to be caused by bombs.

Reality is that only one has the cause of the accident confirmed that it was not a bomb. The authorities were wrong when they said the cause of the fatal aircraft accident was a bomb. They admitted the error. They corrected the error. The now correct official probable cause for the fatal Boeing 747 accident which has all the realities above which matches the four Boeing 747s is electrical/wiring which shorted on the forward cargo door unlatch motor which turned the latching cams just enough for the enormous internal air pressure to burst outward at the midspan latches of that door allowing the door to open outward and upward tearing off much fuselage skin with it and sucking/blowing out nine passengers and their seats into engine number three causing fire in it. The loud noise of the decompression was recorded on the cockpit voice recorder. The power supply in the adjacent main equipment compartment was abruptly cut off by the force of the explosion.

That above description for the one confirmed by reality evidence matches the other three in those significant similarities and many more.

The forward cargo door ruptured/opened in flight for the four as confirmed by reality of twisted metal, sounds, wires, and plastic.

The cause of the door rupture can be considered although the only cause confirmed by evidence for the door rupture/opening is electrical/wiring with very flimsy circumstantial evidence support for bomb or missile conspiracy explanation.

Known faulty wiring is probably the cause of the four certain door ruptures in flight for the four early model Boeing 747s that suffered explosive decompression in flight, AI 182, PA 103, UAL 811, and TWA 800.

UAL 811 is the one 747 that returned to tell its tale and give the evidence described above and pictured below. This hole was not caused by a bomb but by an electrical/wiring short.

There is urgency in presenting this analysis to public safety officials so that the hazard may be removed. As I type this warning the danger exists for thousands of currently flying passengers in early model Boeing 747s.

There is injustice to correct for three accused for AI 182 and one convicted for PA 103, and the US Navy for firing a missile at TWA 800.

All are innocent. There were no bombs and no missiles and no conspiracies among Sikhs, Libyans, Navy, government agencies, nor the airlines or manufacturer to hide the realities described above. All are reluctant to accept that what happened to one Boeing 747 happened to three others and could happen again. They continue to cling to wishful thinking.

Most cultures prefer pleasant lies and will pay much money for them; you are rich, beautiful, smart, funny, and cool. The culture rewards those lies in advertising and politicians' promises with money and votes.

I give unpleasant truth and am not praised (and not surprised): planes are dangerous fuel laden machines existing in hostile environments with thousands of parts that can fail at any time. They have in the past, they have in the four instances, and they will in the future.

The current interest is AI 182 and the injustice against three accused. It will broaden. The official confirmation of wiring/cargo door for AI 182 will take time and persuasion using the facts, data, and evidence. As I have found over the twelve years as I have strenuously tried to discredit the explanation, the wiring/cargo door evidence always stands there irrefutable and true, always confirming the validity of the hypothesis.

More evidence is available in hangars and in videotapes that will further reinforce the explanation. Access needs to be granted.

I have faith in the reality of the evidence. The evidence needs to be presented to have its effect. That is my effort at this time; to present the evidence to those with the power to persuade, which is you, ladies and gentlemen. I thank you very much for your efforts so far and can only say, we have just begun.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.

US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Intimidation of witnesses? Hmmmm......**

Globe 7-day Search

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Still waiting for justice

PAUL SULLIVAN

Monday, December 4, 2000

The Canadian justice system has never seen anything like it. As two men arrested in the Air-India bombing cool their heels in a Vancouver jail, the rest of us wait to see if this crime, the biggest mass murder in Canadian history, can ever be successfully tried.

It has been 15 years since Air-India Flight 182 exploded off the Irish coast, killing 329 people, most of them Indo-Canadians. It has taken the RCMP that long to arrest suspects linked to a group called Babbar Khalsa, which was formed to punish the enemies of the Sikhs and has long been thought by police to harbour the people who organized the bombing.

Throughout those 15 years, Babbar Khalsa's members and supporters have been active in British Columbia's Sikh community, while one individual has spent a decade in jail for building a bomb that was apparently intended to blow up an Air-India plane but went astray and killed two baggage handlers in Japan.

The magnitude of this undertaking is breathtaking. It has taken 60 RCMP officers and $50-million to amass a body of evidence that took 13 prosecutors two years to go through. As many as 1,000 witnesses may be called. The Mounties have promised more arrests, and the trial, when -- and if -- it is finally scheduled, could take as long as three years.

So many lives have been sacrificed or irrevocably altered by this malignancy, which has bound together the fates of British Columbia and the Indian state of Punjab, where Sikh separatists have been fighting a bloody war of independence for decades:

The families of the victims, wondering whether the murderers would ever be brought to trial;

Peaceful and law-abiding Sikhs, vilified and even murdered by shadowy conspirators in their own community to shut them up;

Courageous journalists, most notably The Vancouver Sun's Kim Bolan, who won't shut up even though she has been threatened.

Now, with the arrest of Ripudaman Singh Malik and Ajaib Singh Bagri, there is some hope that Canadian

justice will weather the enormous challenges and resolve the case. Mr. Malik, one of the community's most prominent figures and a wealthy man, is putting together a legal "dream team" that evokes the O.J. Simpson trial. Millions of dollars in property have already been pledged to support Mr. Bagri's defence. They will mount a formidable defence, starting with a bail hearing that could come in the next few weeks.
One of the ugliest subthemes in this epic story of the murder of innocents is the assassination of outspoken community newspaper editor Tara Singh Hayer and the intimidation of other potential witnesses. Mr. Hayer was shot in his own garage two years ago, 10 years after surviving an earlier assassination attempt. So far, the RCMP have not been able to nail the person responsible for Mr. Hayer's murder.
And the intimidation continues. One man fears for his life after militants confronted him with his own statement to police and warned him that he would be considered a traitor if he testified. How they gained access to confidential evidence is a mystery.
A Punjabi-language radio host quit his job recently after rocks were thrown through his studio window. Sukhminder Singh Cheema says he can no longer keep broadcasting in the face of threats and intimidation, and claims his own station owner told him to lay off the Air-India story, a charge the owner

has denied.
Mr. Hayer's assassination makes it clear that the threats must be taken seriously. No one in the community is safe, including B.C. Premier Ujjal Dosanjh, who was beaten with a crowbar outside his law office in 1985 for being a moderate and repudiating violence.
The Mounties have warned militants to stay away from the witnesses, but what can the police do when people are convinced their cause is righteous and they can use any means to achieve it? For most Canadians, the attack by the Indian military against the Golden Temple of Amritsar in 1984 is a not-so-current event. For Sikh separatists, many of them in British Columbia, it was an unspeakable desecration and escalation to all-out war. That the revenge murder of 329 innocents was equally unspeakable seems lost on the militants.
There are those who believe this case will never go to trial. The evidence is long in the tooth; the accused are mounting a vigorous defence; being a witness is hazardous to one's health. That it has taken the authorities so long to act on this crime means that the cancer has worked itself deeply into the body of the Sikh community.
There is no hope of healing until justice is done. The roots of violence go deep, indeed.

psulli@sullivanmedia.com

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Feelings...and he never went to jail...**

Friday, 8 December, 2000, 15:59 GMT **Record damages for sacked Sikh officer**

Sergeant Gupal Virdi was sacked nine months ago

A Sikh police sergeant sacked after being wrongly accused of sending racist hate mail has received record damages of £150,000.

Gurpal Virdi won the payout for hurt feelings after he was racially discriminated against by the Metropolitan Police.

Last week he was offered his post back by the force, which has also issued an apology.

Mr Virdi was dismissed in March after a disciplinary panel found him guilty of sending the racist mail.

No evidence

He was accused of targeting himself and other ethnic minority officers in the division where he was based in Ealing, West London.

But in August an employment tribunal found there was no evidence against the 41-year-old, and that he had been the victim of racial discrimination by investigating officers.

The damages award - £110,000 more than the previous record payout at an employment tribunal remedy - was made at London Central Employment Tribunal courts.

According to the Commission for Racial Equality it is also a record award for injury to feelings.

Apology refused

Mr Virdi, from Cranford, Middlesex, was at first refused an apology despite the tribunal findings.

That prompted the Metropolitan Police's independent advisory group to accuse the force of failing to learn the lessons of the Stephen Lawrence case.

Following his reinstatement, Mr Virdi was handed a letter of apology from Deputy Commissioner Ian Blair.

The letter said the force accepted unconditionally the findings of the employment tribunal, and apologised to Mr Virdi and his family "for the distress that this extended episode has caused".

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From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Bail hearing for Mr. Bagri**

Here is the latest news (updated 12/16/00), from the Vancouver Sun
regarding the bail hearing for Ripudaman Singh Malik and Ajaib Singh
Bagri whom are charged with the bombing of Air India flight 182 on June
25, 1985.

The hearing is set to begin on Thursday, December 21st at the B.C.
Supreme Court.

Dear Mr. Campbell, 17 Dec 00

21 December is the 12th anniversary of the PA 103 'bombing' and that anniversary will be noted by the judges because it will be noted in the press. Who chose the date? The prosecution? In that case, it was no coincidence and that's prejudicial.

Well, the official Canadian report offers the cause of the accident as non-bomb but opening of forward cargo door in flight.

"3.4.1 Aircraft Break-up
The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction."
(Note that floor panels separating in an upward direction gives same evidence as floor beams going in down direction, which is what happens to explosive decompression when floor beams, not panels, get sucked down, whereas, a bomb makes floor beams go up, which did not happen.)

2.10.2 Analysis by Accidents Investigation Branch (AIB), United

Kingdom
The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182.

3.4.6.14 That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a high explosive device, then the spectra should have shown large low frequency content, but this was absent.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-
"It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182.
"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.

If the wiring/cargo door cause can be broached in public, then the aviation press and investigators can turn their attention to it. I have faith in the evidence to speak and say it was explosive decompression which mimics a bomb, but was not a bomb because the CVR did not hear a bomb. Then the 15 years of similar events can be examined for matches-UAL 811, UAL preflight, PA 125 all had doors open which were not bombs. In addition, only in the past few years has the danger of PolyX wiring become known. AI 182, as well as TWA 800, PA 103, and UAL 811, all had that faulty wiring.

Standing alone, the evidence of AI 182 shows grave doubts about a bomb; with the matches of similar events of the past 15 years which were not 'bombs', the evaluation shifts to non bomb and to the authenticated cause, faulty wiring causing the forward cargo door to open in flight.

Using hindsight is fair and intelligent. In hindsight, AI 182 matches non bomb events in similar aircraft. There is a reasonable, plausible alternative to a bomb and it's in the government report. Below is Chart 12 from the NTSB public docket for TWA 800 and it shows the four CVR tapes at event time for UAL 811, AI 182, TWA 800 and PA 103. These sudden loud sounds are very rare in plane crashes. All four sounds have been ruled out as 'bomb' sounds. The other remarkable feature of this evidence is the abrupt power cut to the CVR and FDR on all four; that is extremely rare and difficult to do on a huge 747.

AI 182 was a plane crash, not a bank robbery.

Ah, it's so frustrating...Good luck with the bail hearing. It can't hurt to bring up the Canadian and UK Government's suggestion that it was an open cargo door in flight and the Government's expert who says it was not a bomb based upon CVR evidence.

(It would be funny except men's lives and their families lives are at stake....bombs are loud, spherical and powerful, they leave evidence of residue and damaged airframe components. The evidence in four Boeing 747 accidents for which a bomb was the first and foremost explanation shows that the sound of the 'bomb' is missing on all four CVR tapes, the 'shotgun' type blast was mild and directed for PA 103, and no other bomb specific evidence was found on AI 182. It's funny because these four 'bombs' were quiet, directed, mild, left no Semtex residue, and were placed in the plane in one place, then flew, landed, then flew, landed, then flew, then 'went off'. No way do real bombs act that way.)

If you concede or assume it was a bomb for AI 182, your struggle later on to prove your client's innocence will be much more difficult. Now is the time to bring up the official doubts about the 'bomb' and the later events of UAL 811 and TWA 800, in my humble opinion.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Good luck, everything is possible. I know they deserve bail.**

*2001*VANCOUVER (CP) - A B.C. Supreme Court judge reserved decision Tuesday on whether two men accused in the bombing of an Air India flight that killed 329 people will be granted bail. Justice Patrick Dohm made the ruling after Crown and defence lawyers concluded five days of submissions at the bail hearing. The judge did not set a date for the release of his decision.

"The Crown has made its submissions," Geoff Gaul, spokesman for the Attorney General's office, said outside the courthouse Tuesday.
"Currently they're in detention. They've applied for their bail so now it's for the judge to decide whether they should be granted bail."
Ajaib Singh Bagri and Ripudaman Singh Malik have been in custody since they were arrested Oct. 27. No trial date has yet been set and the men have not entered pleas.
Dohm issued a publication ban on the evidence, standard in a bail hearing.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Why am I not surprised.**

Dear Jeffrey, too bad, I would have loved to have testified and to have shown that there was no bomb, just bad wiring causing a door to open inflight, as happened a few years later and confirmed, UAL 811.

'"The horror of the circumstances leading to the murder of the 329 passengers and crew of Air India Flight 182 is almost beyond human comprehension," wrote Dohm. '

The horror of a judge making up his mind that it was murder before evidence is presented is almost beyond belief.

It is a severe injustice to keep those innocent men in jail years before a trial.

PA 103 is about to wind up and those two will probably be guilty also. The tactic of saying it was a bomb that blew those two 747s out of the air but it was not the accused that did it will not work.

There was no crime. No criminals.

"Special security considerations are necessary for all those persons actually involved in the trial or those assisting them."

Why is that?

Well, whenever you are ready to look at the evidence that supports by assertions above, I'll be here.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

Two charged in Air India bombing to stay in custody, B.C. Supreme Court rules*Updated 6:40 PM ET January 10, 2001*VANCOUVER (CP) - A B.C. Supreme Court judge denied bail Wednesday to two men charged in the worst mass murder in Canadian history, citing the need to "maintain the public's confidence in the administration of justice."
Associate Chief Justice Patrick Dohm made the ruling

following a five-day bail hearing last month. "Any reasonable, fair-minded person aware of these circumstances, including the curves and bumps in the evidence, and cognizant of the presumption of innocence, would not have confidence in the justice system if the accused were released from custody," Dohm wrote in his 17-page decision.

Ripudaman Singh Malik, a millionaire Vancouver businessman, and Ajaib Singh Bagri, a Kamloops, B.C., mill worker, face a total of eight counts in relation to the crash of Air India Flight 182 and a bomb explosion at a Tokyo airport that killed two baggage handlers.

They have been in custody since they were arrested Oct. 27.

Dohm ruled the men would be held despite dismissing Crown concerns that if released, the accused might flee to Pakistan using false passports or by obtaining passports from other countries.

He said that "given the circumstances here of both accused and their connections to Kamloops and Vancouver, I think there is only a slight risk of flight should they be released."

Still, under a Criminal Code section dealing with maintaining confidence in the administration of justice, Dohm decided they must be detained.

"The horror of the circumstances leading to the murder of the 329 passengers and crew of Air India Flight 182 is almost beyond human comprehension," wrote Dohm.

"It is difficult to think of a more planned and deliberate act.

"There is, against both the accused in my view, a strong prima facie (at first view) case of very bad conduct resulting in serious harm."

Bagri, 51, and Malik, 53, are charged with first-degree murder and conspiracy to commit murder of those killed when Flight 182 went down off the coast of Ireland on June 23, 1985.

Most of the 329 victims were Canadian. The bombing remains the worst act of aviation terrorism in the world.

The men are also charged with the murders of two baggage handlers killed when a bomb exploded at Tokyo's Narita airport an hour before Flight 182 went down.

The bomb that exploded at Narita was destined for Air India Flight 301. Bagri and Malik are charged with the attempted murder of its passengers and crew.

Bagri is also charged in a 1988 assassination attempt of Tara Singh Hayer, who published the Indo-Canadian Times and was an outspoken critic of Sikh extremists. Hayer was murdered in 1998 and police are still investigating the case.

The men will remain in jail for another 18 months before their trial is scheduled to start.
The trial length and distant start date have been a major concern of the defence and Crown.
Dohm noted the defence believes the earliest the trial could be completed would be late 2002 or early 2003.
"The trial schedule . . . does cause me considerable concern," said the judge.
"Special security considerations are necessary for all those persons actually involved in the trial or those assisting them."
He said he wanted "the earliest of trial dates" and would monitor the progress of the defence and Crown on a monthly basis.
Two others are also named as unindicted co-conspirators in the bombing plot.
Talwinder Singh Parmar was the leader of the militant Sikh separatist group Babbar Khalsa, which is dedicated to the creation of a separate state called Khalistan in Punjab.
Parmar was killed by Indian police in October 1992.
Inderjit Singh Reyat was convicted of manslaughter in 1991 and sentenced to 10 years for his role in the Narita bombing.
Friends and family of both the accused and the victims filled the courtroom throughout the bail hearing.

The Air India bombing came after the Indian army attacked the Golden Temple in Amritsar, India, the holiest shrine of Sikhism, in June 1984.
That event triggered a chain of killing and terrorism that included the assassination of Indian prime minister Indira Gandhi by her Sikh bodyguards in October 1984.
The RCMP has said there will be more arrests in the case that has amassed volumes of evidence. It's the largest, most expensive investigation every undertaken by the RCMP, with an estimated cost of more than $30 million.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Wiring/cargo door explanation**

Dear Mister Jim Hall, Bernard Loeb, Ron Schleede (Ret), Al Dickinson, Jim Wildey, Bob Swaim of NTSB, and Misters McSweeny Mr. Ron Wojnar Mr. Dimtroff, Mr. Schalekamp, Mr. Breneman, Mr. Lyle Streeter of FAA, and FBI agents at the New York office, 16 Jan 01

This is John Barry Smith responding with a rebuttal to Chairman Jim Hall of NTSB who states in a 14 December 2000 letter that the wiring/cargo door explanation for TWA 800 has been considered and ruled out. The NTSB, as represented by the Chairman, Jim Hall, and Bernard Loeb, Ron Schleede (Ret), Al

Dickinson, Jim Wildey, Bob Swaim states that the NTSB has considered the wiring/cargo door explanation for TWA 800 and ruled it out based upon evidence and has corresponded with me numerous times. That evidence is incomplete and NTSB has not corresponded with me numerous times. NTSB has written me a few times with short statements of opinion telling me they are right and I am wrong. In addition, the NTSB has failed to respond to the specific absolute refuting evidence to the center tank as the initial event and have consistently refused for over four years to discuss the wiring/cargo door explanation or even meet with me to allow me to present a decade of research and analysis which has led me to conclude that the same probable cause of faulty wiring leading to a ruptured/open cargo door in flight has caused four Boeing 747 accidents, including UAL 811 and TWA 800. The actual refuting evidence to the center tank explanation and the actual confirming evidence of the wiring/ cargo door explanation is listed below in response to NTSB assertions.

NTSB: ÒThank you for your October 2, 2000, letter regarding Mr. John Barry Smith's assertion that the TWA flight 800 accident was caused by a wiring/switch fault in the accident airplane's electrical system, which led to the rupture of the midspan latches of the forward cargo door in flight. He asserts that this rupture precipitated the sequence of events that led to the explosion of the fuel/air vapor in the center wing tank (CWT).Ó

JBS: Yes, that is my assertion with the clarification that it was wiring based upon new evidence of the faults of Poly X wiring in all aircraft, and in particular, early model Boeing 747s such as TWA 800, which shorted on the door unlatch motor.

NTSB: ÒAs you know, on August 23, 2000, the National Transportation Safety Board concluded that the probable cause of the TWA flight 800 accident was an explosion of the CWT resulting from ignition of the flammable fuel/air mixture in the tank. The source of ignition energy for the explosion could not be determined with certainty, but the Board concluded that, of the sources evaluated by the investigation, the most likely was a short circuit outside of the CWT that allowed excessive voltage to enter the CWT through electrical wiring associated with the fuel quantity indication system.

NTSB: ÒAs you know, on August 23, 2000, the National Transportation Safety Board concluded...Ó

JBS: Concluded but not published. The final report is yet to be available to the public six months after the ÒNational Transportation Safety Board concluded.Ó Why is that?

NTSB: "The source of ignition energy for the explosion could not be determined with certainty,..."
JBS: The NTSB does not have an ignition source for the center tank explosion which is conclusive evidence that the probable cause of initial event as center tank explosion is not confirmed and that all other reasonable alternative explanations are plausible until ruled out by proper and thorough evaluation. A reasonable alternative mechanical explanation that has precedent and supported by official documents should be thoroughly investigated. The wiring/cargo door explanation is mechanical, plausible, supported by Public Docket evidence, has precedent in a similar type aircraft and has not been thoroughly investigated to the standard set by the precedent, UAL 811 in NTSB AAR 92/02. To say an explosion happened and not have the ignition source positively identified after years of searching and tests is to

say the current explanation is incomplete and very possible not the initial event. There are three essential factors for a fuel explosion; air, fuel, ignition source; to not have all three is to admit the current explanation may be wrong. In fact, the wiring/ cargo door explanation does have an ignition source for the CWT explosion; a FODDed, on fire engine number three which ignited the center tank as the disintegrating wreckage fell after the explosive decompression caused by the ruptured/opened cargo door in flight allowed the nose to be torn off. This scenario is supported by wreckage debris locations, CVR and FDR data, and the precedent of UAL 811Õs FODDed and on fire engine number three. The actual refuting evidence of the center tank as the initial event is the absence of any sooted material on the passengers or the fuselage forward of the wing indicating the nose came off first in a generally straight tear line followed by the explosion of the tank which sooted those parts of the fuselage aft of the leading edge of the wing. In addition, the sudden loud sound on the CVR does not match the sound of a center tank explosion as compared with a known center tank explosion CVR sound in a NTSB chart. Also, the port side just forward of the wing is smooth while the starboard side is shattered which indicates a unilateral event and not the bilateral damage that a center tank event would show. The NTSB explanation as a center tank explosion is partly right because the center tank did explode, but the NTSB has the timing wrong, it was not the cause but a symptom.

NTSB: Ò...the most likely was a short circuit outside of the CWT that allowed excessive voltage to enter the CWT through electrical wiring associated with the fuel quantity indication system.Ó

JBS: So very vague as to be meaningless. A short circuit outside the CWT includes 98% of the aircraft. The wiring/cargo door explanation has precedent of bare wires in the cargo door area of the confirmed cargo door accident, UAL 811. TWA 800 wreckage has bare wires in that cargo door area:

The Systems Exhibit 9A, page 116:
"Some wires found in the section of W480 from forward of station 570 and identified as BMS13-42A had numerous cracks in the insulation. Most of the cracks in this bundle were found to expose the core conductor when examined by microscope. Only within five feet of the aft end of the W480 bundle from station 570-900 were insulation cracks found."

(Note that BMS13-42A is Poly-X wiring. Cargo door location is FS 560-670 and cracked wires discovered are within that zone. Frayed wires in that area have shorted before and caused the forward cargo door to open in flight, NTSB AAR 92/02 UAL 811. Water has been seen pouring out of a forward cargo bay of a Boeing airliner. Water and leaking electricity make a powerful conductor. Both are known to exist in Boeing cargo compartments.)

NTSB: ÒThe Safety Board did consider the possibility that the TWA flight 800 accident might have been initiated by the in-flight separation of the forward cargo door. All eight of the latching cams along the bottom of the door were found in the latched position and, along with some pieces of the cargo door itself, remained attached to the pins along the lower door sill. There were no indications of preimpact failure of the hinge at the top of the door. Investigators verified that these cams, pins, and sill pieces were from the forward cargo door by matching the fractures to the attaching pieces of structure. This evidence indicates that the door was closed and locked at impact. Further, deformation and fracture patterns on the door matched damage to the adjacent fuselage structure, confirming that the door was in the closed position at the time of impact.

NTSB: "The Safety Board did consider the possibility that the TWA flight 800 accident might have been initiated by the in-flight separation of the forward cargo door."

JBS: Considered but not investigated nor evaluated to the standard set for confirmed ruptured/open cargo door in flight, UAL 811. The UAL 811 AAR 92/02 has a complete metallurgical examination of the entire door, latches, cams, pins, overpressure relief doors, manual locking handle, hinge, and torque tubes. The TWA 800 ÔconsiderationÕ of the forward cargo door consists of one sentence, Docket Number SA-516, Exhibit No. 15C, Report Number 97-82, Section 41/42 Joint, Forward Cargo Door, "Examination of the lower lobe forward cargo door showed that all eight of the door latching cams remain attached (along with pieces of the door itself) to the pins along the lower door sill." A one sentence dismissal of a plausible mechanical explanation with precedent in a similar accident by an incomplete examination of eight of ten latches is not up to the aircraft accident investigation standards set by the NTSB in previous reports.

NTSB: "All eight of the latching cams along the bottom of the door were found in the latched position and, along with some pieces of the cargo door itself, remained attached to the pins along the lower door sill."

JBS: Misleading statement from NTSB of the word "all"; there are ten latches per cargo door for a total of twenty latches. Only eight have been recovered and were attached to a cargo door sill which was found in the aft debris field. The only two references to a ÔsillÕ in the TAGS database refer to the aft sill, none for the

forward:
8/5/96 0:00:00,,"C122",,,"40 39 46.90","-72 37 27.90","aft cargo door - lower sill latches and locks","RF45A","L16","Fuselage","Green","FS 1880",10/12/96 12:55:48,"8/05/96-70",0,0,,
8/25/96 0:00:00,,"C2155",,"C714","40 39 46.40","-72 37 27.80","FS 1810, outer frame aft cargo door panel STR 24R-28R (aft upper main cargo door sill)","RF98","16L","Fuselage","Green","FS 1810"

There are no references to any aft or forward cargo door parts in the addendum to the TAGS database, Exhibit 21F Appendix 5: ÒUpdated Wreckage Not Included in Tags Table.Ó

Eight is not ten. Ten is complete for forward cargo door; eight is incomplete. The two missing latches are the midspan latches, the location of which is exactly where the outward peeled ruptures occur in the forward cargo door as confirmed by photographs of the actual shattered forward cargo door wreckage of TWA 800.

ÒXÓ marks the spot of the outward peeled rupture of the aft midspan latch of the forward cargo door of TWA 800. Note hinge and red paint smears on fuselage skin above shattered door.

The large gaping hole to the left of the yellow tag marks the spot of the outward peeled rupture of the missing forward midspan latch of the forward cargo door of TWA 800. Also note red paint smears above hinge, inward pillowing of skin lower down on door pieces, and absence of most of recovered door pieces.

NTSB: ÒThere were no indications of preimpact failure of the hinge at the top of the door.Ó

JBS: There were indications of failure at the top of the door with red paint smears that would only occur when the door ruptured/ opened in flight. These paint smears match the style of paint smears of the UAL 811 cargo door area when the door ruptured/ opened out and upward and slammed into the fuselage skin above leaving door paint on the fuselage.

NTSB: ÒInvestigators verified that these cams, pins, and sill pieces were from the forward cargo door by matching the fractures to the attaching pieces of structure.Ó

JBS: The items only refer to the eight pieces recovered and do not refer to the two missing midspan latches. Metallurgical examination and report of those Òcams, pins, and sill piecesÓ is absent, unlike the two AAR of UAL 811.

NTSB: ÒThis evidence indicates that the door was closed and locked at impact.Ó

JBS: Absolutely false logic and refuted by the incomplete recovery of evidence and absolutely refuted by photographic evidence of the actual wreckage of the few recovered door pieces which show outward petal shaped ruptures, paint smears, and the location of wreckage debris in the ocean that indicated clearly the forward cargo door ruptured in flight as the initial event and separated in pieces which created the entire shattered area around the forward cargo door on the starboard side. The port side opposite the cargo door is smooth and unshattered which refutes the center tank explosion as the initial event since a ÔcenterÕ event would cause equal bilateral damage, not the severe unilateral damage on starboard side, the cargo door side. A latched cargo door sill in which the rest of the door is shattered and tossed to the wind is not a door which is closed and locked at impact. The actual confirming evidence that the forward cargo door opened in flight is the photographs showing the outward peeled ruptures at the two midspan latches, the engine blade in the right horizontal stabilizer, and the sudden loud sound on the CVR which matches a previous ruptured cargo door in flight on a similar type aircraft.

NTSB: ÒFurther, deformation and fracture patterns on the door matched damage to the adjacent fuselage structure, confirming that the door was in the closed position at the time of impact.Ó

JBS: Absolutely incorrect and proven by photographic evidence. There is no ÒdoorÕ; there are dozens of pieces of the door with most of it still missing and unrecovered as shown by photographs and the recovered wreckage database. To say a ÔdoorÕ is Òin the closed positionÓ when the manual locking handle has not been recovered and examined to determine if it in the proper position and stowed is to give a worthless opinion about the status of a door. A latched cargo door sill in which the rest of the door is shattered and tossed to the wind is not a door which is in the closed position at the time of impact. The few pieces of the forward cargo door which were recovered were found many hundreds of yards apart from each other according to wreckage plot and indicate the door did not shatter upon impact but before impact. The TAGS database lists all the pieces of the forward cargo door which were recovered and constitute less than 50% of the door and confirmed by the wreckage reconstruction: (Note ÔwhiteÕ tag which means it was later changed and contradicts the ChairmanÕs statement below.)
8/4/96 0:00:00,,"B155",,,"40 39 04.30","-72 38 27.20","forward cargo door lift",,"L22","Fuselage","Yellow",
8/5/96 0:00:00,,"B189",,,"40 39 04.30","-72 38 27.20","FS

540-580 STR 24R-30R with top right corner of forward cargo door","RF3D","L21","Fuselage","Yellow","FS 540-580",
8/5/96 0:00:00,,"B221",,,"40 39 04.30","-72 38 27.20","small section of upper forward cargo door","RF3E","L21","Fuselage","Yellow",
8/5/96 0:00:00,,"B223",,,"40 39 04.30","-72 38 27.20","FS 600-720 STR 24R-26R with rear top part of forward cargo door","RF3C","L21","Fuselage","Yellow","FS 600-720",
8/8/96 0:00:00,,"B334",,,"40 39 04.70","-72 38 26.80","forward cargo door segment","RF3M",,"Fuselage","Yellow",,
8/26/96 0:00:00,,"B2015",,,,,"metal strap with internal cargo door switch for forward cargo door; FS 560; WL 164; RBL 96",,"L21","Fuselage","White","FS 560",
8/5/96 0:00:00,,"B2029",,"B223","40 39 04.30","-72 38 27.20","forward cargo door segment","RF3N",,"Fuselage","Yellow",
8/5/96 0:00:00,,"B2101",,"B223","40 39 04.30","-72 38 27.20","aft pressure limiting door forward cargo door","RF3K",,"Fuselage","Yellow",,
8/5/96 0:00:00,,"B2102",,"B223","40 39 04.30","-72 38 27.20","forward pressure limiting door forward cargo door","RF3L",,"Fuselage","Yellow",

There are no references to any aft or forward cargo door parts in the addendum to the TAGS database, Exhibit 21F Appendix 5: Updated Wreckage Not Included in Tags Table.

NTSB: ÒYou indicate that Mr. Smith claims that "only eight [of 20 door latches from TWA flight 800] have been recovered, and they are all from one sill found in the aft debris field" and that "[t]he only cargo door sill found in the aft fuselage debris field belongs to the rear cargo door, and is not the forward cargo door sill." The forward cargo door was found in the "yellow" wreckage recovery zone, which contained the nose portion of the airplane and pieces of the fuselage forward of about station 840. The aft portion of the airplane, including wreckage from the rear cargo door, was found in the "green" wreckage recovery zone, which contained most of the airplane wreckage, including pieces of the fuselage aft of about station 1000. Therefore, Mr. Smith is incorrect in asserting that the only recovered cargo door pieces were those from the rear cargo door.Ó

NTSB: ÒThe forward cargo door was found in the "yellow" wreckage recovery zone, which contained the nose portion of the airplane and pieces of the fuselage forward of about station 840.Ó

JBS: The Ôforward cargo doorÕ was not found anywhere. It was shattered into many pieces (one found in ÔwhiteÕ zone) as shown by the reconstruction photographs and less than 50% of the total door was recovered as shown by the TAGS wreckage database. The important pieces to determine if the cargo door was properly latched/did not rupture in flight are missing to include the manual locking handle, and the two midspan latches. None of the recovered pieces of the forward door were sooted which refutes the center tank as initial event since the forward door is very near the center tank. There was only one cargo door sill recovered and it was found in the aft debris field.

In addition, the color of a tag was changed even though the piece landed in a different color zone which depicts the actual landing location of the debris.
ÒDOCKET NO. SA-516
EXHIBIT NO. 211
NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

Appendix 8: Tag Renumbering Procedure
(5 pages)
TWA 800 Tags System Procedure
Tag Re-Numbering
OTECH CAJ 9/25/96
Applicability:
When a tag number needs to be changed. Primarily reason: when the tag alpha designator (A B C or X
Y Z) or color code (RED, YELLOW, GREEN) is found to be at odds with the debris field in which the
object was actually found. Such tags are referred to as Òout-of-areaÓ tags.
Re-tagging may also be necessary for debris field locations which cannot be verified. If database
validation processes indicate that existing tag location information is not verifiable, then re-tagging to
WHITE will be accomplished using this procedure and associated documentation.
For those situations where documentation indicates that re-tagging would revise the debris field
location (i.e., the tag color should be changed), back-up documentation will be maintained to support the
re-tag action.Ó

JBS: At odds with the debris field? The debris field is reality. Pieces landed where they landed for a physical reason. Sophisticated location techniques were used and latitude and longitude locations were logged as the pieces were retrieved. Where the pieces landed is of paramount importance and to administratively change the landing location is very misleading and nonexcusable. The pieces were found to be at odds with the debris field only using the center tank as the initial event. The original location of the debris field pieces make sense when using the wiring/cargo door explanation to explain why fuselage pieces forward of the wing landed where they did. (The overall debris appraisal was made by Docket Number SA-516, Exhibit No. 22A, Trajectory Study, page 3: "The wreckage distribution shows that parts were initially shed from the area just forward of the wing.") The center tank is not Ôjust forward of the wingÕ while the forward cargo door is. The center tank is aft of the leading edge of the wing and thus parts were not initially shed from that area which means it was not the initial event.

NTSB: ÒTherefore, Mr. Smith is incorrect in asserting that the only recovered cargo door pieces were those from the rear cargo door.Ó

JBS: A completely wrong and ignorant statement by Chairman Hall of NTSB. I never said and do not assert now that Òthe only recovered cargo door pieces were those from the rear cargo door.Ó In fact, I refer over and over to the forward cargo door pieces; they are conclusive proof that the forward door ruptured in flight. To say I assert Ò... the only recovered cargo door pieces were those from the rear cargo door,Ó is to show conclusively that the NTSB does not understand the wiring/cargo door explanation, has not seriously considered the explanation, has not discussed the explanation with me, and is content with confused thinking about it.

The wiring/cargo door explanation does refer to the recovered pieces of the aft cargo door (also to many other parts of TWA 800) and asserts that the only cargo door sill of two which were on TWA 800 when it took off was found in the aft debris field and is most likely that of the aft cargo door, a door which is identical in size, function, and parts to the forward cargo door. All pieces of the aft cargo door recovered are listed below; (Note that that there are more pieces recovered for the aft door than for the forward door and no ÔwhiteÕ changed tags.)

8/4/96 0:00:00,,"C111",,,"40 39 46.90","-72 37 27.90","aft cargo door cutout (#1860)/seats/fuselage",,,,"Green",,.
8/5/96 0:00:00,,"C122",,,"40 39 46.90","-72 37 27.90","aft cargo door - lower sill latches and locks","RF45A", "L16","Fuselage","Green","FS 1880",
8/21/96 0:00:00,,"C644",,,"40 39 46.89","-72 37 26.59","aft cargo door lower aft section","RF45F","L15.5","Fuselage","Green","FS 1910",
8/25/96 0:00:00,,"C2155",,"C714","40 39 46.40","-72 37 27.80","FS 1810, outer frame aft cargo door panel STR 24R-28R (aft upper main cargo door sill)","RF98","16L","Fuselage","Green","FS 1810"
8/9/96-37" ,,"C2133",,"C673","40 39 47.04","-72 37 26.90","aft cargo door fragment","RF45G","L16","Fuselage","Green","FS 1810",
8/25/96 0:00:00,,"C1080",,,"40 39 46.40","-72 37 27.80","FS 1900-1940 aft cargo door surround, STR 41R-44R","RF45E","L 15.8","Fuselage","Green","FS 1900-1940",
8/4/96 0:00:00,,"C2252",,"C114","40 39 46.90","-72 37 27.90","FS 1820-1840 STR 23R-27R with aft cargo door hinge","RF30A","L16","Fuselage","Green","FS 1820-1840"
8/19/96 0:00:00,,"C2336",,"C932","40 39 47.36","-72 37 27.71","FS 1780-1840 STR 38R-46R forward lower corner of aft cargo door cut-out","RF54E","L16","Fuselage","Green","FS 1780-1840",
8/4/96 0:00:00,,"C2340",,"C112","40 39 46.90","-72 37 27.90","FS 1810-1836 STR 27R-30R, forward right upper corner of aft cargo door","RF99","L16","Fuselage","Green","FS 1810-1836",
8/4/96 0:00:00,,"C111",,,"40 39 46.90","-72 37 27.90","aft cargo

door cutout (#1860)/seats/fuselage",,,,"Green",,
8/21/96 0:00:00,,"C644",,,"40 39 46.89","-72 37 26.59","aft cargo door lower aft section","RF45F","L15.5","Fuselage","Green","FS 1910",

There are no references to any aft or forward cargo door parts in the addendum to the TAGS database, Exhibit 21F Appendix 5: Updated Wreckage Not Included in Tags Table.

NTSB: ÒYou also state that Mr. Smith asserts that "all ten locking latches, the manual locking handle, the viewing ports, and two 'overpressure relief doors' have not been fully accounted for in the investigation and are not in the wreckage database." The Safety Board recovered and accounted for all of the closing hardware for the forward cargo door. All ten of the closing cams and pins are in the recovered structure database and are physically located on the reconstructed portion of the airplane. (A metallurgical report on the forward cargo door discusses only the eight latching cams and pins on the bottom of the door and does not discuss the two alignment pins and cams on the sides of the door.)

NTSB: ÒThe Safety Board recovered and accounted for all of the closing hardware for the forward cargo door.Ó
JBS: Absolutely not true: Ôall the closing hardwareÕ is missing from all of the wreckage pieces databases, from the public docket, from examination and evaluation in Exhibits, and the actual wreckage reconstruction. In fact, all of the forward cargo door has not been recovered, accounted for, or evaluated, with less than 50% recovered and those few consist of ÔsegmentsÕ ÔpiecesÕ and Ôparts.Õ The closing hardware is extensive and included, torque tubes, bellcranks, manual locking handle, ten cams, pins, latches, and overpressure relief doors within the door.

To claim that all closing hardware for the forward cargo door was recovered and accounted for is a falsehood.

NTSB: ÒAll ten of the closing cams and pins are in the recovered structure database and are physically located on the reconstructed portion of the airplane.

JBS: There is no documentation that of the twenty identical closing cams and pins, the alleged ten belong to the forward cargo door and not the aft. There is no documentation of the missing two midspan latches from the forward cargo door being found. There is no evaluation of the condition of any of the cams and pins of either door. In the entire wreckage databases there is no report of any ÔcamsÕ nor ÔpinsÕ in the recovered structure database. The two midspan latches of the forward door are not physically located on the reconstructed portion of the airplane as proven by photographs.

NTSB: Ò(A metallurgical report on the forward cargo door discusses only the eight latching cams and pins on the bottom of the door and does not discuss the two alignment pins and cams on the sides of the door.)Ó
JBS: Misleading statement by NTSB and metallurgist Jim Wildey, as the two midspan latches are not trivial Ôalignment pins and camsÕ, but identical cams, pins, and latches to the lower eight. The top of the door is held by a lengthwise hinge and the lower sill of the door is held by eight latches. The two sides, each eight feet tall, are held in by one latch per side, the midspan latch. The lower eight latches have locking sectors which press against the cams to prevent inadvertent opening in flight. The two midspan latches have no locking sectors. This absence of two sectors per door is the fatal design error of the door in addition to being outward opening and nonplug. An

Airworthiness Directive issued after the forward cargo door of UAL 811 ruptured/opened in flight to strengthen the locking sectors had no effect on the two midspan latches because they have no locking sectors to strengthen. Those two locations is where the ruptures occurred in TWA 800, at the midspan latches where no locking sectors existed, as confirmed by photographs. To Ònot discuss the two alignment pins and cams on the sides of the doorÓ as NTSB admits is to admit to an incomplete examination and evaluation of the forward cargo door, a door initially considered to be the initial event of TWA 800.

NTSB: ÒIn your letter, you also indicate that Mr. Smith asserts that "[b]lades on the Number 3 engine were found damaged, in a manner consistent with explosive decompression of the adjacent forward cargo door." However, physical evidence indicated that damage to the number 3 engine's fan blade airfoils was due to the blade mid span shrouds shingling (overlapping) and tearing out part of the airfoils when the engine impacted the water. Further, the damage noted on the number 3 engine's low- and high-pressure compressor airfoils was similar to that observed on the other three engines' compressor airfoils. None of the four engines installed on TWA flight 800 had any damage that could have been caused by the ingestion of a foreign object. Therefore, this damage does not support Mr. Smith's contention that the forward cargo door separated in flight.

NTSB: ÒNone of the four engines installed on TWA flight 800 had any damage that could have been caused by the ingestion of a foreign object. Ò

JBS: Absolutely incorrect statement as shown by actual examination of engine number three as reported in the TWA 800 Public Docket:

Exhibit 8A, Page 11, paragraph 3, discussing results of engine 3 disassembly, "Of the 46 fan blades in the fan rotor, 21 blades with complete or partial airfoils and 6 root sections were recovered. All of the fan blades had sooting on the convex airfoil surfaces. Most of the full length airfoils were bent rearward and the tips outboard of the outer midspan shroud were bent forward slightly. About half of the fan blades had impact damage to the leading and trailing edges. Almost all of the impact damage to the airfoils could be matched to contact with the midspan shroud on an adjacent blade. One full length blade had four soft body impacts along the leading edge and a partial airfoil had a soft body impact, which had some streaking extending rearward."

NTSB: ÒTherefore, this damage does not support Mr. Smith's contention that the forward cargo door separated in flight.Ó

JBS: The damage to engine number three conclusively supports the wiring/cargo door explanation that the forward cargo door separated in flight by showing that foreign objects and door skin ejected after explosive decompression were ingested into the adjacent engine number three which led to uncontainment and the spitting out of a blade into the right horizontal stabilizer immediately behind the engine. Docket No. SA-516, Exhibit No. 7A, Structures Group Report, page 33: "5.1 Horizontal Stabilizer, "Some of the items found in the horizontal stabilizer are sections of seat track, a stator blade from turbine section, and glitter." On 5.1.1 Right Horizontal Stabilizer, page 34, "An engine stator blade from turbine section penetrated the upper honeycomb surface near the outboard trailing edge

JBS: Only 58% of the fan blades were recovered which means 42% were missing. It is very likely the 'stator blade' found in right horizontal stabilizer was from engine number three which sits directly in front of it. "Almost all' of the 'impact damage,' was explained which implies some wasn't explained. All blades in engine three had soot. Soot means fire. FOD usually means fire. Only engine number three had any sooting inside engine. One full blade and one partial blade had 'soft body impacts'. There is nothing normally soft inside a jet engine. Soft body impact means foreign object damage which could mean the soft bodies of passengers ejected from the open fuselage, as happened with UAL 811. Streaking could be blood streaks. Missing blades in engine three and one blade found directly aft in right horizontal stabilizer recovered far away from main engine means uncontainment in flight. Uncontainment means engine number three was not intact at water impact but implies destruction and fire inflight. The FODDed, uncontained, spewing blades, on fire engine number three is very likely the plausible ignition source for the nearby center tank which was disintegrating into fuel vapor as it fell.

NTSB: ÒFinally, you state that Mr. Smith asserts that "[t]he FDR [flight data recorder] plots of TWA [flight] 800, Pan Am [flight] 103, and UAL [United Airlines flight] 811 are consistent with the explosive decompression of the right forward cargo door" and that "[b]ad wiring ... caused the forward cargo doors to open in flight on high time B747's [including these airplanes and Air India flight 182] ... and that [t}he photographic, CVR [cockpit voice recorder], FDR, FOD [foreign object damage], and other evidence points to a common scenario of cargo door failure." You also state that Mr. Smith believes "the outward peeled ruptures in metal shown in photographs ... are clear evidence of cargo door failure, not of a [CWT] explosion. Mr. Smith is correct that the United Airlines flight 811 accident was caused by the in-flight separation of the forward cargo door.

However, the investigation of the Pan Am flight 103 accident (in which the Safety Board participated extensively) revealed overwhelming evidence that the accident was precipitated by the explosion of a bomb in the forward cargo compartment, not by inadvertent opening of the forward cargo door. Further, regarding Mr. Smith's contention that the "outward peeled ruptures" from the TWA flight 800 airplane are indicative of an in-flight cargo door failure, the investigation's Sequencing Group (which included participants from all of the parties to the investigation) reached a different conclusion. The Sequencing Group determined that the damage to the airplane was consistent with an overpressure in the CWT as the initiating event, not a failure of the cargo door.

NTSB: ÒMr. Smith is correct that the United Airlines flight 811 accident was caused by the in-flight separation of the forward cargo door.Ó

JBS: I asset the above because of NTSB AAR 90/01 and 92/02 regarding UAL 811: NTSB conducted an incomplete investigation of the forward cargo door of UAL 811 and came to an incorrect probable cause in AAR 90/01 for its opening in flight leading to nine fatalities: Improper latching. Upon further investigation the door was found to be properly latched and the cause to be electrical. A new AAR was published which was AAR 92/02, giving the new probable cause. The NTSB TWA 800 investigation in AAR 00-03 is also incomplete leading to the wrong probable cause as the center tank exploding as the initial event. A precedent has been set of NTSB conducting an incomplete investigation leading to an incorrect probable cause in an AAR leading to the event occurring again (UAL preflight uncommanded opening of cargo door) and thus having to write another AAR with the new probable cause. This sequence will happen again unless further investigation of the wiring/cargo door explanation is conducted for TWA 800. A precedent has been set for NTSB to further investigate an accident even though a final AAR has been published. A precedent has been set for NTSB to discover and admit an error of opinion and correct it.

From
NTSB AAR 92/02:

NTSB/AAR-92/02
(SUPERSEDES NTSB/AAR-90/01)

The wrong probable cause in AAR 90/01 for UAL 811: ÒThe National Transportation Safety Board determines that the Probable Cause(s) of this Accident was: The sudden opening of the improperly latched forward lobe cargo door in flight and the subsequent explosive decompression.Ó

The new probable cause in AAR 92/02 for UAL 811: ÒBefore the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.
Thus, as a result of the recovery and examination of the cargo

door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.
The issues in this investigation centered around the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.
The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff.Ó

NTSB: ÒHowever, the investigation of the Pan Am flight 103 accident (in which the Safety Board participated extensively) revealed overwhelming evidence that the accident was precipitated by the explosion of a bomb in the forward cargo compartment, not by inadvertent opening of the forward cargo door.Ó

JBS: There is not Òoverwhelming evidence that the accident was precipitated by the explosion of a bomb in the forward cargo compartment, not by inadvertent opening of the forward cargo door.Ó That NTSB statement is unsupported opinion and shows that NTSB also influenced incorrectly the PA 103 probable cause as reported in AAIB AAR 2/90. Pan Am 103 is another similar event of TWA 800. It has many similarities that match TWA 800 which are supported by facts, data, and evidence. The wiring/ cargo door explanation concludes PA 103 was an ruptured/open cargo door inflight, as was Air India Flight 182.
PA 103, AI 182, and TWA 800 are the only Boeing 747 accidents

to have the following unusual and rare similarities:
non Section 41 retrofit
early model
poly x wired
Boeing 747
experienced hull rupture forward of the wing in cargo bay.
nose came off
damaged number three engine
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
outward peeled skin in cargo door area
longitudinal break in forward cargo door,
more severe inflight damage on starboard side
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
torn off skin in forward cargo door area on starboard side,
outward peeled skin in cargo door area
downward bent floor beams in cargo door area,
destruction initially thought to be have been caused by a bomb.

NTSB: ÒFurther, regarding Mr. Smith's contention that the "outward peeled ruptures" from the TWA flight 800 airplane are indicative of an in-flight cargo door failure, the investigation's Sequencing Group (which included participants from all of the parties to the investigation) reached a different conclusion. The Sequencing Group determined that the damage to the airplane was consistent with an overpressure in the CWT as the initiating event, not a failure of the cargo door.

JBS: Again, that conclusion is unsupported opinion which is contradicted by facts, data, and evidence elsewhere in the Public Docket such as NTSBÕs own Trajectory Study. The Sequencing Group is James F. Wildey II, National Resource Specialist-Metallurgy. He is not an aircraft accident investigator. The TWA 800 Public Docket SA-516, Exhibit 18A is the Metallurgy/Structural Group Chairman Factual Report Sequencing Study, signed by only Mr. Wildey. Contrary to the NTSB statement above, the Sequencing Group did not determine that the failure of the cargo door was not the initiating event as the words, ÒCargo DoorÕ are not to be found in any of the 57 page exhibit. There is nothing in the ÒStudyÓ about the forward cargo door, which is a serious omission as the ruptured/opened door was initially considered by NTSB to be the initial event and the forward cargo door lies very close to the center tank. This is further evidence that the wiring/cargo door explanation has not been properly evaluated by NTSB.

NTSB: ÒMr. Smith's assertion that the CVR evidence for the four accidents mentioned in your letter indicate a common scenario is also incorrect. The CVR termination sound signatures for Pan Am flight 103, Air India flight 182 (both of which were brought down by bombs exploding in flight), and TWA flight 800 were all characterized by a rapid increase in amplitude with no evidence of prior anomalies. In contrast, the CVR from the United Airlines flight 811 accident involving the in-flight separation of the cargo door revealed a longer-term sound signature with a slower onset. Additionally, the loud terminating sound on the United Airlines flight 81 1 CVR is preceded by several precursor lower-order events, some of which were noticed and commented on by the flight crew.

NTSB: ÒThe CVR termination sound signatures for Pan Am flight 103, Air India flight 182 (both of which were brought down by bombs exploding in flight), and TWA flight 800 were all characterized by a rapid increase in amplitude with no evidence of prior anomalies.Ó

JBS: The CVR examinations for all four accidents have ruled out a bomb sound and match each other and UAL 811. To state a bomb went off in an aircraft and yet have the CVR not have a bomb sound is to logically rule out the bomb as the cause of the sudden loud sound and thus the accident. An alternative must be found and it is in the explosive decompression sound. UAL 811 had that explosive decompression sound and it matches AI 182, TWA 800, and PA 103.

NTSB: ÒIn contrast, the CVR from the United Airlines flight 811 accident involving the in-flight separation of the cargo door revealed a longer-term sound signature with a slower onset. Additionally, the loud terminating sound on the United Airlines flight 81 1 CVR is preceded by several precursor lower-order events, some of which were noticed and commented on by the flight crew.Ó

JBS: NTSB Chart 12 below which compares all CVR sound of the four accidents. They match in the very rare occurrences of a sudden loud sound, not a bomb sound, which is then almost immediately followed by an abrupt power cut to the FDR. UAL 811 did not have any Ôlower-order eventsÕ picked up by the CVR as the time in the chart is in milliseconds. In spite of much effort to make the sudden loud sound a bomb sound, the sounds lack the low frequencies which exist in bomb sounds and the rise time is too slow for the explosion of a bomb. All of the four sounds match the known sound of the explosive decompression of UAL 811 forward cargo door rupturing/opening in flight. The NTSB CVR study omits any detailed analysis of this important sudden loud sound.

NTSB: ÒIn sum, Mr. Smith's position is simply not supported by the facts. Our correspondence database indicates that Mr. Smith has written the Safety Board many letters regarding his theories about the cause of the TWA flight 800 accident. The Board has responded to Mr. Smith numerous times, indicating that Board investigators have considered his theories and that no evidence exists to support his conclusions. In March 1998, 1 informed Mr. Smith that our correspondence had exhausted this issue and that he should expect no further response from the Board on this subject. I am pleased to have had this opportunity to provide you with details about the Board's position on this issue. However, I continue to believe that it would not be productive to correspond with Mr. Smith further about his theories regarding the cause of the TWA flight 800 accident.

NTSB: ÒIn sum, Mr. Smith's position is simply not supported by the facts.Ó

JBS: My position is supported by ample facts from four similar accidents, from the Public Docket, from government AARs, from photographs, and other official documents.

NTSB: ÒOur correspondence database indicates that Mr. Smith has written the Safety Board many letters regarding his theories about the cause of the TWA flight 800 accident. The Board has responded to Mr. Smith numerous times,...Ó

JBS: I have written the NTSB many times but they have not responded numerous times to me. Senator John McCain wrote suggesting a meeting with me but NTSB declined. Congressman

Sam Farr has asked for a meeting with me but NTSB, Mr. Drake, refused and reiterated that, in fact, they will not correspond, discuss, meet with me ever. (Note the effort to make the messenger the point of argument instead of the message of wiring/cargo door explanation. I am trivial; the message of wiring/cargo door safety item is paramount.)

NTSB: ÒHowever, I continue to believe that it would not be productive to correspond with Mr. Smith further about his theories regarding the cause of the TWA flight 800 accident.Ó

JBS: Not productive? The NTSB and the FAA have never tried for a productive exchange of ideas with me. NTSB has selected random statements and attempted to contradict them while ignoring the irrefutable facts that rule out center tank explosion as initial event and support the wiring/cargo door explanation.
Those facts among many which will never go away are:
Sudden loud sound on the CVR.
Stator blade in right horizontal stabilizer.
Photograph of forward cargo door showing paint smears, missing midspan latches, outward petal shaped rupture holes at midspan, pillowing inward force on other parts of door.
Three other similar events with similar evidence with one event, UAL 811, being a confirmed electrical/cargo door caused accident:

TWA 800 and UAL 811 were both:
aged
high flight time
poly x wired
early model Boeing 747
and shortly after takeoff
while climbing

experienced a sudden initial event in the forward cargo hold which left a
short
sudden
loud
sound on the cockpit voice recorder, an
abrupt data loss to the flight data recorder,
foreign object damage to starboard engine #3
more severe inflight damage on starboard side,
smooth port side forward of the wing
at least nine never recovered bodies,
torn off skin in forward cargo door area on starboard side,
rupture at forward cargo door at aft midspan latch,
outward peeled skin on upper forward fuselage,
downward bent floor beams in cargo door area,
vertical fuselage tear lines forward of the wing and aft of forward cargo door,
inadvertent opening of forward cargo door considered as probable cause.
bare wires found in cargo door area.
destruction initially thought to be have been caused by a bomb but ruled out later.

In summation:

The matching facts between UAL 811 and TWA 800 are sufficient to warrant a thorough investigation of the wiring/cargo door explanation for TWA 800 which would match the standard of aircraft accident investigation of UAL 811 with its two AARs, 90/01 and 92/02. The wiring/cargo door explanation is supported by enough evidence to interview the discoverer at length about it.

ÒWhen men are ruled by fear, they strive to prevent the very changes that will abate it.Ó Alan Paton.

NTSB is driven by fear and pride. Pride comes before a fall.

Therein lies the fault/mistake/crime.

The tragedy is not that a government agency, in this case NTSB, FAA, and FBI, missed something.

The tragedy is not that a civil servant, in this case, James Wildey, was asked to do something, aircraft accident investigation, in which he was not qualified as a metallurgist.
The tragedy is not that an agency, NTSB, relied on an official for an evaluation report which was error filled, laden with mistakes, and incomplete, the instant quoted letter and Exhibit 15C.

The tragedy is not that an agency composed of individuals, Jim Hall, Bernard Loeb, Ron Schleede (Ret), Al Dickinson, Jim Wildey, Bob Swaim of NTSB, and Misters McSweeny Mr. Ron Wojnar Mr. Dimtroff, Mr. Schalekamp, Mr. Breneman, Mr. Lyle Streeter of FAA, makes up its mind as to a sequence of events, center tank explosion as initial event, and then tries very hard to make that sequence make sense even to the extent of altering evidence, yellow and red location tags to white tags.

The tragedy is not that an agency with a politically connected appointed official, Jim Hall, not very educated about the area he has responsibility for, aviation, tries to find a explanation that does not ruffle too many feathers, a one off explosion with unknown ignition source.

The tragedy is not that taxpayer money is wasted on a huge project, TWA 800 wreckage reconstruction, and then the evidence discovered, ruptured forward cargo door in many pieces with most missing, is ignored.

The tragedy is not than an official, Mr. Schalekamp, saw the evidence of ruptured cargo door in flight and agreed, but later quickly recanted when he realized it was not the official position.

The tragedy is not than an official of an agency, Mr. Streeter of FAA, refuses to get involved with an issue that the agency can pass over to another, FAA to NTSB and FBI to NTSB, although that agency is tasked with the issue, public safety.
The tragedy is not that an investigating agency, NTSB, FAA, and FBI, focuses solely on an explanation that fits its perceived best interest, bomb, missile, or random event, while ignoring all reasonable alternatives which are perceived to be contrary to that interest, wiring/cargo door explanation.

The tragedy is that the agencies, NTSB, FAA, and FBI, were informed over a period of years of a serious public safety issue and actively rejected any evaluation of that issue to the extent of changing the evidence, to wrongly accuse a citizen, to refuse to confirm or rule out the presented facts, data, and evidence, and of refusing to meet with the proponent, or discuss through letters the reasonable, plausible explanation. To miss a life or death safety item is human and understandable and sad; to reject a life or death safety item given by a qualified citizen over a period of years supported by documentation is inhuman and incomprehensible and a tragedy. And you, NTSB, FAA, and FBI, have done that for over four years and are doing that right now.

The metaphor I think of is that of a crossing guard who is told over and over again a truck is coming and to put down the guard to protect the children continually crossing the street. The guard says no. The guard says IÕm wrong. The guard says IÕm crazy. The guard says go away. The guard ignores the verbal, written, graphic warnings supported by documents, photographs, and testimony that an event which has happened before is going to happen again, a truck plowing into a group of children at a crosswalk because the guard refused to put down the barrier. The guard then attacks me by saying bad things about my character and motives. The guard never asks, ÔWhy do you say that a truck is coming?

And then of course the truck comes, just as TWA 800 came along as I was presenting my correlation to UAL 811 for PA 103 all during the early 1990s prior to July 17th, 1996, to media and the insurance agency. I knew right away what TWA 800 was and immediately starting informing NTSB, FAA, and FBI of the forward cargo door problem with Boeing 747s.

The error of judgment which leads to the tragedy is continuously rejecting for over four years an experienced citizensÕ opinion supported by facts, data, evidence, photographs, charts, documents, interviews with witnesses, and precedent which contradicts that agencyÕs opinion. I have been in a sudden, night, fiery, fatal, jet aircraft accident. I have spent forty years in aviation related endeavors. After years of research, I offer a mechanical explanation with precedent in a similar type aircraft. Wiring/cargo door explanation for TWA 800 is plausible, reasonable, and must be further investigated lest it occur again. Further investigation starts with meeting with me. For a public safety agency to refuse to meet and discuss a plausible explanation for a fatal accident with a citizen when the official version is incomplete is inexcusable and most likely criminal should another cargo door rupture open in flight leading to fatalities.

The tragedy is that the agencies entrusted by the public to protect their lives do not and will not ask the question of an experienced citizen with supporting documents to explain his public safety discovery: wiring will again short a door unlatch motor on and the midspan latches of the forward cargo door of a Boeing 747 will rupture again leading to fatalities, as happened with AI 182, PA 103, UAL 811, and TWA 800. The public trust has been betrayed by officials who will not inquire or investigate a reasonable alternative to their position because of fear and pride. The question has never come, ÒMr. Smith, why do you say that wiring caused the forward cargo door of TWA 800 to rupture at the midspan latches?Ó

In summary: An amateur sleuth going up against the initial mystery and the authorities believing a different way has a hard job. He has to be persuasive, charming, have all the right answers, and at least have some authority who will discuss with him the alternatives. It worked for Sherlock Holmes in fiction and the Campbells for UAL 811. The problem is that the persons who usually go against the common wisdom and discover a contrary truth are not likable nor charming. They do not say what the agency wants to hear and thus become well liked. It takes a confident, tolerant government agency who really wants to do its job right and solve the mystery of TWA 800 by discussing alternatives with someone they instinctively donÕt like. NTSB is not that agency. Nor the FAA. Nor the FBI.

In sum: What is left for this individual citizen who has labored more or less alone for over a decade with no support from government, manufacturer, airline, media, or independent safety organizations? Bitterness, anger, sarcasm, ridicule, are not usual persuasive words but they do make one smile and grimace, keep the morale up, and allow the wiring/cargo door cause to continue to the next Chairman so I will say one word which sums up my attitude towards authority who has got it wrong, keeps on repeating the error, refuses to meet with someone who can correct that life and death error, and yet officially seriously evaluates explanations that make no sense such bombs, missiles, meteorites, and a spontaneous fuel tank explosion with a mystery ignition source:

HA!

Respectfully submitted,

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Not me**

Engineer has alternate theory on plane disaster Boiler expert links jet's age, design to why roof ripped off

By Gary Stoller
USA TODAY

As an Aloha Airlines jet descended for landing on Maui, Hawaii, passenger Matt Austin noticed the luggage racks rattling and swaying when the thrust reversers came on.

It didn't startle him. He had seen that happen before on other older Aloha jets. But Austin remembered the name painted across the plane's exterior: Queen Lili'uokalani. It was a 19-year-old Boeing 737.

A week later -- on April 28, 1988 -- the same jet's roof ripped open 24,000 feet over the Pacific Ocean, killing one flight attendant and seriously injuring seven passengers and a crew member. Austin counted himself lucky. Aloha Flight 243's last flight didn't really begin to grip him until the next year, when the National Transportation Safety Board issued its accident report.

This is a detective story. It's about a mystery that aviation professionals say was solved 12 years ago and the persistence of Austin, a former Hawaii boiler inspector, who has spent all those years and $45,000 of his money trying to prove that the experts got it wrong.

It's also about an accident that forever changed maintenance practices for old planes and about an alternative theory that could have far-reaching consequences. Finally, it's about the intriguing possible parallels between boiler safety and airplane safety.
But first it helps to know something about Austin. A mechanical engineer, Austin has no professional expertise in airplane accidents. He is an expert on boilers; the NTSB consulted him about a train boiler explosion in Gettysburg, Pa. Austin, 43, runs a consulting business, Hawaiian Steam Engineering, which designs, inspects and restores boilers and locomotives. He also consults for the U.S. Navy on servicing nuclear submarine power plant components.
Since 1989, Austin has researched the Aloha accident independently, always maintaining that his only motivation is "engineering truth" and a conviction that sharing his insights can prevent similar accidents. He has a Web site, **www.disastercity.com**, where he details his theories on the Aloha accident and other disasters.
If Austin's theories are correct, a design that is intended to prevent catastrophic failures on nearly all Boeing jets could be flawed. It may even pose a danger to passengers, Austin says. Boeing says the design meets FAA requirements and works as intended.
Austin also says his study has convinced him that:
* Old jets are not safe to fly, even if all required maintenance has been done.
* The FAA's aging aircraft program, which requires airlines to repair and inspect old jets, should be scrapped. The program allows planes to fly beyond their design life and relies on airline inspectors who may not detect all structural problems, he says.
To reach those conclusions, Austin purchased and pored over more than 4,000 pages of NTSB accident findings. He attended a course for airline maintenance managers on aging aircraft and

studied books for aeronautical engineers. He bought special computers to study the NTSB's photos of the accident and related forensic evidence.

Austin also corresponded with NTSB investigators, FAA officials and a Boeing engineer. The investigators stand by the NTSB's conclusions but say they respect Austin's engineering knowledge.

"In every accident I ever worked, all kinds of crazies came out of the woodwork with theories about what happened," says former NTSB investigator Brian Richardson, who led the NTSB group that studied why the Aloha jet broke apart. "Matt Austin is not one of those people. He has good, solid credentials, and he's not going off the deep end."

The NTSB says it will not reopen the accident investigation, but Richardson says the FAA should study Austin's theory. Then goes a major step further.

"Matt may well have nailed the cause of the accident," he says. "I don't really know."

An important accident

Aloha Flight 243 was bound from Hilo to Honolulu when its roof tore off. An emergency landing was made in Maui.

Many aviation experts consider the flight the most significant accident in commercial aviation. It showed how inadequate airline maintenance procedures and poor FAA oversight can result in tragedy, and it prompted an FAA program to more vigilantly inspect aging airplanes.

The NTSB, which investigated the Aloha accident, concluded the jet's roof and walls tore off in flight because multiple fatigue cracks existed in the jet's skin.

Those cracks developed, the NTSB said, because lap joints that were supposed to hold the fuselage together became corroded and failed. A lap joint connects two overlapping metal sheets of the fuselage.

The role of lap joints on the Aloha plane is what first captured

Austin's attention. He read a story about lap-joint failure in the accident and realized the same words had been written about a boiler explosion in Brockton, Mass., in 1905.

The boiler connection

The danger of failed lap joints is well known in the boiler industry, which stopped using them on large boilers in the 1920s. In Brockton, a shoe factory boiler explosion collapsed a building, killing 58 people and injuring 117 others.

When a boiler's lap joint fails, a hole opens in the boiler's shell. The water inside instantly turns to steam, and increased pressure causes an explosion. Such a phenomenon is known as a fluid hammer, which Austin says caused the Aloha accident.

If Austin's theory is correct, it solves a question that the accident's investigators asked: Why didn't Boeing's "fail-safe" design, which is supposed to prevent a massive breakup, work? Boeing says the 737 was designed to decompress safely with as much as a 40-inch crack in the plane's skin, the 0.036-inch thick, aluminum outer layer of the fuselage. Instead of an explosive decompression, the hole in the skin is supposed to release internal pressure in a controlled way. In the Aloha accident, investigators concluded that more damage occurred -- about 18 feet of the fuselage tore away -- because many fatigue-caused cracks had gone undetected.

Austin says that a weakened fuselage was not the main reason for the extensive damage.

A 10-inch-by-10-inch hole opened, he says, in the roof of the front cabin at a location known as body station 500. (Body stations are identifying points on the fuselage that are measured in inches from near the nose of the jet to the rear.) A powerful stream of air swept an Aloha flight attendant off her feet and toward the hole, Austin says. Her head and right arm went through the hole, he says, but her body momentarily plugged it, creating a jolt of pressure that ripped the jet apart. The flight

attendant was swept out and her body was not recovered.
"Slamming the door on a 700-mile-per-hour jet stream creates a localized, short-duration high-pressure spike, up to several orders of magnitude (greater than) the allowable design pressure," Austin says. "This is a fluid hammer."
Forensic evidence, Austin says, shows where the flight attendant's skull struck the exterior of the plane. The location of the skull print is consistent with the location of a plugged hole at body station 500, he says.
The NTSB's official accident report says, however, that the breakup of the jet began about 5 feet farther forward, at about body station 440.
But Richardson, the former NTSB investigator, says Austin pinpointed a mistake in the NTSB's report. He says he always assumed the breakup began close to the point that Austin says.
The wreckage that could reveal where the breakup occurred is at the bottom of the Pacific Ocean.

NTSB not persuaded

USA TODAY brought Austin's analysis to NTSB Chairman James Hall, who joined the board 5 years after the Aloha accident and recently announced his resignation. He said Austin's theory makes sense, but the NTSB doesn't believe it happened that way.
"We don't disagree with Mr. Austin's explanation about how an airplane can decompress at 24,000 feet after a 10-inch-by-10-inch hole is blown open in the skin and about how devastating the 'fluid hammer' effect can be at this altitude," Hall said in a letter. "We disagree, however, with his conjecture involving the role the flight attendant's body played. . . .
"The roof of the Aloha airplane came off as a result of multiple site damage -- mainly, small fatigue cracks that emanated from many chamfered rivet holes. These cracks joined together, resulting in the catastrophic separation of the skin."

Austin agrees that the many fatigue cracks weakened the structure, but he says the plane wouldn't have ripped apart if the hole hadn't been plugged. And, Austin adds, "The NTSB validated my fluid-hammer theory. They couldn't say anything more without reconvening a pool of experts and reopening the investigation."

Richardson says he never heard of the fluid-hammer theory until Austin explained it. No one on his structural team, he says, ever mentioned it during the course of the investigation.

He says, though, he'll stand behind his and the NTSB's conclusions. "We never thought that the hole in the fuselage remained small enough long enough for anything to plug it and produce the kind of pressure spike that is common to the pressure vessels that you are familiar with," Richardson wrote Austin.

Austin says, however, that the difference between the NTSB's findings and his analysis is, "We're 60 inches and probably 20 thousandths of a second apart."

He says he enlarged NTSB photos of the skull print, used a computer to view them from a different angle and pinpointed the skull print's exact location. "The skull print is the key," Austin says. "It wouldn't be there so graphically if the flight attendant didn't plug the hole. If there would have been an out-rush of air without a hole being plugged, her whole body would have been sucked out at once away from the aircraft."

Austin also corresponded with FAA officials in 1998. He was told that the FAA intended to do studies on his theory, but the agency later said it couldn't do the work because Congress had cut the FAA's research budget.King Frey, a retired aeronautical engineer who worked for two aircraft manufacturers, Hughes and Douglas, and for Northrop Grumman, which makes fuselages for 747s, buys the fluid-hammer theory.

"Matt's reasoning and logic is right on target, and he has an excellent probable theory that should be researched," Frey says.

The odds are very small that such a phenomenon will occur, Frey says, "but rare things do happen."
As 737s get older, however, it raises the possibility from an astronomically small number to a number that should be taken seriously, Frey says. The increased possibility of a fluid-hammer effect, he says, needs to be heeded by Boeing and airline mechanics.
Regardless of whether he's right about the Aloha accident, he questions whether a plane can be designed for a safe decompression when a fuselage tears open. That would cause a powerful stream of air to escape from the cabin, he says, which could sweep up persons or objects not belted down, shatter eardrums and cause more serious injuries.
"Safe decompression is a fly-it-'til-it-breaks philosophy," he says. "It's stupid to have a design concept that says a plane is OK until it blows a hole at 24,000 feet."

Boeing defends design against theory

Boeing officials say their design is sound and meets FAA regulations. Further, the company says, it tested the plane for the theory that Austin has. Boeing's Jack McGuire says computer simulations were done in 1965 to test what would happen if a 40-inch hole -- one much larger than the hole that Austin believes popped open on the Aloha plane -- was plugged. The tests showed that cabin pressure is maintained longer, increasing passengers' chances of survival, he says. Richardson says research is needed to study Boeing's safe-decompression design. "I think it's worth determining if this type of scenario should be a design consideration in the future," says Richardson, who is now an airline pilot. "Testing by the FAA/manufacturer is the only way to determine if it can happen in an aircraft, absent funding by some private source. The FAA should spearhead the effort to see if Boeing's fail-safe design is viable."
FAA officials in Washington did not respond to written questions

about safe-decompression design and aging aircraft.
Richardson and some other aviation experts believe the FAA should study the fluid-hammer phenomenon.
"Matt's efforts and goals are commendable," he says. "The industry needs to be constantly reminded of the past so it can be ever vigilant in the future."
That's Austin's credo. "Disasters keep recurring because we don't learn from those that have struck in the past," he says. "History is repeating itself before our eyes." Cover story

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Perry Dulai**

Dear Mr. Campbell, I just had a nice chat with Perry Dulai, who says he is a private investigator who works for Mr. Peck.

I agreed to the discuss the facts of the AI 182 with him regarding the wiring/cargo door explanation for its destruction.

He said he will meet with you tomorrow, he recognized your name.

He may have come to my mechanical explanation independently, which is interesting.

I trust we are singing from the same song sheet.

I replied below to him.

Cheers,
Barry

At 4:38 PM -0800 1/23/01, John Barry Smith wrote:
Dear Mr. Barry, we are currently working to free Mr. Ajaib Singh Bagri and Mr. Ripudaman Singh Malik from the Air India Bombing trial for which they have already been denied bail. We have seen some of your information online and it seems to be very intriguing and amazing. We would like to get into contact with you and possibly even meet you in person and discuss some facts with you. If you could email us at this address and leave a number for us to contact you at that would be very appreciated. I'll also leave a cell phone number of a friend of mine, Perry, and you can get into touch with him if you like. The number is 1-604-833-4550. Thank you very much and we look forward to seeing you in the future.

We would like to get into contact with you and possibly even meet you in person and discuss some facts with you.

Dear Perry, we just talked on the phone.

I look forward to discussing with you the details of AI 182 and the wiring/cargo door explanation for the event.

There's three guys on the planet that know for sure the two accused did not plant a bomb on AI 182, the two accused and me.

Cheers,

Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **Fwd: Wiring/cargo door explanation/judgment**

Date: Wed, 7 Feb 2001 09:37:49 -0800
To: DefenceTeam
From: John Barry Smith <barry@corazon.com>
Subject: Wiring/cargo door explanation/judgment
Cc:
Bcc:
X-Attachments:
Dear 'Defence' Team

"A cruel story runs on wheels, and every hand oils the wheels as they run." - Ouida (Marie Louise de la Ramee), English writer (1839-1908).

Was the 'new evidence' that Col Gaddaffi was to produce but didn't the wiring/cargo door explanation for PA 103?

Regarding the judgment: A 'relatively mild blast' that gives a 'shotgun type discharge' that makes no sound on the CVR and makes a hole '20"' in the side of a Boeing 747 is not a bomb. Understand, not a bomb. It was shotgun type device that made a directed small hole in the side of a plane that is designed to withstand small 20 inch holes. The shotgun type device was fired after the huge explosive decompression in the same cargo hold that made a thirty foot by forty foot hole in the side of the plane, a hole not designed to be withstood.

All of the above is confirmed by the AAIB report if you read it with the point of view of an open cargo door inflight and the consequences of that event.

Let me repeat, no bomb. Bomb makes a powerful blast, makes a loud noise, is spherical, and the damage is considerable. What PA 103 has is a directed, mild blast that made a small hole. A mild bomb is an oxymoron and those that believe PA 103 was a bomb are oxen. Even firecrackers are 'powerful'. A real bombs has gone off in a 747 before and the plane turns around and lands.

Explosive decompression such as a nine foot by ten foot door inadvertently opening inflight tears of skin making a loud noise, and can fire off firearms in baggage nearby, and makes a huge hole which so weakens the structure the 300 knots force tears off the nose.

Which makes more sense? Which is supported by AAIB report and precedent of UAL 811? Which fits the facts? Which is contrary to political emotions? If you, the defence team, are unwilling to pursue a plausible explanation supported with hard evidence that will exonerate your client, then he is truly doomed.

Get off this cruel story conspiracy nonsense and think science. It's a plane crash, not a bank robbery.

It's worthy of an appeal, no bomb, no crime, no criminal. Plausible alternative reasonable mechanical explanation available with precedent, wiring/cargo door explanation for PA 103.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

This indicated

that a relatively mild blast had exited AVE 4041 and impinged at an angle on the forward face of AVN 7511.

As part of the reconstruction process, the recovered pieces of containers were reassembled, principally by Mr Claiden, an engineering inspector with the AAIB. When this was done, it was ascertained that with two exceptions there was no damage to containers other than was to be expected from the disintegration of the aircraft and the containersÕ fall to the ground. It was however found that there was unusual damage to an aluminium container AVE 4041 and a fibre container AVN 7511. From the loading plan of the containers it was ascertained that AVE 4041 was situated immediately inboard of and slightly above the shattered area of the fuselage, and AVN 7511 was situated immediately aft of AVE 4041. The reconstruction of AVE 4041 demonstrated severe damage to the floor panel and outboard base frame member in the outboard aft quadrant, and also on the internal aspect of that part of the container there were some areas of blackening and pitting. There was also damage to the panels and frame members at the lower aft side of the overhang, and again areas of blackening and pitting. The full details of the nature and extent of the damage are to be found in the evidence of Mr Claiden, and are confirmed in the evidence of Dr Hayes and Mr Feraday, forensic scientists with the Royal Armaments Research and Development Establishment (ÒRARDEÓ). The nature of the damage indicated a high-energy event, and the sooting and pitting indicated an explosion. Mr Claiden, whose evidence was given in an

impressively
careful and restrained manner, stated ÒI have no doubts in my mind that such an event
occurred from within the containerÓ, the only occasion on which he stated an
absolutely unqualified opinion. Because of the distribution of the areas of sooting and
pitting, and in particular the absence of any such signs on the base of the container, it
appeared to Mr Claiden that, assuming that an explosive device was contained in a
piece of luggage in the container, the likelihood was that that piece of luggage was not
lying on the floor of the container but was lying probably on top of a case on the floor
and projecting into the overhang of the container. Ascertainment of the precise
location of the explosive device was assisted by consideration of the damage to the
adjacent container AVN 7511. The forward face of that container had a hole
approximately 8" square about 10" up from the top of the base radiating out from
which were areas of sooting extending up to the top of the container. This indicated
that a relatively mild blast had exited AVE 4041 and impinged at an angle on the
forward face of AVN 7511. Combining that information with the damage to AVE
4041, the likely position of an explosive device was about 13" above the floor of AVE
4041. On that assumption allied to the previous assumption that the piece of luggage
containing the device was projecting into the overhang, the position of the device
would be approximately 25" from the skin of the fuselage. We found the evidence of
Mr Claiden wholly credible, reliable and compelling so far as it went. He was not
however an expert on explosives or the effects of explosives. The

conclusion reached
by Dr Hayes and Mr Feraday as to the position of the explosive device coincided with
that of Mr Claiden, and in addition Mr Feraday was present at tests in the USA.
These tests involved the use of luggage filled metal containers and the placing of
plastic explosives within Toshiba radio cassette players in a garment filled suitcase.
The tests confirmed the opinion he expressed as to the position of the explosive
device and the quantity of explosive involved.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **I have referred PA 103 defence team to you**

Dear Mr. Campbell, I have referred the PA 103 defence team to you as they attempt to appeal the judgment against one of their clients. Both teams can help each other if in contact.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

adlaw@planet.nl, rskeenqc@compuserve.com, adlaw@callnetuk.com is email for those below:

Gentlemen Kamal Maghur,
Mr. Alistair Duff,
Mr. Stephen Mitchell,
Mr. Richard Keen,
Murdo Macleod,
Eddie MacKechnie,
McGRIGOR DONALD SOLICITORS,
Alex Prentice,
William Taylor,
John Beckett

Below sent today:

Dear Defence Team,

New evidence is TWA 800 and UAL 811 which match PA 103. TWA 800 and UAL 811 were not caused by bombs although both were initially thought to be. Yes, the comparisons are detailed, it took years of research and analysis to present the observations below.

They match like fingerprints and they are the same probable cause. They are all bombs, or all center tank explosions or all electrical/cargo door events. UAL 811 is the victim that did not die, just badly wounded and came back to tell its tale.

'jeffreytcampbell@home.com' is Mr. Jeffrey Campbell. He faces the same problems you have faced in defending yet another two persons accused of putting a bomb in a plane..which flew and landed, and flew and landed...and flew and came apart in the air.

Completely preposterous hypothesis.

The appeal needs something solid, not whining, and wiring/cargo door explanation gives aircraft accident reports from government agencies, including British, Canadian, and American.

Details at www.corazon.com, check out the facts for yourself if you doubt the validity of my wiring/cargo door explanation for PA 103. At least read the first page, five minutes is not too long to ask for a man about to spend at least 20 years in prison.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

811 to 103 below:
aged
non Section 41 retrofit
high flight time
early model-100
poly x wired
Boeing 747
experienced hull rupture forward of the wing on right side in cargo door area
shape of hull rupture forward of the wing on the right side is rectangle with specific rectangular shape.

fodded number three engine
on fire number three engine.
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
outward peeled skin in cargo door area
longitudinal break at midline of the forward cargo door at midspan latch,
took off in no sun
running late
more severe inflight damage on starboard side
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
torn off skin in forward cargo door area on starboard side,
outward peeled skin on upper forward fuselage,
downward bent floor beams in cargo door area,
destruction initially thought to be have been caused by a bomb.
182 103 800 below:

non Section 41 retrofit
early model
poly x wired
Boeing 747
experienced hull rupture forward of the wing in cargo bay.
nose came off.
damaged number three engine
sudden sound on CVR
loud sound on the CVR
short duration sound on the CVR
abrupt power cut to FDR
outward peeled skin in cargo door area
longitudinal break in forward cargo door,
took off in no sun
running late

more severe inflight damage on starboard side
at least nine never recovered bodies
vertical fuselage tear lines forward of the wing and aft of cargo door
torn off skin in forward cargo door area on starboard side,
outward peeled skin in cargo door area
downward bent floor beams in cargo door area,
destruction initially thought to be have been caused by a bomb.

'jeffreytcampbell@home.com' is Mr. Jeffrey Campbell. He faces the same problems you have faced

Reply-To: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
From: "Jeffrey T. Campbell" <jeffreytcampbell@home.com>
To: <barry@corazon.com>
Subject: air india
Date: Wed, 8 Nov 2000 10:30:43 -0800
Organization: Peck and Company
X-Priority: 3
Mr. Corazon,

I am an associate with Peck and Company, which has been retained to represent Mr. Bagri in the Air India prosecution. I understand that you have authored a study in which you concluded that the cause of the crash of Flight 182 may not have been a bomb.

We would be very interested in taking a look at your study. Could you please advise how we might obtain a copy?

Thank you for your assistance.

Yours truly,

PECK and COMPANY

Jeff Campbell

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Jeffrey_T._Campbell
Subject: **For your common interest**

Dear Members of the Defence Team:

Gentlemen Kamal Maghur,
Mr. Alistair Duff,
Mr. Stephen Mitchell,
Mr. Richard Keen,
Murdo Macleod,
Eddie MacKechnie,
McGRIGOR DONALD,
Alex Prentice,
William Taylor,
John Beckett

The precision of the English language is a wonderful thing to behold.

For instance: "Improvised Explosive Device".

Lots of syllables, three words, rolls off the tongue; is it just those wordy British playing with words? I don't think so.

Is it snooty Scots making fun of American English? I don't think so.

Is it a euphemism? Possibly and if so, for what?

eu¥phe¥mism \"yu-fe-'mi-zem\ n [Gk euphemismos, fr. euphemos auspicious, sounding good, fr. eu- good + pheme speech] : the substitution of a mild or pleasant expression for one offensive or unpleasant; also : the expression substituted ˜ eu ¥phe¥mis¥tic \'yu-fe-"mis-tik\ adj
Is it those aircraft investigators for PA 103 afraid to say the euphemism, "bomb"? I don't think so.

I believe that British citizens, which includes Scotland where the crash took place, and England, where I was born, take pride in their language and write exactly what they mean to say, no more and no less. "Improvised Explosive Device" is exactly that and was exactly cause of the nose coming off PA 103.

What was the meaning in the minds of the actual aircraft investigators who actually looked as the wreckage and determined that it was caused by an "Improvised Explosive Device".

Perception is in the mind of the beholder and it is usually in the self interest of the reader. 'Bomb' is a very satisfying perception for "Improvised Explosive Device" for many to include the manufacturer, the airline, the government oversight, and the media. It absolves most of guilt and makes a lot of money for some. Only to a few accused is the perception against the interest.

Why did the aircraft investigators not say 'bomb'? That's a good question. My answer is that when the total investigation by the aircraft investigators was completed, they evaluated the CVR which did not have a 'bomb' sound on it, the 'relatively mild blast' that occurred on the port side, the directed versus spherical damage in the container, and the small twenty inch hole of the shatter zone, and could not in good conscience call the probable cause a 'bomb.' The total damage did support the conclusion of an inflight breakup of PA 103 which was caused by a catastrophic explosive decompression which must have been caused by an "Improvised Explosive Device" so they said so.

Is there an alternative to 'bomb' for a perception of "Improvised Explosive Device"? Another good question and the answer is yes, many.

Propane gas cannisters, fireworks, blasting caps, dynamite, inflatable rafts, airbags, grenades, and anything else you can think of that would penetrate the pressurized hull and allow an explosive decompression to rupture the hull which would then allow the 300 knots to tear the plane apart are all alternatives to 'bomb' as an "Improvised Explosive Device".

There's one missing device from the list above; a complicated device with bellcranks, torque tubes, hinge, cams, pins, locking sectors, overpressure relief doors, and a locking handle. This device has been documented to have caused a fuselage of an early model Boeing 747 to suffer explosive decompression in flight in the past leading to fatalities: UAL 811 of February 1989, just two months after PA 103. The killer device was not meant to cause an explosive decompression but it did so and was thus inadvertently improvised.

im¥pro¥vise \"im-pre-'vz\ vb -vised; -vis¥ing [F improviser, fr. It improvvisare, fr. improvviso sudden, fr. L improvisus, lit., unforeseen] 1 : to compose, recite, play, or sing on the spur of the moment : extemporize <~ on the piano> 2 : to make, invent, or arrange offhand <~ a sail out of shirts> ˜ im¥pro¥vi¥sa¥tion \im-'pra-ve-"za-shen, 'im-pre-ve-\ n ˜ im¥pro¥vis¥er or im¥pro ¥vi¥sor \'im-pre-"v-zer, "im-pre-'v-\ n

The device which was improvised and caused an explosion was the forward cargo door of UAL 811. My explanation accuses this same device as causing the explosive decompression of PA 103.

Let me show you the damage the door caused at the first depicted moment in the AAIB report when it ruptured/opened in flight:

The damage above shows the first pieces to leave PA 103; it's the top half of a forward cargo door. This type of damage of a longitudinal split in the door matches exactly the damage of the UAL 811 door.

A instant later the damage of PA 103 is enlarged:

At the same time as above, the below was happening on the port side of PA 103, the 'bomb' side:

Note how little damage is done by the 'bomb' and how much damage is done around the forward cargo door at the same instant in time. The small dark blue rectangle on the port side shows the size of the actual shatter zone caused by the 'rather large shotgun' giving a 'relatively mild blast' as the AAIB investigators wrote.

A Boeing 747 is designed and can withstand a hole in the side of the fuselage about 20 inches around. The aircraft is not designed and can not withstand a hole the size of the damage you see on the starboard side of PA 103 just instants after the initial event, about thirty feet by thirty feet around the forward cargo door.

An instant later the damage gets worse again with the shape of the 'squarish' hole matching the smaller 'squarish' cargo door hole in UAL 811.

UAL 811 after landing. (The sudden loud sound on the CVR and abrupt power cut to the FDR of this flight matches the CVR sudden loud sound and abrupt power cut of PA 103 CVR and FDR.)

The point gentlemen, is that a forward cargo door of an early model Boeing 747 can be called an "Improvised Explosive Device" under certain circumstances and evidence. The device has in the past caused a fatal explosion which was not meant to be.

To assume an "Improvised Explosive Device" as the AAIB investigators judiciously and precisely used to describe the probable cause of PA 103 to be a 'bomb' is to assume the perceptions of those who believe it is in their best interest to call it so.

It is not in the best interest of your client, who is now appealing his life sentence in prison, to perceive it so. He may believe, as the rest of the world does, that PA 103 was 'bombed' out of the sky but he did not do it. Is he an aircraft accident investigator? No, he's not but he does read the papers and watch TV which all tell him it was a 'bomb'.

The papers and the TV are wrong, PA 103 was not brought down by a bomb, but by an "Improvised Explosive Device" which most closely matches the inadvertent opening of the forward cargo door of an early model Boeing 747 in flight, an event which has happened before in another fatal accident, UAL 811. The forward cargo door of PA 103 is the "Improvised Explosive Device".

The above is irrefutable because I use actual photographs, documents, and official drawings by the actual investigators to support the wiring/cargo door explanation. I do not use vague and contradictory conspiracy nonsense to explain a plane crash.

Gentlemen, I think you know about conspiracies and crimes such as bank robberies, assaults, rapes, and other violent crimes. But do you know about airplanes? We are talking airplanes here. I know about airplanes. I am a pilot; I have thousands of hours in the air, and most of all, I have survived a sudden night fiery fatal jet airplane crash. I know whereof I speak when it comes to aviation.

And I also know about 'bombs'. They are called many things. As the last human in a chain of humans to detonate nuclear bombs I know about bombs. I was a bombardier navigator on a US Navy carrier jet which carried four one megaton hydrogen bombs. The Navy calls them 'Special Weapons' to which I always reply, "If these ain't special weapons, I don't what is.' Other euphemisms are thermonuclear devices, atom bombs, super bomb, and 'when the balloon goes up', The bombs are actually conventional charges which set off an atomic explosion which detonates the hydrogen bomb.

PA 103 was not a bomb. Bombs are not relatively mild, directed, look like a shotgun type discharge, and make no sound although that is what others would have you believe. Do not suspend your disbelief at such a stretch of logic.

Explosive decompression as caused by an inadvertently opened forward cargo door inflight is massive, makes a loud sound, and can cause the discharge of an improperly loaded firearm in the nearby baggage container.

PA 103 destruction was indeed caused by an "Improvised Explosive Device". The device was not a bomb, nor a shotgun type discharge, but a forward cargo door that ruptured/opened in flight, probably caused by faulty wiring turning on the door unlatch motor, as has happened before.

Please use this information to form the basis of your appeal. It will work because once the evidence of mechanical cause for PA 103 is investigated thoroughly the validity of the wiring/cargo door explanation will become apparent.

A visit to Farnborough to examine the forward cargo door will confirm further the many matches to UAL 811 in pin, hinge, and cam damage. It may be too late for that, unfortunately, but not too late to bring new evidence to the appeal court of a mechanical explanation for the plane crash.

At the very least, contact me via email or phone for discussion. Time is short.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT
To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **UAL 811 report**

To: aniljit singh uppal <aniljitsingh@hotmail.com>
From: John Barry Smith <barry@corazon.com>
Subject: UAL 811 report
Cc:
Bcc:
X-Attachments:
Microsoft Word 6.0 Document MSWordDoc Word.Document.6 C:\WORD6\TEMPLATE\NORMAL.DOT National Transportation

Safety Board National Transportation Safety Board
Washington, D.C. 20594
Brief of Accident
Adopted 06/25/1990
DCA89MA027
FILE NO. 63 02/24/89 HONOLULU, HI AIRCRAFT
REG. NO. N4713U TIME (LOCAL) - 02:09 HST

MAKE/MODEL - BOEING 747-122 AIRCRAFT DAMAGE
- Substantial FATAL SERIOUS MINOR/NONE
ENGINE MAKE/MODEL - P&W JT9D-3A CREW 0
3 16
NUMBER OF ENGINES - 4 PASS 9 2 326
OPERATING CERTIFICATES - Flag carrier/domestic
NAME OF CARRIER - UNITED AIRLINES
TYPE OF FLIGHT OPERATION - Scheduled
- International
- Passenger
REGULATION FLIGHT CONDUCTED UNDER - 14 CFR 121

LAST DEPARTURE POINT - HONOLULU, HI CONDITION
OF LIGHT - Night (dark)
DESTINATION - AUCKLAND, OF
WEATBER INFO SOURCE- Pilot
AIRPORT PROXIMITY - Off airport/airstrip
AIRPORT NAME - Unk/Nr BASIC WEATHER - Visual
(VMC)
RUNWAY IDKNTIFICATION - Unk/Nr LOWEST
CEILING - Unk/Nr
RUNWAY LEHGTH/WIDTH (Feet) - Unk/Nr
VISIBILITY - Unk/Nr
RUNWAY SURFACE - Unk/Nr WIND DIR/SPEED - Unk/
Nr

RUNWAY SURFACE CONDITION - Unk/Nr
TEMPERATURE (F) - 0
PRECIPITATION - Unk/Nr

PILOT-IN-COMMAND AGE - 59 FLIGHT TIME (Hours)
CERTIFICATES/RATINGS TOTAL ALL AIRCRAFT - 28000
Airline transport LAST 90 DAYS - Unk/Nr
Single-engine land, Multi-engine land, Single-engine sea
TOTAL MRKE/MODEL - 1650
Glider TOTAL INSTRUMENT TIME - Unk/Nr
INSTRUMKNT RATINGS
Airplane

FTL #811 WAS A SCHEDULED PASSENGER FLIGHT FROM LOS ANGELES TO SYDNEY, AUSTRALIA, WITH STOPS IN HONOLULU (HNL), HI, AND AUCKLAND, NEW ZEALAND. THE FLT WAS UNEVENTFUL UNTIL AFTER DEPARTURE FROM HNL. WHILE CLIMBING FROM FL220 TO FL230 THE CREW HEARD A "THUMP" FOLLOWED BY AN EXPLOSION. AN EXPLOSIVE DECOMPRESSION WAS EXPERIENCED AND THE #3 AND #4 ENGS WERE SHUTDOWN BECAUSE OF FOD. THE FLT RETURNED TO HNL AND PASSENGERS WERE EVACUATED. INSPECTION REVERLED THE FORWARD LOWER LOBE CARGO DOOR DEPARTED INFLT CAUSING EXTENSIVE DAMAGE TO THE FUSELAGE AND CABIN ADJACENT TO THE DOOR. NINE PASSENGERS WERE EJECTED AND LOST AT SEA. INVESTIGATION CENTERED AROUND DESIGN AND CERTIFICATION OF THE DOOR WHICH ALLOWED IT TO BE IMPROPERLY LATCHED, AND THE OPERATION AND MAINTENANCE TO ASSURE AIRWORTHINESS OF THE DOOR AND LRTCHING MECHANISM. (SEE NTSB/AAR-90/01)

Brief of Accident (Continued)

DCA89MA027
FILE NO. 63 02/24/89 HONOLULU, HI AIRCRAFT REG. NO. N4713U TIME (LOCAL) - 02:09 HST

Occurrence# 1 AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION
Phase of Operation CLIMB - TO CRUISE
Findings
1. - DOOR, CARGO/BAGGAGE - UNLATCHED
2. - DOOR, CARGO/BAGGAGE - SEPARATION
3. - MAINTENANCE, INSPECTION OF AIRCRAFT - IMPROPER - COMPANY MAINTENANCE PBRSONNEL
4. - ACFT/EQUIP, INADEQUATE DESIGN - MANUFACTURER
5. - ACFT/EQUIP, INADEQUATE STANDARD/ REQUIREMENT - FAA(ORGANIZATION)
6. - AIR COND/HEATING/PRESSURIZATION - DECOMPRESSION

The National Transportation Safety Board determines that the Probable Cause(s) of this Accident was: THE SUDDEN OPENING OF THE IMPROPERLY LATCHED FORWARD LOBE CARGO DOOR IN FLIGHT AND THE SUBSEQUENT EXPLOSIVE DECOMPRESSION. CONTRIBUTING TO THE ACCIDENT WAS A DEFICIENCY IN THE DESIGN OF THE CARGO DOOR LOCKING MECHANISMS, WHICH MADE THEM SUSCEPTIBLE TO INSERVICE DAMAGE, AND WHICH ALOWED THE DOOR TO BE UNATCHED, YET TO SHOW A PROPERLY LATCHED AND LOCKED POSITION. ALSO CONTRIBUTING TO THE ACCIDENT WAS THE LACK OF PROPER MAINTENANCE AND INSPECTION OF THE CARGO DOOR BY UNITED AIRLINES, AND A LACK OF TIMELY CORRECTIVE ACTIONS BY BOEING AND THE FAA

FOLLOWING A PREVIOUS DOOR OPENING INCIDENT.
Format Revision 7/95
PB92-910402
NTSB/AAR-92/02
(SUPERSEDES NTSB/AAR-90/01)
NATIONAL
TRANSPORTATION
SAFETY
BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION--
LOSS OF CARGO DOOR IN FLIGHT
UNITED AIRLINES FLIGHT 811
BOEING 747-122, N4713U
HONOLULU, HAWAII
FEBRUARY 24, 1989
U.S. GOVERNMENT PRINTING OFFICE: 1989 0-942-365
NTSB/AAR-92/02 PB92-910402
NATIONAL TRANSPORTATION
SAFETY BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989
Adopted: March 18, 1992 Notation 5059C
Abstract: This report explains the explosive decompression resulting from the loss of a cargo door in flight on United Airlines flight 811, a Boeing 747-122, near Honolulu, Hawaii, on February 24, 1989. The safety issues discussed in the report are the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors,

and emergency response. Recommendations concerning these issues were made to the Federal Aviation Administration, the State of Hawaii, and the U.S. Department of Defense.

CONTENTS

5. APPENDIXES

EXECUTIVE SUMMARY

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.

The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.

A year after the accident, the Safety Board was uncertain that the cargo door would be located and recovered from the Pacific Ocean. The Safety Board decided to proceed with a final report based on the available evidence without the benefit of an actual examination of the door mechanism. The original report was adopted by the Safety Board on April 16, 1990, as NTSB/AAR-90/01.

Subsequently, on July 22, 1990, a search and recovery operation was begun by the U.S. Navy with the cost shared by the Safety Board, the Federal Aviation Administration, Boeing Aircraft Company, and United Airlines. The search and recovery effort was supported by Navy radar data on the separated cargo door, underwater sonar equipment, and a manned submersible vehicle. The effort was successful, and the cargo door was recovered in two pieces from the ocean floor at a depth of 14,200 feet on

September 26 and October 1, 1990.

Before the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.

Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.

The issues in this investigation centered around the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

As a result of this investigation, the Safety Board issued safety recommendations concerning cargo doors and other nonplug doors on pressurized transport category airplanes, cabin safety, and emergency response.

NATIONAL TRANSPORTATION SAFETY BOAR

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989

1. FACTUAL INFORMATION

1.1 History of the Flight

On February 24, 1989, United Airlines (UAL) flight 811, a Boeing 747-122 (B-747), N4713U, was being operated as a regularly scheduled flight from Los Angeles, California (LAX) to Sydney, Australia (SYD), with intermediate stops in Honolulu, Hawaii (HNL) and Auckland, New Zealand (AKL).

The flightcrew assigned to the LAX/HNL route segment reported no difficulty during their flight.

A flightcrew change occurred when flight 811 arrived at HNL. The oncoming captain stated that he and his crew reported to UAL operations 1 hour and 15 minutes prior to the flight's scheduled departure time from HNL. The crew had completed a 34-hour layover (rest period) in HNL.

The captain reviewed the flight plan, the weather, pertinent NOTAMs, and maintenance records, and signed the Instrument Flight Rules (IFR) clearance before boarding the airplane.

Flight 811 departed HNL gate 10 at 0133 Honolulu Standard Time (HST), 3 minutes after the scheduled departure time, with 3 flight crewmembers, 15 cabin crewmembers, and 337 passengers. The flightcrew attributed the short delay to cabin crew problems with arming the 5L cabin door emergency exit slide and the normal securing of the 2L door after a somewhat extended passenger boarding process. The second officer stated that all cabin and cargo door warning lights were out prior to the airplane's departure from the gate. He said that he dimmed the annunciator panel lights at his station while the airplane was departing the gate area.

The captain was at the controls when the flight was cleared for takeoff on HNL runway 8R at 0152:49 HST. The auxiliary power unit (APU), which was used during the takeoff, was shutdown shortly after making the initial power reduction to climb thrust. The flightcrew reported the airplane's operation to be normal during the takeoff and during the initial and intermediate segments of the climb. The flightcrew observed en route thunderstorms both visually and on the airplane's weather radar, so they requested and received clearance for a deviation to the left of course from the HNL Combined Center Radar Approach Control (CERAP). The captain elected to leave the passenger seat belt sign "on."

The flightcrew stated that the first indication of a problem occurred while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed (IAS) of 300 knots. They heard a sound, described as a "thump," which shook the airplane. They said that this sound was followed immediately by a "tremendous explosion." The airplane had experienced an explosive decompression. They said that they donned their respective oxygen masks but found no oxygen available. The airplane cabin altitude horn sounded and the flightcrew believed the passenger oxygen masks had deployed automatically.

The captain immediately initiated an emergency descent, turned 180(to the left to avoid a thunderstorm, and proceeded toward HNL. The first officer informed CERAP that the airplane was in an emergency descent and appeared to have lost power in the No. 3 engine. The appropriate 7700 emergency code was placed in the airplane's radar beacon transponder and an emergency was declared with CERAP at approximately 0220 HST. The No. 3 engine was shut down shortly after commencing the descent because of heavy vibration, no N1 compressor indication, low exhaust gas temperature (EGT), and low engine pressure ratio (EPR).

The second officer then left the cockpit to inspect the cabin area and returned to inform the captain that a large portion of the forward right side of the cabin fuselage was missing. The captain subsequently shut down the No. 4 engine because of high EGT and no N1 compressor indication, accompanied by visible flashes of fire. The flightcrew initiated fuel dumping during the descent to reduce the airplane landing weight.

The airplane was cleared for an approach to HNL runway 8L. The final approach was flown at 190 to 200 knots with the No. 1 and No. 2 engines only. During flap extension, the flightcrew observed an indication of asymmetrical flaps as the flap position approached 5(. The flightcrew decided to extend inboard trailing edge flaps to 10(for the landing. The right outboard leading edge flaps did not extend during the flap lowering sequence. The airplane touched down on the runway, approximately 1,000 feet from the approach end, and came to a stop about 7,000 feet later. The captain applied idle reverse on the Nos. 1 and No. 2 engines and employed moderate to heavy braking to stop the airplane. At 0234 (HST), HNL tower was notified by the flightcrew that the airplane was stopped and an emergency evacuation had commenced on the runway.

After the accident, UAL ramp service personnel, who had been involved with the cargo loading and unloading of flight 811 before takeoff from HNL, stated that they had opened and closed the forward cargo door electrically. They said that they had observed no damage to the cargo door. The ramp service personnel said that they had verified that the forward cargo door was flush with the fuselage of the airplane, that the master door latch handle was stowed, and that the pressure relief doors were flush with the exterior skin of the cargo door.

The dispatch mechanic stated that, in accordance with UAL procedures, he had performed a "circle check" prior to the airplane's departure from the HNL gate. This check included verification that the cargo doors were flush with the fuselage of the airplane, that the master latch lock handles were stowed, and that the pressure relief doors were flush or within 1/2 inch of the cargo door's exterior skin. He said a flashlight was used during this inspection.

The second officer stated that, in accordance with UAL Standard Operating Procedures (SOP) he had performed an operational check of the door warning annunciator lights as part of his portion of the cockpit preparation. The second officer also stated that he used a flashlight while performing an exterior inspection, again in accordance with UAL procedures. The exterior inspection was conducted while ramp service personnel were performing cargo loading operations and the cargo doors were open. He stated that he had observed no abnormalities or damage.

1.2 Injuries to Persons

Injuries Flightcrew Cabincrew Passengers Others Serious *Lost in flight. An extensive air and sea search for the passengers was unsuccessful.

1.3 Damage to the Airplane

The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward.

Examination of all structure around the area of primary damage disclosed no evidence of preexisting cracks or corrosion. All fractures were typical of fresh overstress breaks.

Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos. 3 and 4. No damage was noted on the left side of the airplane, including engines Nos. 1 and 2.

The right wing had sustained impact damage along the leading edge between the No. 3 engine pylon and the No. 17 variable camber leading edge flap. Slight impact damage to the No. 18 leading edge flap was noted.

There was a break and scuff in the wing leading edge aft of engine No. 4 and a scuff in the wing leading edge outboard of engine No. 4. There was a large indentation (to a depth of nearly 8 inches) in the area just above the outboard landing light, and the landing light covers were broken. There was a small puncture in the upper surface of the No. 14 krueger flap and impact damage to the wing leading edge just aft of the No. 14 krueger flap. There was a gash on the upper wing surface aft of the No. 14 krueger flap and leading edge, as well as punctures to the wing leading edge aft of the number 16 krueger flap. The under wing surface aft of the krueger flaps also sustained impact damage.

The right wing also had sustained damage at the wing-to-body fairing and two flap track canoe fairings.1 Wing-to-body fairing damage was limited to surface scraping forward of and below the wing. The outboard surface of the No. 6 flap track canoe fairing revealed a slightly more significant gouge mark. The most severe damage was evident on the inboard surface of the No. 8 flap track canoe fairing, where three separate punctured areas were observed. The trailing edge flaps were not damaged.

The leading edge of the right horizontal stabilizer had several dents. The most severe dents, located 8 to 10 feet from the stabilizer root, were approximately 3 inches wide and 1 inch deep. No punctures were found. The vertical stabilizer had multiple small and elongated indentations with a maximum depth of 1/2 inch near the right base of the leading edge. A small gouge and two small scrapes were noted at midspan of the upper rudder.

A piece of cargo container was found lodged between the No. 3 engine pylon (inboard) and the wing underside. The piece of metal had severed the pneumatic duct for the leading edge flaps. Various nicks and punctures were evident on the inboard side of the No. 3 engine pylon. The No. 4 engine pylon had a small puncture near the leading edge of the wing.

The external surfaces of the No. 3 engine inlet cowl assembly exhibited foreign object damage including small tears, scuffs and a large outwardly directed hole. The entire circumference of all the acoustic (sound attenuator) panels installed on the inlet section of the cowl had been punctured, torn, or dented. None of the No. 3 engine cases were penetrated by objects, nor was there evidence of fire damage to any visible engine components and accessories. The

leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage.

External damage to the No. 4 engine inlet and core cowls was confined to the inboard side of the inlet cowl assembly. The damage consisted of one major scuff mark, four lesser scuff marks and one crescent- shaped cut. The sound attenuator panels that were installed in the inlet area of the inlet cowl assembly had not been penetrated. The No. 4 engine fan blade airfoils had sustained both soft and hard object damage from foreign objects. The cargo door separation resulted in the loss of fuselage shell structure above the cargo door, along with main cabin floor structure below seats 8GH through 12GH (see figure 3). The missing floor area extended inboard from the interior of the right side fuselage wall to the inboard seat track of seats 8GH through 12GH.

The supply and fill lines from the flightcrew oxygen bottle, and the supply line for the passenger oxygen system had been broken below the cabin floor inboard of the missing cargo door.

The two cabin pressurization out-flow valves, located on the underside of the fuselage, aft of the rear cargo compartment, were found fully open. The two over-pressure relief valves located on the forward left side of the airplane were found in the normal closed position. These valves were removed and bench tested. (See section 1.16.3, Pressurization System.) The majority of the cabin floor-to-cargo compartment blowout panels were found activated. The blowout panels are designed to relieve excess pressure differential following an explosive decompression to prevent catastrophic damage to the cabin floor structures.

The estimated damage to the airplane was $14,000,000, based on UAL's costs to repair it.

1.4 Other Damage

No other property damage resulted from this accident.

1.5 Personnel Information

The crew consisted of 3 flight crewmembers (the captain, the first officer, and the second officer) and 15 cabin crewmembers. (See appendix B.)

1.6 Aircraft Information

1.6.1 General

On February 24, 1989, the United Airlines B-747 fleet consisted of 31 airplanes, including: 2 B-747-222B, 11 B-747-SP, 5 B-747-123, and 13 B-747-122 series airplanes. N4713U was equipped with

four Pratt & Whitney model JT9D engines.
The accident airplane, serial No. 19875, registered in the United States as N4713U, was manufactured as a Boeing 747-122 transport category airplane by the Boeing Commercial Airplane Company (Boeing), Seattle, Washington, a Division of the Boeing Company. N4713U, the 89th B-747 built by Boeing, was manufactured in accordance with Federal Aviation Administration (FAA) type certificate No. A20WE, as approved on December 30, 1969. The airplane was certificated in accordance with the provisions of 14 CFR Part 25, effective February 1, 1965. The maximum calculated takeoff weight for flight 811 was 706,000 pounds. The flight plan data showed an actual takeoff weight of 697,900 pounds. The center of gravity (CG) for takeoff was computed at 20.4 percent mean aerodynamic chord (MAC). The forward and aft CG limits were 12 and 29.7 percent MAC, respectively.
At the time of the accident, N4713U had accumulated 58,815 total flight hours and 15,028 flight cycles. N4713U had not been involved in any previous accident. Records indicated that the airplane had been inspected and maintained in accordance with the General Maintenance Program as defined in UAL Operations Specifications and in accordance with the FAA approved Aircraft and Powerplants Reliability Program. The records indicated that all required inspection and maintenance actions had been completed within specified time limits and all applicable airworthiness directives (AD) had been accomplished or were in the process of being accomplished, with the exception of AD 88-12-04, which was applicable to the B-747 lower lobe cargo door, and which had only been complied with partially. (See section 1.6.8 for explanation).

1.6.2 Cargo Door Description and Operation

Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Electrical power for operation of the cargo door switches and actuators is supplied from the ground handling bus, which is powered by either external power or the APU. See figure 17 for a diagram of the cargo door electrical circuitry. The engine generators cannot provide power to the ground handling bus. APU generator electrical power to the ground handling bus is interrupted when an engine generator is brought on line after engine start. The APU generator "field" switch can be reengaged by the flightcrew, if necessary on the ground, to power the ground handling bus. The air/ground safety relay automatically disconnects the APU generator from the ground handling bus, if it is energized, when the airplane becomes airborne and the air/ground relay senses that the airplane is off the ground.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with pull-in hook pins on the sides of the door frame. (See figure 4 for cargo door components).

The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. Figure 5 depicts a lock sector and latch cam in an unlocked and locked condition.

Figure 4.--Boeing 747 lower lobe forward cargo door.

Figure 5.--Cargo door latch cam and lock sector in unlocked and locked ositions.

The door has three electrical actuators for opening/closing and latching of the door. One actuator (main actuator) moves the door from the fully open position to the near closed position, and vice versa. A second actuator (pull-in hook actuator) moves the pull-in hooks closed or open, and the third actuator (latch actuator) rotates the latch cams from the unlatched position to the latched position, and vice versa. The latch actuator has an internal clutch, which slips to limit the torque output of the actuator.

Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull- in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator. The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The B-747 cargo door has eight (8) view ports located beneath the latch cams for direct viewing of the position of the cams by means of alignment stripes. Procedures for using these view ports for verifying the position of the cams were not in place or required by Boeing, the FAA, or UAL (see 1.17.5 for additional information).

Closing the door manually is accomplished through the same sequence of actions without electrical power. The door actuator mechanisms are manually driven to a closed and latched position by the use of a one-half inch socket driver. The door can also be opened manually with the use of the socket driver. There are separate socket drives for the door raising/lowering mechanism, the pull-in hooks, and the latches.

Operating procedures for the normal electrical operation of the forward and aft cargo doors are outlined in the UAL Maintenance Manual (MM). Authorization for deferral of maintenance on the door power system is contained in the UAL B-747 Minimum Equipment List (MEL). In addition, operating procedures for dispatching aircraft with an inoperative door electrical power system (manual operation) are specified in the operator's MEL.

The UAL MM differs from Boeing's recommended MM. UAL had modified Boeing printed material or replaced pages with their own methods and procedures for conducting maintenance functions. The modifications to the manufacturer's MM were accepted by the FAA through "approval" by the FAA Principal Maintenance Inspector (PMI). Electrical cargo door open/close operations in the UAL and Boeing MM's are approximately the same, except the final "Caution" statement differs in methods to ensure that the latch cams are closed:

United Airlines Maintenance Manual

CAUTION DO NOT FORCE HANDLE. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

Boeing Airplane Company Maintenance Manual

CAUTION DO NOT FORCE HANDLE. IF RESISTANCE IS FELT, CHECK LATCH ALIGNMENT STRIPES THROUGH VIEWING PORTS IN DOOR. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

The following step in Boeing's MM does not appear in the UAL MM: "Check that the Cargo Door Warning Light on flight engineer panel goes out." The UAL flightcrew checklist includes a check of the warning light as part of the cockpit procedures for dispatch.

Prior to the issuance of AD-88-12-04 (see 1.6.8), UAL ramp service personnel only operated the cargo doors electrically. Manual operation was accomplished only by maintenance personnel. AD-88-12-04 required the additional procedure of recycling the master latch lock handle following manual operation of the latch actuator.

1.6.3 UAL Boeing 747 Special Procedures--Doors

The Safety Board's investigation revealed that UAL had published a "special maintenance procedure" in the UAL MEL for manual operation of the cargo door. The Maintenance Manual Special Procedures, 5-8-2-52, dated January 1988, were incorporated into UAL's MEL for use by maintenance controllers and work foremen in issuing instructions or procedures to mechanics. The procedure allowed the use of a special 1/2-inch socket drive wrench as the primary tool for use in manually opening or closing the cargo door. The document further authorized, as an alternate tool, an air-driven torque-limiting screwdriver. UAL procedures required approval by San Francisco Line Maintenance and the station maintenance coordinator before an air-driven screwdriver could be used to operate the doors of a B-747 airplane with an inoperative cargo door power system.

At the Safety Board's public hearing, the FAA PMI and the FAA B-747 maintenance inspector for UAL testified that prior to the accident they were unaware of an FAA authorization for UAL's use of an air-driven torque-limiting screwdriver on B-747 cargo doors. However, the FAA's approval for the use of the tool was noted in the MEL section of the airline's maintenance manual. The original approval had occurred before the current inspectors assumed their respective positions. Both testified that they had not reviewed UAL's B-747 MEL because they assumed that the

previous inspectors had reviewed it.
According to UAL, the calibration/adjustment for the torque-limited air-driven screwdrivers was tested every six months. Safety Board investigators found no records for the calibration/adjustment of the power tools used to manually open and close UAL B-747 cargo doors.
The Safety Board received statements from UAL supervisory maintenance personnel at all UAL stations and contract facilities for B-747 operations indicating that air-driven screwdrivers had not been used by maintenance personnel to open or close the forward cargo door on N4713U in the months prior to the accident.
1.6.4 UAL Maintenance Program
Airplanes operated by UAL are maintained under an FAA-approved continuous airworthiness maintenance program, as required by 14 CFR Part 121, Subpart L. The requirements of the UAL maintenance program are detailed in their Operations Specifications, dated November 21, 1988. Generally, UAL has an overall in-house capability to perform virtually all of the maintenance required on its own airframes and powerplants. All of the required major airframe and powerplant maintenance for N4713U had been performed at the UAL maintenance facility in San Francisco, California.
UAL's maintenance and inspection program is scheduled either at specific flight hour or calendar intervals. These maintenance and inspection programs are designated as: Service No. 1, Service No. 2, or A, B, C, MPV, and D Checks.
The work scope of Service Checks consists of a general inspection of the airplane and engines, including servicing of consumable fluids, oxygen, and tire pressures. The Service No. 1 check involves an inspection at each maintenance facility where the airplane lands. The Service No. 2 check is performed at a maintenance facility where the airplane is scheduled for at least

12 hours of ground time. The maximum time interval between Service No. 2 Checks is not to exceed 65 flight hours.

The "A" Check is performed at intervals not to exceed 350 flight hours. This check includes an extended inspection of the cockpit, cabin, cargo compartments, landing gear, tires, and brakes. It does not include a detailed inspection of the cargo doors.

The Phase Check ("B" Check) is scheduled on a calendar basis, not to exceed 131 days. The scope of the "B" Check contains items of inspection such as interior safety equipment and functional verification of various aircraft systems and components. It does not include a detailed inspection of the cargo doors.

The "C" Check is heavy maintenance oriented and is scheduled on a calendar basis, every 13 months. The "C" Check work scope is substantial and includes:

structural inspection items;

corrosion repair;

prevention and inspection of critical flight control systems; and,

a detailed inspection of the cargo doors.

The Mid-Period Visit (MPV) Check is a heavy maintenance inspection that is scheduled at intervals not to exceed 5 years. Items requiring scheduled overhaul are contained in the check as well as inspections of the airplane structure and interior.

The D Check, completes the routine scheduled B-747 maintenance plan and is scheduled at intervals not to exceed 9 years. The work scope is very similar to the MPV Check and consists of heavy maintenance to the airplane structure, landing gear, interior, and airplane systems, including the cargo doors.

1.6.5 Maintenance Records Review

A review of the airplane's history indicated that the forward and aft cargo doors were the original doors and neither had been removed for repair or replaced for cause. There was no record of major repair to either door or adjacent airplane structure.

The forward cargo door's forward mid-span latch pin had been removed because of gouging of the pin surface, during the last "C" check on

November 28, 1988. According to the available maintenance documents, including the most recent "D" check, a full cargo door rigging check had not been accomplished. UAL maintenance personnel indicated that no rigging of the forward or aft cargo doors was required during the following checks:

1. "D" check accomplished April 1984;
2. "C" checks accomplished November 11, 1987, and November 28, 1988; and,
3. "B" checks accomplished March 21, 1988 and July 27, 1988;

The records prior to the "D" check in 1984 and the "C" check accomplished in November 1987 were not required to be retained. This procedure complies with FAR 121.380.

The logbook of N4713U was reviewed and all numbered pages were in sequential order with none missing. The airplane had been released for flight by UAL, HNL Maintenance, in accordance with UAL procedures. The Los Angeles to HNL segment of flight 811, on February 23, 1989, generated four logbook discrepancy entries. All items were cleared by HNL maintenance and none were related to the cargo door. No new deferred items were generated and no current deferred items were corrected. The Maintenance Release document for flight 811 indicated that all deferred items were in accordance with the UAL Minimum Equipment List (MEL) and none referenced the forward cargo door.

UAL stores its maintenance information in an "electronic logbook," entitled Aircraft Maintenance Information System (AMIS). This system tracks on a daily and worldwide basis the flightcrew defect reports, all nonroutine maintenance defects, and maintenance corrective actions for the UAL airplane fleet. The system follows an Airline Transport Association (ATA) chapter format. According to UAL, the AMIS information is used as part of UAL's FAA approved maintenance reliability program affording the capability to assess trends at any given time.

A complete history of N4713U was reviewed for the following ATA Chapters:

Chapter-00-Miscellaneous

No significant items associated with the cargo door systems.

Chapter-21-Air Conditioning and Pressurization

An entry, dated August 19, 1988, indicated "Auto and Standby pressure controllers were erratic." UAL maintenance cleared this item as "Checked per Maintenance Manual Chapter (MM) 21-31-00.

Chapter-31-Instruments (Not related to any specific system)

No significant items associated with the cargo door systems.

Chapter-52-Doors (Cargo door section only)

During the period September 7, 1988, through November 1, 1988, a series of five discrepancies on the forward cargo door's electrical opening and closing system were noted. Ground handling personnel were required to operate the door by the manual system. On November 1, 1988, UAL maintenance corrective action for this discrepancy was signed off as, "replaced power unit [lift mechanism] per Maintenance Manual Chapter 52-34-02.

An expanded AMIS history of the N4713U forward cargo door system was prepared beginning December 1, 1988, and continuing until the date of the accident. The history tracked the airplane by each flight and station transited.

During the period December 5, 1988, through December 23, 1988, eight defect reports regarding the opening and closing of the forward cargo door were entered into the system. The reported defects involved problems with the cargo door not always operating with the normal electrical system. Appendix E contains the details of the writeups and corrective actions.

During the period December 23, 1988, through February 23, 1989, two forward cargo door discrepancies were noted on N4713U. On January 3, 1989, the discrepancy was, "Manual lock seals broken." The corrective action was signed off as, "recycled [door] per placard on door and documented. No door problems." On January 15, 1989, the discrepancy was, "cargo door seal, lower aft corner is torn and loose from retainer." The corrective action was "repaired seal." There were no further recorded discrepancies.

On February 23, 1989, a written discrepancy noted "Aft cargo door damaged aft lower corner." The corrective action listed, "Interim repair per (EVA) LM-8-433. Accomplish permanent repair within 60 flight hours."

Chapter-53-Structures (Fuselage)

During the period March 1988, through February 24, 1989, one defect was noted for each of the forward and aft cargo doors on N4713U.

Forward Cargo Door.--On September 6, 1988, the discrepancy was, "Approximately six inches of forward cargo door jamb damaged center of lower side sealing surface." The corrective action was, "Installed doubler and sealed area."

Aft Cargo Door.--On April 22, 1988, the discrepancy was, "Aft cargo door rear sill latch does not spring up to lock." The corrective action was, "Replaced latch."

1.6.6 Service Difficulty Report Information

A review was made of the Service Difficulty Reports (SDRs) for ATA Chapter 52 for all UAL Boeing 747 airplanes. Thirty-nine SDRs were recorded over the period January 31, 1983, through March 21, 1989. The following summarizes data concerning the forward and aft cargo doors:

cases of corrosion;

cases of cracking;

cases of door open (false) indications;

cases where cabin did not pressurize;
cases of cabin pressure loss; and
case of dent caused by ground equipment.
None of the noted SDR cases were recorded for N4713U.

1.6.7 Service Letters and Service Bulletins

Boeing issues information to its customers via Service Letters (SL's) and Service Bulletins (SB's) to inform operators of reported and anticipated difficulties with various airplane models. Twelve SL's provided guidance for maintenance or information applicable to the B-747 cargo doors. Twenty-nine SB's provided guidance for maintenance or information applicable to the B-747 cargo door.

SB-747-52-2097, "Pressure Relief Door Shroud Installation--Lower Lobe and Side Cargo Doors," was issued on June 27, 1975. Revision 1 to SB-747-52-2097 was issued November 14, 1975. In general, the SB recommended the installation of shrouds on the inboard sides of the cargo door pressure relief door openings. The purpose of the shrouds was to prevent the possibility of the pressure relief doors being rotated (blown) to the closed position during the pressurization cycle. This condition could only occur if the master latch lock handle had been left open and the flightcrew failed to note the cargo door open warning before takeoff.

UAL records for N4713U indicated that SB-747-52-2097 had been complied with and the shrouds had been installed on the forward and aft cargo doors. However, examination of the aft cargo door on N4713U revealed that the shrouds were not in place. UAL could not find records to verify if the shrouds had been installed or if they had been removed from either door.

1.6.8 Airworthiness Directives

There had been 141 Airworthiness Directives (ADs) issued that were applicable to the accident airplane. Two ADs were pertinent to the cargo door. AD 79-17-02-R2 ("Inspection of Fore and Aft

Lower Cargo Door Sill Latch Support Fittings,") required an inspection every 1,700 flight hours. The second, AD 88-12-04 ("To Insure That Inadvertent Opening Of The Lower Cargo Door Will Not Occur In Flight,") issued on May 13, 1988, required an initial one time inspection of the cargo door latch locking mechanisms within 30 days of issuance of the AD, and certain repetitive inspections until terminating action for the AD was taken.

The circumstances of a Pan American World Airways (Pan Am), Boeing 747-122 cargo door opening in flight (see 1.17.1 for details) led to the issuance of Boeing Alert Service Bulletins (ASB) 52A2206 on April 8, 1987, and 52A2209 on August 27, 1987, entitled, "Doors - Cargo Doors Lower Lobe Forward and Aft Cargo Doors, Latch Locking System Tests, Operation and Modification." Tests and investigation revealed that latch lock sectors would, in some instances, not restrain the latch cams from being driven open manually or electrically. Movement of the latch cams without first moving the lock sectors to the stowed [unlocked] position would cause bending, gouging, and breaking of the sectors. The FAA issued AD-88-12-04 to make the provisions of SB's 52A2206 and 52A2209 mandatory.

The terminating action for AD 88-12-04 called for installing steel doublers to add strength to the lock sectors to prevent the latch cams from being able to be driven to the open position manually or electrically with the sectors in the locked position. AD 88-12-04 also required that, if the door could not be operated normally (electrically), a trained and qualified mechanic was to open and close the door manually, rather than ramp service personnel. Further, the AD required an inspection of the lock sectors for damage once a cargo door was restored to electrical operation after any malfunction had required manual operation of the door. The amount of time allowed for completing the terminating action portion of AD 88-12-04 was either 18 months or 24 months, from the issue date of the AD, depending on the Boeing 747 model series. Terminating action for the AD had not been accomplished on N4713U prior to the accident, nor was it required since, for this airplane, the deadline for compliance with the terminating action was January 1990. According to UAL, N4713U was scheduled for completion of the terminating action in April 1989, when the airplane was scheduled for other heavy maintenance.

During the Safety Board's investigation it was determined that a clerical error was made by UAL personnel, while attempting to expedite the processing of an advanced copy of a Notice of Proposed Rulemaking (NPRM 87-NM-148-AD), preceding AD 88-12-04. The error involved the omission of one line of text during the typing of the document. Because of that error, the portion of the text of the NPRM (and the final text of the AD) was left out of UAL's maintenance procedures. The omitted text required an inspection of the B-747 cargo door lock sectors every time a cargo door was restored to normal (electrical) operation after manual operation was required.

The UAL maintenance internal auditing system, including quality assurance personnel, did not detect the omission until after the accident. UAL personnel stated that, for unknown reasons, no one within the maintenance or quality assurance programs had reviewed the final AD language for comparison with the UAL maintenance procedure.

A review by Safety Board investigators of forms used by UAL to verify compliance with applicable FAA AD's issued indicated that all of the applicable mandatory ADs were satisfied within their specified time limits. The list provided by UAL to the FAA as part of the FAA's oversight responsibilities showed compliance with AD-88-12-04, with the exception of the terminating action.

Section 1.17.3 contains information relevant to the B-747 cargo door corrective actions taken since the accident.

1.7 Meteorological Information

The accident occurred in night visual meteorological conditions. No adverse weather was experienced, although the flight did have to deviate around thunderstorms during the descent.

1.8 Aids to Navigation

There were no navigational problems.

1.9 Communications

There were no radio communication difficulties between flight 811 and air traffic control (ATC). Members of the flightcrew did not have any difficulty in verbally communicating with each other; however, attempts to communicate with the cabin crewmembers by interphone were unsuccessful following the explosive decompression.

1.10 Aerodrome Information

After the explosive decompression, the airplane returned to HNL, a 14 CFR Part 139 certificated airport on the island of Oahu, Hawaii. The airport is located about 4 miles west of Honolulu, Hawaii.

HNL is a "joint use" airport that is used by the State of Hawaii, the U.S. Air Force, general aviation, commercial, air carrier, air taxi, and military aircraft. Aircraft Rescue and Fire Fighting (ARFF) services are provided by State and Hickam Air Force Base ARFF units. Prior to the emergency landing at Honolulu, flight 811 requested that all available rescue and medical equipment to be on hand when they landed. When the crash alarm was broadcast, all civilian and military fire units responded and were in position in 1-minute at pre-designated stations at runway 8 left.

The Safety Board's investigation revealed that there was no direct radio communications between the State Airport vehicles and Hickam ARFF vehicles. Because there were no direct radio communications, the Chief of the airport's units had to drive his vehicle to the vehicle of the Chief of the Hickam units to coordinate the positioning of ARFF units prior to the landing of

United 811.
The Hickam vehicles are painted olive drab camouflage. During the response, the Chief of the State ARFF vehicles observed a near collision between a State and a Hickam vehicle. He attributed this to the camouflaged Hickam vehicle not being visually conspicuous in spite of the fact that each of the vehicles had a red rotating beacon operating. The response took place on a moonless night and in light rain.

1.11 Flight Recorders

The airplane was equipped with a Sundstrand model 573 digital type Flight Data Recorder (DFDR) and a Sundstrand model AV557-B Cockpit Voice Recorder (CVR).

Examination of the data plotted from the DFDR indicated that the flight was normal from liftoff to the accident. The recorder operated normally during the period. However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent.

The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.

1.12 Wreckage and Impact Information

An extensive air and surface search of the ocean conducted immediately following the accident failed to locate the portions of the airplane lost during the explosive decompression. However, the Safety Board, as well as other parties to the investigation, pursued several avenues to search for and recover the cargo door. Navy radar near Honolulu tracked debris that fell from the airplane when the cargo door was lost. Refinement of the radar data led to a probable "splashdown" point in the ocean. Further assistance from the Navy regarding the ocean currents and drift information led to a probable location of the cargo door and associated debris on the ocean floor.

The undersea search operation was begun on July 22, 1990, using the Orion, a state-of-the-art Navy side-scanning sonar "fish." Searching in the area selected by analysis of radar data and undersea currents, the Orion located a debris field on its first pass over the 14,200-foot-deep ocean floor. The second pass located a significant sonar target, which later analysis indicated was probably the cargo door. Since the Orion is only capable of searching, the debris field was marked with transponders for use during the subsequent recovery phase.

On September 14, 1990, the recovery ship Laney Chouest sailed from Pearl Harbor with the manned, deep-sea submersible Sea Cliff. Safety Board, FAA, Boeing, and UAL engineering staff assisted the recovery team aboard the Laney Chouest. After four dives in the area previously identified as the debris field, only pieces of cargo container and other small debris from the airplane had been recovered. (It appears that the significant target identified by the Orion was a piece of cargo container rather than the cargo door.) On the following dive, however, the lower portion of the cargo door was located and recovered. The fuselage structure above the cargo door was located and raised to the surface on the sixth dive, but heavy seas prevented its recovery. The upper portion of the door was recovered during the Sea Cliff's seventh dive on October 1, 1990. Afterward, it was decided that no further effort could be justified to recover the fuselage structure above the cargo door, and the recovery mission was terminated.

Following recovery of the cargo door, each piece was sprayed with a corrosion inhibitor. The ship promptly returned to Pearl Harbor, and the retrieved door portions were removed and examined before being shipped to Seattle, Washington, for detailed examinations under the supervision of Safety Board staff. Visual examinations on the recovery ship and in Pearl Harbor confirmed that the cargo door lock sectors were in the locked position and that the latch cams were in the nearly open position. Figure 6 depicts the position of the lock sectors and cams as recovered from the ocean. There was no evidence of progressive fractures in the door structure.

The cost for the search mission was $193,000, and the cost for the recovery mission was $250,000. These costs were shared by the Safety Board, the FAA, UAL, and Boeing. Section 1.16 contains information on the examination of the recovered wreckage.

1.13 Medical and Pathological Information

Appendix D contains a list of injuries.

1.14 Fire

There was no fire in the cabin or fuselage. The fires in engines No. 3 and 4 were extinguished after the engines were shut down.

1.15 Survival Aspects

The fatal injuries were the result of the explosive nature of the decompression, which swept nine of the passengers from the airplane.

At 0210, the FAA notified the U.S. Coast Guard that a United Airlines, Inc., B-747, with a possible bomb on board, had experienced an explosion and was returning to HNL. The Coast Guard Cutter, Cape Corwin, departed Maui at 0248 to search the area for debris and the missing passengers. Ultimately, 4 shore commands, 13 surface/air units, and approximately 1,000 persons took part in the combined search and rescue (SAR) operation. The search was t™ erminated at 1200 on February 26, 1989, without recovery of any passenger bodies.

The flight attendants had approximately 20 minutes to prepare the cabin and the passengers for an imminent ocean ditching, and subsequently, for an emergency evacuation. During the 20 minutes they attended to injured flight attendants and passengers, attached the face masks to their emergency oxygen bottles, helped each other don life preservers, helped numerous passengers don life preservers, held up safety cards and life vests to call attention to these items for passengers to use, briefed "helper" passengers to assist in the evacuation, cleared debris away from the exit doors and aisles, closed the doors of the storage compartment above doors 2 left and 2 right, prepared the cabin for an emergency evacuation, and told the passengers to brace for impact.

Several problems were experienced by the flight attendants and the passengers following the decompression, while preparing for a possible ditching, and preparing for the emergency evacuation. These problems included difficulties encountered by flight attendants in connecting face masks to their portable oxygen bottles, the lack of a sufficient number of megaphones, limited visibility from a flight attendant seat, overhead storage compartment doors opening, and donning and fastening life preservers.

Federal Aviation Regulation 14 CFR 25.1447 (c)(4) requires that "portable oxygen equipment must be immediately available for each cabin attendant." Those portable oxygen bottles on N4713U, which were readily available, were not immediately usable because the masks were not attached to the regulators. The flight attendants reported difficulties in attaching the masks to the regulators.

The aft purser ran back to the flight attendant jumpseat at door 5-left for a portable oxygen bottle. However, she found no bottle at this location (none was installed). She then ran back to the 4-left jumpseat, by which time she was "light headed." After the aft purser reached jumpseat 4-left, flight attendant No. 14, who was already sitting there, placed an oxygen mask on her face. The aft purser further stated, "considering the fact that in this case there was no other available source of oxygen, you can't imagine how horrible I felt going back there needing oxygen but finding no oxygen bottle at 5-left. It was terrifying."

A portable emergency oxygen bottle was not required to be stowed at the flight attendant seat at exit 5-right; however, one was stowed in the right coat closet behind the flight attendant seat. In addition, the left side closet and rest rooms were physically separated from the right side closet and rest rooms. This arrangement requires a flight attendant, who was seated at exit 5-left to walk around to the right side of the cabin to obtain the oxygen bottle.

Communication between the flight attendants and passengers was very difficult because of the high ambient noise level in the cabin after the decompression, even though the public address (PA) system was operational. Flight attendants were located at each of the 10 exit doors, yet there were only two megaphones required to be on the airplane; one located at door 1-left and another located a 4-left.

The flight attendants, who were responsible for each of these two doors, used the megaphones to broadcast commands to passengers in their immediate areas and to other flight attendants in preparation for the landing and subsequent evacuation. The other 13 flight attendants (including the one deadheading flight attendant) had to shout, use hand signals, and show passengers how to prepare for the evacuation by holding up passenger safety cards, so passengers could review the information and also know how to put on their life preservers.

As soon as the decompression occurred, the flight attendant in the upper deck business class section went to her jumpseat and donned her oxygen mask, life preserver, and restraint system. While she waited for instructions, and because of intense cabin noise she had to communicate with passengers by holding up a safety card and a life preserver. Passengers sitting in the front rows, in turn, showed safety cards and life preservers to other passengers seated behind them. Eventually everyone understood that they were to read the safety card and put on their preservers. However, the 5 foot 3 1/2 inch flight attendant stated that her jumpseat was so low that she could not directly observe the passengers in the 4th row (last).

A two door overhead stowage compartment that had formerly stored a life raft was located above each exit door. These compartments contained blankets and passenger carry-on luggage. At doors 2-left and 2-right the doors of each compartment had opened downward and blocked each exit. Also the contents of the compartments fell to the floor at the exits. The doors had to be closed before the evacuation because they partially blocked the exit.

The chief purser was not able to tighten the life preserver's two straps around her waist and needed the deadheading flight attendant to tighten them for her. Several flight attendants and passengers had difficulties connecting the two straps around their waists. One flight attendant helped about 36 passengers don their preservers.

Safety Board investigators and United Airlines personnel examined several life preservers from each of the types of preservers produced by five manufacturers. The strap of one manufacturer's preserver was very difficult to tighten around the waist while another from the same manufacturer was easy to tighten. The two vests had different strap material and strap adjustment fittings. Also, the straps are very difficult, if not impossible, to tighten when they are pulled at an acute angle from the wearer's body, i.e. from about 45 to 70 degrees. Holding the hands and straps closer to the waist facilitates easier adjustment of the straps.

1.16 Tests and Research

1.16.1 Cargo Door Hardware Examinations

1.16.1.1 Before Recovery of the Door

The following forward cargo door closing and latching components were returned to the Safety Board's Materials Laboratory for analysis after they were documented in place on the airplane:

Two pull-in hook pins, one from the lower end of the forward side of the door body cutout forward frame, and one from the lower end of the aft side of the body cutout aft frame, with housings;

Two mid-span pins, one from the forward side of the door body cutout forward frame, and one from the aft side of the door body cutout aft frame.

All components were initially examined while installed on the airplane. All eight forward cargo door latch pins, with housings, were removed for further laboratory examination. Also, for comparison, one of the latch pins, with housing, from the aft cargo door was also removed. For orientation purposes, the eight lower latch pin assemblies are referred to by number, with the No. 1 latch pin being the most forward on the lower door sill, and the No. 8 pin being the most aft. When referencing a circumferential location on the latch pins or mid-span pins, a clock position was used. The clock code was oriented looking forward with 12 o'clock being straight up and 9 o'clock being directly inboard.

Based on the orientation of the latching mechanisms, the fully unlatched latching cams would first contact the latch pins from about the 1:15 o'clock position to the 7:15 position as the door was closed. As the cams are being latched around the pins, they would rotate approximately 80(, making contact with the pins from about the 4:15 position to the 10:15 position (See figure 7). Detailed examination of the exposed surface of the pins (the portion of the pins extending from the housings) revealed various types of wear and damage. In general, all of the forward door cargo latch pins had smooth wear over the entire portion of the pin area contacted by the cams during normal closing and opening of the door. The pins also had distinct roughened (smeared) areas between the 6:15 and the 7:30 positions (See figure 8). The roughened areas had evidence of "heat tinting" and transfer of cam material to the surface of the pins. On pins 1 and 8 the roughened areas extended past the pin bottom to the 5:00 position. The 7:30 position approximately corresponds to the area on the pin where the lower surface of the cam would be relative to the pin when the latch cams are in the unlatched or nearly unlatched position.

The forward pull-in hook pin was not significantly bent, but the structure to which it was attached was deformed outward, so the hook pin was deflected significantly outward. Three of the four bolts holding the aft pull-in hook pin had sheared, so the hook pin was also deflected outward. Both hook pin ends were damaged, but neither pin was significantly deformed along its length. There was significant heat tinting on the damaged area of the forward hook pin. Boeing engineering calculations determined that the pull-in hook pins would fail at a 3.5 psi differential cabin pressure with the latch cams unlatched.

The forward mid-span latch pin was relatively undamaged. The aft mid-span latch pin had definite areas of damage. Both pins had wear areas where the cams would contact the pins during latching.

1.16.1.2 After Recovery of the Door

The documentation of the recovered cargo door was divided into four areas: 1) door structure, 2) master latch lock system, 3) latch system, and 4) hook system. A description of the recovered door follows.

1. Door Structure:

The cargo door had fractured longitudinally near the mid-span lap joint near stringer 34R, just beneath the mid-span torque tubes. Except for an area of missing skin between frames 2 and 3 and a portion of frame webs where the upper latch lock torque tube had torn out, the frames and skin of the upper door piece mated to the lower door piece.2 Several areas of the upper door skin along the longitudinal fracture were bent back. In addition, a large area of lower door skin between frame 6 and the aft door edge had peeled downward from the fracture line. The two door pieces are shown together in Figures 9 and 10. Examinations of the fracture surfaces of the skin and frames revealed no evidence of pre-existing cracks. All fractures were typical of overstress separation.

Seven of the eight lock sector slots in the lower beam showed evidence of contact and scraping by the lock sectors. Only the No. 1 lock sector slot was undamaged, although the bracket forward and above the No. 1 slot did appear to have been damaged by contact from the lock sector (slots numbered 1-8, forward-aft). The direction of the scraping on the slots could not be determined conclusively.

The decal covering the latch actuator manual drive port was found broken circumferentially around the edge of the port cover, which was loose and rotated from its normal position (See figure 11). There was an impression in the decal similar to a Phillips-head screw slot in line with the center of the retainer screw securing the cover. There was also a 0.06-inch-long linear slit from 10 to 4 o'clock approximately centered over the retainer screw head (See figures 12 and 13). There was no rotational tearing and no loss of decal material in the area covering the screw head location. During examinations of the door at Boeing, it was noted that the retainer bracket on the inside of the latch actuator manual drive port cover was bowed outward; the port cover was not deformed. The retainer bracket on the inside of the hook actuator manual drive port cover was similarly bowed outward, and the port cover was bowed outward.

The hinge that attaches the cargo door to the fuselage is comprised of several hinge sections--those attached along the upper edge of the cargo door and those along the fuselage just above the cargo door cutout--interconnected with hinge pins. The hinge pins and all hinge sections from N4713U's forward cargo door were intact; all hinge sections rotated relatively easily. All attach bolts from the hinge sections on the door remained attached; conversely, no bolts remained attached to the hinge sections on the fuselage. Several areas on the hinge sections, such as the fuselage hinge sections, showed evidence of contact from the door during overtravel (See figure 14). In addition, the fuselage forward hinge sections were slightly bent. The upper flange of the door, to which the door hinges are attached, was not deformed. The forward cargo door can rotate open 143 degrees before the hinge would deform, permitting the door to contact the fuselage above.

Examination of the outer skin contour of the upper door piece revealed that it had been crushed inward. There were also many areas on the outer skin where blue and red paint transfer marks could be seen. These marks were generally forward of the aft pressure-relief door, and the blue marks were located above the red marks. The UAL paint pattern incorporates red and blue stripes along the fuselage above the cargo door. Figure 15 is a plot of the documented paint marks on the upper door piece.

There was no evidence of the pressure relief door shrouds found on the forward door; however, most of the inner door lining to which the shrouds attach was missing.

2. Master Latch Lock System:

All eight lock sectors were found in the locked position--actually past the fully locked position. They had been pulled through the lock sector slots in the lower beam of the cargo door. (When they are fully locked, the lock sectors should be recessed in the lower beam approximately 3/8 inch). All lock sectors had deflected off the high shoulder of the latch cams due to interference with the partially unlatched cams. Prior to disassembly of the components, the interference between the cams and the lock sectors was removed by rotating the cams to the latched position.

Examination of the lock sectors disclosed that the bottom of the lower arm of each lock sector was gouged. For seven of the eight lock sectors, the distance from the main gouge area to the location of the interference between the latch cam and the lock sector was approximately 0.75 inch. (The No. 2 lock sector was corroded and had fractured at the location of the large gouge common to the other seven lock sectors. Consequently, it was not in contact with the No. 2 latch cam when the door was retrieved).

The master latch lock handle housing and trigger were found relatively flush with the door outer skin. The top of the handle was recessed approximately 0.50 inch inward from flush, and the bottom of the handle was protruding approximately 0.40 inch outward from flush (See figure 16). This

Figure 15.--Documented paint marks on outer skin of upper door piece. Dashed line is approximately 8 degrees from horizontal.

position of the handle indicates that the lock sectors were in a position past fully locked. The fuse pin was found in three pieces but was heavily corroded. The handle housing was undamaged. Two of the three connecting rods between the master latch lock handle and the lock sector torque tube were bowed slightly, but they were otherwise intact. No deformation was observed on any section of the lock sector torque tube, although one of the six bearings assembled on the torque tube had been damaged. The No. 3 bearing inner race and its torque tube locator sleeve were displaced forward approximately 0.20 inch from the bearing housing centerline. The outer race was broken and pushed forward out of the housing.

The lower two connecting rods between the lock sector torque tube and the torque tube below the pressure-relief doors were undamaged; however, the upper connecting rod had separated at the upper, tapered end. The torque tube below the pressure-relief doors were missing, and the pressure-relief door connecting rods had separated at the lower, tapered end. The remaining portion of each rod was undamaged, but the forward pressure-relief door was jammed open into the cutout.

3. Latch System:

All eight lower latch cams were found in a nearly unlatched position, and all of them were binding against the lock sectors except the No. 2 cam (lock sector No. 2 had broken). Latch cams 1-6 were approximately 62 degrees from the fully latched position, and cams 7 and 8 were approximately 70 degrees from fully latched. Full rotation of the latch cams is 80 degrees.

Several of the lower latch cams contained compression and smearing damage on the lower lip of the latch cam cavity ("lower" relative to an open cam). This damage is consistent with the forceful movement of the cams across the latch pins.

The four rods between the latch actuator torque tube and the four bellcranks containing the latch cams were attached and undamaged. No section of the latch actuator torque tube was damaged, and the bearings/supports along the tube were intact. The latch actuator was removed and later disassembled. No anomalies were found.

4. Pull-in Hook System:

The forward and aft pull-in hooks were found near the closed position. Both of them exhibited wear patterns consistent with contact with the pull-in hook pins during door operation. For both the forward and aft hooks, the inboard edge of the pull-in hook channel contained compression and smearing damage consistent with a forceful movement of the hooks over the pins while the hooks were in the closed or nearly closed position.

1.16.2 Forward Cargo Door Electrical Component Examinations

1.16.2.1 Before Recovery of the Door

Several electrical components associated with the operation of the forward cargo door were examined on the airplane and were then removed for further testing. These components included the No. 2 ground handling power bus relay, the air/ground safety relay, the No. 1 auxiliary power circuit breaker, and the outside and inside door control switches. All of these components were tested for both single faults and intermittent failures. The test results showed that all of the switches/relays were functional, although a loose wire connection was found on the outside door control switch. This loose wire connection showed evidence of overheated insulation on the two terminal lugs that attach to terminal No. 5, and there was evidence of a burn (arc point) on the top of the screw head for terminal No. 5. Terminal No. 5 is associated with power for the door "close" cycle, and not the door "open" cycle.

An electrical continuity check was performed on the cockpit cargo door warning light system components that remained with the airplane. This check confirmed the integrity of the circuit from the door area to the cockpit. The examination of the two bulbs that comprise the forward cargo door warning light revealed that one bulb was inoperative. The other bulb, which is in parallel with the inoperative bulb, was found operative. The illumination of the display legend, which reads "FWD CARGO DR" on the flight engineer's panel, was discernible with one bulb inoperative. A functional check of the circuit, which allows the cockpit warning lights to be dimmed during night operations, was also performed. The check consisted of removing the card containing this circuit and installing it in another B-747. The test was satisfactory in that the dim/bright circuit functioned properly.

1.16.2.2 After Recovery of the Door

Switches--General

The cargo door was recovered with all of its position sensing switches installed in their proper locations. The electrical junction box was found attached to the door but damaged. The switches recovered and examined were: S2 Master Latch Lock; S3 Door Warning; S4 Latch Close; S5 Hook Position; S6 Fwd Mid-Span Latch Open; S7 Door Close; S8 Hook Close; and S9 Aft Mid-Span Latch Open. Figure 17 provides a diagram of the cargo door's electrical circuitry.

Five of the eight position-sensing switches installed on the door had evidence of external damage to the switch housing. The damage on four switches (S2,S3,S4,S8) consisted of primarily compression dimpling on the housing. The S5 switch exhibited mechanical impact damage on the switch housing and mounting bracket. The striker assembly for switch S8 was loose (2 of 3 rivet fasteners sheared). The electrical wiring recovered with the door exhibited signs of tensile separation from overload at all failure points examined.

Each switch was photographed and its installed position was documented. Electrical continuity readings were taken with an ohmmeter across the poles of each switch at the first point of wire separation as found on the door. After the readings were recorded, all switches were removed from the door so that photographs and x-rays of each switch could be taken. Electrical continuity readings were retaken.

Disassembly of each switch consisted of: (1) drilling two holes in the switch housing to release trapped water from the switch (2) cutting a small window in the switch housing to examine the internal basic switches (3) removing the housing, (4) removing the internal bracket, and (5) removing basic switch covers.

During the drilling step, water was released from every switch when the holes were drilled in the switch housing. The water was filtered into a glass container. The quantity was not measured but appeared to be less than 5 mL. The residue from the filtered water trapped on the filter media had a blue-green color.

After the switch housing was removed, an ohmmeter was connected across the 1-2 poles of the switches that would not transfer electrical continuity (S2,S3,S4,S6,S7) when actuated. The rivets were then drilled out of the internal bracket. After the last of the two rivets were drilled out, the switch contacts

Figure 17b.--Diagram of cargo door electrical circuitry.

transferred to the other pole on S2, S3, and S4. On S6, the used3 basic switch was held closed by its plunger. S7 transferred after the switch housing and water inside were removed.

During removal of the basic switch covers, a trend was noted in the discoloration of some of the basic switches. The used switch had a reddish-brown coloration. The unused switch was not discolored.

Each switch was found to be wired correctly to its poles and through its contacts within the basic switches. All contacts operated with light finger pressure after removal of the basic switch covers. There was no evidence of pitting, excessive corrosion, or heat distress in the contacts of any of the switches.

The following sections detail pertinent observations concerning each switch.

The S2 master latch lock is given particular significance because of its function to protect against inadvertent door operation and is thus described in more detail. It is a single-pole double-throw (SPDT) switch used to sense the unlocked position of the door lock sectors. The switch is mounted in the aft lower corner of the door. A bracket attached to the No. 7 lock sector depresses the switch when the door lock sectors are rotated to their unlocked position. When the bracket attached to the lock sector contacts the switch plunger and depresses it, the circuit path through the switch is closed and 28VDC electrical control power to the door is established. When the force on the plunger is relaxed, the circuit is opened and 28VDC electrical control circuit is removed.

The wires leading to the S2 switch had been cut by the team after the recovery in an attempt to test continuity through the switch. The door recovery team reported that it found continuity through the 1-3 contacts but not through the 1-2 contacts. The switch plunger was actuated by the recovery team. The recovery team noted that the switch did not transfer continuity during these tests. The operation of the switch plunger would normally transfer continuity. Subsequent detailed examination of the S2 switch confirmed the findings of the recovery team.

The area around the upper face of the internal bracket was bent toward the basic switches and had evidence of corrosion residue. The bracket was found broken. The switch contacts transferred from the 1-3 actuated position to the 1-2 nonactuated position when the bracket was removed. Scanning electron microscope examination of the fracture surfaces revealed evidence of overload and corrosion.

The external switch housing was dented. The final examination performed on the switch consisted of removing the plastic covers on the basic switches. Prior to removal of the basic switch covers, it was noted that the cover to the used basic switch was cracked. The contacts functioned normally when exercised by light finger pressure.

Microscopic examination revealed a black discoloration near one of the lower contact posts of the used basic switch. Energy dispersive spectrometric examination of the residue disclosed the presence of gold, iron, magnesium, sodium, and chlorine. No mechanical or electrical anomalies were detected with the basic switch contacts.

Additional testing was performed by Boeing on switches of a similar design to those used on the accident airplane's cargo door. The testing was conducted to identify conditions that would result from salt water immersion at a pressure depth of 14,200 feet for 18 months. The testing verified that external damage to the switch housing occurred at pressure depths of 7,000 feet and greater. Switch seal leakage and subsequent internal corrosion was also noted. None of the testing performed by Boeing duplicated internal switch damage that caused basic switch contact closure or internal damage to the switch support bracket.

Wiring:

The electrical wiring recovered with the cargo door was documented in place before being removed for further tests. About 40 percent or 112 feet of wire from the original length of approximately 274 feet was recovered and examined. Of this amount, about 46 feet of wire installed in the aircraft forward of the cargo door was not examined. Most of the wires leading from the door to the fuselage were not recovered. There was no visible external evidence of burning, arcing, or heat distress in any of the wires removed. Several areas of wire insulation damage were found.

Thirty five wires were identified that could provide a possible short circuit path that could drive the latch actuator open with or without failures of other door electrical components if the ground handling bus was energized. The wires were schematically coded by function. Wires coded (-..-..-) were denoted for wiring that provides open command logic to the latch actuator. Wires coded (--.--.--.) were denoted for additional wiring enabled by an activated (failed) S2 switch. Wires coded (-o-o-o-o) were denoted for wiring providing 28VDC power from the C285 circuit.

Potential short circuit paths were identified for the cargo door that could provide 28VDC to the latch actuator control circuit relay. These potential short circuit paths can cause the latch actuator to drive the latches toward their open position if 115VAC power is available to the latch actuator motor. The potential short circuit paths include two bare wires shorting against each other, bare wire-to-metal structure-to-bare wire contact, wire to conductive fluid (such as water) to wire, or a combination of the aforementioned.

Conductive contact of (-o-o-o-o) or (--.--.--) coded wire with (-..-..-) coded wire could potentially result in providing a 28VDC circuit path to the latch actuator open circuit. Direct wire-to-wire paths are coded in Figure 17 as defined above. The two-wire short circuit paths are identified as wire pairs consisting of wire 101-20 shorting with any of the following wires; 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

If the S2 master latch lock switch fails in the "Not Locked" position, there are additional wire pairs that provide short circuit paths. These are coded in Figure 17 as (--.--.--) to (-..-..-..) wire pairs.

Short Circuit Wire Damage Simulation Tests:

Tests were conducted by Boeing and United to simulate typical examples of bare wire short circuiting to determine the extent of visible wire damage that would be expected in the 28VDC cargo door control circuit.

United performed tests on BMS 13-42 wire, the wire type used in the B-747 cargo door control circuit. Visible electrical short circuit damage on bare BMS 13-42 wire surfaces was difficult to create at 28VDC. Surface damage was considered visible when detected by microscopic examination at 15X magnification. United testing simulated the relay coil resistance variations that would be found during typical in-service conditions. A current of 1.0 A at 28VDC created visible surface damage on momentary bare wire-to-bare wire contact. Multiple contacts at 1.0 A provided a more positive indication. A single momentary contact between two bare BMS 13-42 wires with 0.160 A at 28VDC did not create visible surface damage. Contact between a BMS 13-42 bare wire and Alclad 2024-T3 metal (airplane and cargo door structure) with 0.160A at 28VDC did not create visible surface damage. Boeing performed wire tests on BMS 13-48 20 gauge wire. The test setup used the MS27418-2B door latch actuator control relay in parallel with the 60B00311-2 door restraint solenoid, the actual electrical loads used in the B-747 cargo door latch actuator control circuit. A single momentary contact of a bare 28VDC power wire, with a bare wire connecting to the relay of the solenoid, showed small pithead area developed at the point of wire contact that was visible without magnification.

Wire Examination Procedure:

All of the recovered wires were examined in the Safety Board's Materials Laboratory on a mylar sheet to simulate their installed positions. Labels were used to identify the coded wires using the manufacturer's original wire identification numbers imprinted on each wire's insulation. Wire pairs for direct electrical short circuiting were located in two common wire bundles installed on the cargo door. One common wire bundle was associated with the P3 plug connector, the other with the P4 plug junction box. The wire bundles were examined visually for areas of obvious insulation damage. Each individual wire was also examined with a stereo-microscope. Representative wire damage features were photographed.

Wire Damage Found:

Seven wires numbered 101-20, 102-20, 105-20, 107-20, 108-20, 122-20, and 135-20 had visible damage located near a 3.8 inch position as measured from the P3 plug pin tips. This common position on the wire corresponds to a 360-degree loop in the wire bundle, which is located immediately below the junction box. Figures 18 and 19 show typical wire damage. Wire 122-20 had an open insulation area approximately 0.25 inch long. The other four wires had flattened insulation damage areas.

In the P4 plug connector wire bundle, three wires displayed insulation damage. Wires 113-20, 121-20, and 124-20 had transverse insulation nicks, which exposed bare conductors. All three had insulation nicks 3 inches from the P4 plug pin tips; wires 121-20 and 124-20 had additional insulation nicks 34 inches from the plug pin tips. The two P4 insulation damage locations corresponded to wire bundle clamp positions.

1.16.3 Pressurization System

The pressure relief valves located on the left side of the fuselage in the forward cargo compartment were removed from the airplane and subjected to bench tests at the UAL maintenance facility in San Francisco, California. No significant anomalies were discovered and both valves performed within specified tolerances.

1.16.4 General Inspection of Other UAL Airplanes

During the on-scene phase of the investigation, the Safety Board investigators examined six other B-747 airplanes while they were on the ground at HNL (four UAL airplanes and two operated by other carriers) to observe routine cargo door operations and to assess the condition of latching components. Generally, the door operations were normal. During the examination of latch pins on these airplanes, it was noted that most had a smooth wear ridge at the 9:00 position (looking forward) or were undamaged. All wear areas on the pins were smooth.

During electrical operation of the aft cargo door on one of the other UAL B-747 airplanes (N4718U), the pull-in hooks did not pull the door fully closed and the latch cams completed the closure. During operation of the latch cams, the bottom of the door moved, first circumferentially downward and then inboard. This additional movement was approximately 1/4 inch. A definite "thunking" noise was discernible as the door moved to its closed position at the end of cam rotation. On one occasion, the door would not open under electrical power. The door was "kicked" by a UAL mechanic, power was reapplied, and the door opened properly. Examination of the door by UAL mechanics, disclosed that the riveted plate holding the aft pull-in hook switch striker was loose.

All eight lower latch pins for the forward cargo door on N4718U exhibited a smooth ridge near the 9:00 position. Pins No. 1 and 2 also showed a smooth ridge at the 6:30 position with a smooth wear area between the 6:30 and 9:00 position. The forward and aft midspan cams of both forward and aft cargo doors had a heavy gouge mark corresponding to the end of the midspan latch pin. N4718U was subsequently removed from service for repair of the aft cargo door latching mechanisms.

1.17 Additional Information

1.17.1 Previous Cargo Door Incident

On March 10, 1987, a Pan American Airways B-747-122, N740PA, operating as flight 125 from London to New York, experienced an incident involving the forward cargo door. According to Pan Am and Boeing officials who investigated this incident, the flightcrew experienced pressurization problems as the airplane was climbing through about 20,000 feet. The crew began a descent and the pressurization problem ceased about 15,000 feet. The crew began to climb again, but about 20,000 feet, the cabin altitude began to rise rapidly again. The flight returned to London.

When the airplane was examined on the ground, the forward cargo door was found open about 1 1/2 inches along the bottom with the latch cams unlatched and the master latch lock handle closed. The cockpit cargo door warning light was off.

According to the persons who examined the airplane, the cargo door had been closed manually and the manual master latch lock handle was stowed, in turn closing the pressure relief doors and extinguishing the cockpit cargo door warning light. Subsequent investigation on N740PA revealed that the latch lock sectors had been damaged and would not restrain the latch cams from being driven open electrically or manually. It was concluded by Boeing and Pan Am that the ground service person who closed the cargo door apparently had back-driven (opened) the latches manually after the door had been closed and locked. The damage to the sectors, and the absence of other mechanical or electrical failures supported this conclusion.

Further testing of the door components from N740PA and attempts to recreate the events that led to the door opening in flight revealed that the lock sectors, even in their damaged condition, prevented the master latch lock handle from being stowed, until the latch cams had been rotated to within 20 turns (using the manual 1/2 inch socket drive) of being fully closed. A full cycle, from closed to open, is about 95 turns with the manual drive system.

1.17.2 FAA Surveillance of UAL Maintenance

The Denver, Colorado, FAA Flight Standards District Office (FSDO) holds the operating certificate for United Airlines, Inc. The FAA FSDO in San Francisco, California, has the primary surveillance and oversight responsibility for UAL maintenance.

The FAA's PMI has the responsibility to oversee an airline's compliance with Federal Regulations with respect to maintenance, preventive maintenance, and alteration programs. The PMI determines the need for, and then establishes work programs for, surveillance and inspection of the airline to assure adherence to the applicable regulations. A portion of the PMIs position description reads as follows:

Provides guidance to the assigned air carrier in the development of required maintenance manuals and recordkeeping systems. Reviews and determines adequacy of manuals associated with the air carrier's maintenance programs and revisions thereto. Assures that manuals and revisions comply with regulatory requirements, prescribe safe practices, and furnish clear and specific instructions governing maintenance programs. Approves

operations specifications and amendments thereto.
Determines if overhaul and inspection time limitations warrant revision.
Determines if the air carrier's training program meets the requirements of the FARs, is compatible with the maintenance program, is properly organized and effectively conducted, and results in trained and competent personnel.
Directs the inspection and surveillance of the air carrier's continuous airworthiness maintenance program. Monitors all phases of the air carrier's maintenance operation, including the following: maintenance, engineering, quality control, production control, training, and reliability programs.
At the Safety Board's public hearing on this accident, the PMI for United Airlines at the time of the flight 811 accident stated that he was trained as an FAA air carrier inspector and had been assigned to United Airlines since November 25, 1985. In addition to attending the normal FAA indoctrination course, he had received training in accident investigation, compliance enforcement, nondestructive testing, enforcement, and composite materials. To qualify for the position of PMI, he had completed a 3-week management training course at Lawton, Oklahoma. This was supplemented by a 2-week course on management training systems.
According to the PMI, FAA surveillance of UAL B-747 maintenance activities was organized around the daily work schedule of the FAA air safety inspector, specifically assigned to the UAL B-747 fleet by the PMI. The schedule for surveillance is normally prepared a year in advance by the FAA computerized Work Planning Management System (WPMS). Each FAA inspector is assigned specific responsibilities in the surveillance and monitoring of the airplane fleet to which he is assigned.
The PMI stated that assigned inspectors conducted surveillance of the UAL airplanes while they were in light or heavy

maintenance and when they were released to service or in the process of preparing for a flight. Postflight surveillance was also performed. He said, as a routine, the inspectors visually inspected the airplanes and reviewed the airplane log records either during en route checks, while in flight, or upon termination of various flights. He said that inspectors conduct spot ramp inspections; however, they do not routinely observe ramp service operations as part of the surveillance program.

He said that FAA inspectors are not required to inspect the airplanes, but merely are to observe ramp service activities. Deficiencies or malfunctions were to be noted. The assigned inspector or the PMI would then report these observations to the UAL quality assurance liaison person or directly to UAL management.

The PMI stated that the FAA had conducted five special surveillance inspections of UAL in the previous 3 years and 5 months. The last special inspection, an MEL Survey Inspection, was completed in 1988. That inspection primarily addressed how many deferred maintenance items were being carried or deferred on each aircraft during a specified time period.

The PMI stated that his office does not approve the method by which the carrier complies with an AD, unless specified in the AD. However, a scheduled surveillance method was in place to review the carrier's AD compliance process and the ADs applicable to certain fleets. Each assigned inspector had a schedule for performing this oversight in his work program. The PMI or his staff review a monthly report from the carrier listing ADs applicable to a particular fleet and their compliance. The FAA's surveillance of the carrier's AD compliance process involved a review of this list, not actual shop visits to verify compliance.

The inspector assigned to the UAL B-747 fleet stated that approximately 30 percent of his time was spent on actual ramp

maintenance
surveillance. Other activities included: en route inspections, station inspections, meetings, classes and administrative paper work. Spot ramp inspections were scheduled as a normal routine, as well as by mandate in a particular AD.

The PMI stated that foreign contract maintenance bases were inspected once a year at a minimum. The PMI had the prerogative to use geographical surveillance inspectors (inspectors from other FAA offices), or inspectors from his office more familiar with UAL maintenance procedures to conduct inspections or investigations.

The PMI and the B-747 maintenance inspector assigned to UAL testified that, prior to this accident, they were not aware of any problems involving the operation of B-747 cargo doors, including the problems reported with N4713U during December 1988. The PMI testified that he could always use more inspectors to "conduct more in-depth surveillance and monitor UAL's fleet more adequately."

The extensive documentation of maintenance performed on UAL B-747 airplanes was forwarded to the PMI's official library by US mail. The data were ultimately channeled to the B-747 maintenance inspector. The PMI and maintenance inspector testified that the voluminous paperwork and work schedules precluded their monitoring the information to determine trends on problem areas.

1.17.3 Corrective Actions

On March 31, 1989, the FAA issued telegraphic (AD) ADT 89-05-54. This AD superseded AD 88-12-04 and required certain procedures to be accomplished when operating the cargo doors. These included: confidence checks of the door mechanical and electrical systems, inspections of the door locking mechanisms, and repairs if necessary. The AD also accelerated the schedule for terminating action to place steel doublers on the latch lock sectors, and it reinstituted the procedures for using the eight view ports to verify the position of the latch cams, after the door is latched and locked.

The FAA, in conjunction with the Air Transport Association, the manufacturers, and other interested parties, are collectively working to address the human factor issues in the readability and understandability of ADs and SBs by line maintenance personnel. They are also reviewing the entire range of design, maintenance, and operation of outward opening doors to develop advisory information for pertinent parties.

FAA representatives stated at the Safety Board's public hearing that the FAA is increasing their operations and airworthiness inspector staffing by approximately 1,000 new hires in the next 3 fiscal years.

The PMI for UAL at the time of the accident stated at the Safety Board's public hearing that, as a result of the accident, "we have intensified our surveillance on the cargo door activities to the point where the assigned inspectors and inspectors who are not assigned to that particular fleet, 747s, are doing night surveillance, early morning surveillance, and we have intensified our surveillance on the cargo door in watching the operation of the cargo door to comply with the Airworthiness Directive."

On August 23, 1989, the Safety Board issued three safety recommendations (A-89-92 through -94) to the FAA. The recommendations urged the FAA to:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams.

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently.

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions.

Section 4.0 contains the FAA's response to the recommendations and the status of the followup actions.

On October 12, 1989, the FAA issued NPRM 89-NM-148-AD, which proposed the amendment of ADT-89-05-54. The proposed revisions would require modification of the warning systems for the forward and aft cargo door, and the main deck cargo door, if installed. The modifications would provide visual warnings to flightcrew and ground crew when the doors are not fully closed, the latch cams are not rotated to the closed position, or the lock sectors are not in the locked position. Further, the source for the warning signal would monitor the position of the latch cams. Public comments for the NPRM were due by December 27, 1989.

Boeing has completed tests that have verified the integrity of the upgraded latch lock sectors to prove that the latch cams cannot be back-driven through the lock sectors mechanically or electrically. Boeing also has been conducting tests on the B-747 cargo door to evaluate the effects of unrepaired damage and abuse on the latch/lock system. The tests, which determined the allowable damage limits on the latch lock system and mechanism support structures, were completed in March 1990. Additionally, Boeing conducted tests to evaluate any unlatching tendencies under cabin pressure loads. These tests were completed in November 1990 and included the measurement of loads in the latch system as the latch cams are rotated incrementally from the fully latched position to the unlatched position under pressurization loads.

The first series of tests included electrical backdriving of the latch cams into the lock sectors (both steel and steel reinforced were tested) with a modified latch actuator (the maximum output torque of the modified latch actuator was roughly twice that of a normal, torque-limiting latch actuator.) During these tests, the maximum cam rotation was 22.2 degrees against steel reinforced lock sectors and 18.8 degrees against the all-steel lock sectors. During the second set of tests, which measured the effects of internal pressure loads on partially unlatched cams, it was discovered that pressurization did not create any significant loads in the latch mechanism with the door fully closed and the latch cams positioned up to 45 degrees from the fully latched position. Both series of tests show that if the latch cams were somehow electrically backdriven by a latch actuator that had no torque-limiting ability, the steel or steel-reinforced lock sectors would limit the amount of cam rotation such that the partially unlatched cams would still prevent pressure loads from forcing the door open.

1.17.4 Boeing 747 Cargo Door Certification

Title 14 CFR 25.783, Amendment 25-15, effective October 24, 1967, was the original certification basis for Boeing 747 cargo doors. Specifically, Part 25.783(e) and (f) applied to doors for which the initial opening movement is outward (non-plug type doors). Those rules specified that:

(e) There must be a provision for direct visual inspection of the locking mechanism by crewmembers to determine whether external doors, for which the initial opening movement is outward (including passenger, crew, service, and cargo doors), are fully locked. In addition, there must be a visual means to signal to appropriate crewmembers when normally used external doors are closed and fully locked.

(f) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure.

Amendment 25-23, effective May 8, 1970, added the following text to paragraph (f): "...or failure of a single structural element." Amendment 25-23 did not apply to the initial certification basis for the B-747.

Amendment 25-54, effective October 14, 1980, expanded Part 25.783 (e), (f), and (g) to read:

(e) There must be a provision for direct visual inspection of the locking mechanism to determine if external doors, for which the initial opening movement is not inward (including passenger, crew, service and cargo doors), are fully closed and locked. The provision must be discernible under operational lighting conditions by appropriate crewmembers using a flashlight or equivalent lighting source. In addition, there must be a visual warning means to signal the appropriate flight crewmembers if any external door is not fully closed and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed and locked indication is improbable for doors for which the initial opening movement is not inward.

(f) External doors must have provisions to prevent the initiation of pressurization of the airplane to an unsafe level if the door is not fully closed and locked. In addition, it must be shown by safety analysis that inadvertent opening is extremely improbable.

(g) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure or failure of a single structural element.

At the Safety Board's public hearing, the FAA and the Boeing representatives acknowledged that during certification of the Boeing 747 the loss of a lower lobe cargo door was not considered to be an "acceptable event." Therefore, redundant mechanical devices and operational procedures were incorporated to protect against loss of the door in flight. Initial FAA certification approval of the Boeing cargo door design and operation included the installation and use of eight view ports on the door for ground personnel to observe the alignment of paint stripes on the latch cams with arrows on the latch pin support fitting, thereby complying with the requirements of 14 CFR 25.783(e), which require a ". . . provision for direct visual inspection of the door locking mechanism ...," to determine if the door is closed and locked.

In correspondence dated November 24, 1969, and May 15, 1970, Boeing requested that the FAA approve the use of a visual inspection of the pressure relief doors of the cargo doors as an alternate method for determining the locked condition of the door. This design also provided a visual indication to the flightcrew via the cargo door warning light on the flight engineer's warning light annunciator panel. Boeing's request stated that this means of compliance "... provides a simpler check whereby only the pressure relief doors need to be checked ...," by the ground crew, in lieu of actually observing the latch cams and alignment stripes through the eight view ports. Boeing also provided a Failure Analysis to support its request. The conclusion of the Failure Analysis reads: "Any failure, mechanical or electrical, within the latching system which results in open latches will always be indicated by open pressure relief doors." The FAA approved their alternate method on June 8, 1970. Subsequently, the procedures for maintaining the view ports and the alignment stripes in a serviceable condition,

which had been included in the UAL MM were removed. Also, the provision for observing the alignment stripes as part of the door closing procedure were not required for B-747 airline operators.

At the Safety Board's public hearing, a Boeing witness, in answer to a question relative to Boeing's possible consideration of modifications or design changes to the B-747 cargo door indication system to install a position switch directly on the latch cams, stated, "We are looking into the best possible designs that would provide indication on the cams and door closed, both exterior to the aircraft and in the flight deck. We are going to look into that.... However, we want to achieve the required indication in the most reliable method and we have not yet determined what that will be, or any changes (that) are necessary, or would make it more reliable than the way the system operates currently."

1.17.5 Advisory Circular AC 25.783-1

Advisory Circular (AC) 25.783-1 was issued December 10, 1986, on the subject, "Fuselage Doors, Hatches, and Exits." AC 25.783-1 set forth the acceptable means of compliance with the provisions of Part 25 of the FAR's dealing with the certification of fuselage doors. Specifically, it provides for an acceptable method for showing compliance with the provisions of Part 25.783, Amendment 25-54.

Neither the provisions of Part 25.783, Amendment 25-54, nor the guidelines of AC 25.783-1 were part of the certification basis of the Boeing 747.

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.

The airplane was being prepared for flight at the UAL maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.

The aft cargo door was cranked open manually, the C-288 circuit breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident. With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage.

UAL personnel notified the Safety Board of the occurrence, and the airplane was examined at JFK by representatives of the Safety Board, United Airlines, and Boeing. After the wires in the damaged area were electrically isolated, electrical operation of the door was normal when the door was unlocked. When the door was locked (master latch lock handle closed), activation of the door control switches had no effect on the door. This indicated that the S2 master latch lock switch was operating as expected (removing power from the door when it was locked). After the on-site examinations, the wiring bundle was cut from the airplane and taken to the Safety Board's materials laboratory for further examination.

The wiring bundle with the damaged wires contained all electric control wires (28 volt DC) and power wires (115 volt AC) that pass between the fuselage and the aft cargo door. From the forward side of the J-4 junction box, the bundle progresses in the forward direction, just above the forward pressure relief door, then upward, following the forward lift actuator arms. The bundle then enters an empty space between two floor beams, where the bundle has an approximate 180-degree bend when the door is closed. From this location, the wiring bundle progresses inboard, through a fore-to-aft intercostal between two floor beams. The wiring bundle then splits, with wires going in several directions.

The bundle is covered by the flexible conduit approximately from the lower end of the lift actuator arms to the fore-to-aft intercostal between the floor beams.

The conduit covering the wiring bundle is intended to prevent the wire bundle from being damaged during opening and closing of the door and during cargo handling operations. The conduit is a sealed flexible interconnector consisting of a convoluted helical brass innercore covered by a bronze braid. The innercore is soldered at every other convolute, and should be capable of withstanding pressures exceeding 1,000 pounds per square inch (psi). Boeing has indicated that the conduit is an evolutionary improvement and that it has been installed on all B-747 airplanes produced since 1981 (from line number 489 on). Airplane N152UA was delivered in April 1987.

Airplanes produced prior to 1981, including N4713U, used a bungee retraction system, to retract the cargo door wire bundle. Guidelines for the replacement of the bungee sys tem with the flexible conduit were covered in Boeing Service Bulletin 747-752-2170, dated August 1981. The service bulletin was prompted by reports that the wire bundle bungee retraction system had not retracted the wire bundle sufficiently to prevent trapping the bundle between the cargo door and the door frame. UAL did not perform the retrofit on N4713U, which was line number 89, nor was the company required to do so.

Examination of the wires in the damaged area on the wiring bundle revealed that four of the wires were similar in appearance, with insulation breaches that progressed through to the underlying conductor. Adjacent to the breach on these four wires, the insulation was blackened, as if it had been burned. Another wire contained an extensive breach but no evidence of burned insulation. The damaged area was located on the bundle at a position approximately corresponding to a conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism. This support bracket was found bent in the forward direction. In addition, mechanical damage was noted on adjacent components in this area.

A second damaged area was noted on the wiring bundle at a position approximately corresponding to the conduit swivel clamp at the elbow between the two arms of the forward lift actuator mechanism. Wires in this area were missing portions of their exterior coating, but no breaches to the underlying conductors were noted.

The exterior braid on the conduit contained minor rub marks and was slightly kinked at a position corresponding to the area on the wires with breached insulation. Additional examinations revealed that the innercore of the conduit contained multiple circumferential cracks in the areas corresponding to the damage areas on the wires. The cracks were in the convoluted innercore directly adjacent to the inside diameter of the conduit.

The lock sectors, latch cams, and latch pins from the aft cargo door were examined on the incident airplane and were generally in excellent condition. There was no evidence to suggest that the cams had ever been electrically (or manually) driven into or through the lock sectors.

Boeing also informed the Safety Board that, in May of 1991, a B-747 operated by Quantas was found to have chafing of the wires in the wire bundle to the aft cargo door. This airplane also had a flexible conduit protecting the wires, and the chafing was located approximately at the standoff pin on the bracket at the upper arm of the forward lift actuator.

The Safety Board determined that the chafing of the wires on the airplane involved in the JFK occurrence was caused by, or was greatly accelerated by, the circumferential cracks in the conduit and that the cracks in the conduit were caused either by repeated flexing of the conduit as the cargo door opens and shuts or by unusual stresses on the conduit generated concurrently with damage to the conduit guide bracket and attached standoff pin on the upper end of the forward lift actuator upper arm.

A portion of the wire bundle for the forward cargo door on many B-747 airplanes is also covered by a flexible conduit that is very similar to the conduit for the aft cargo door. However, there are substantial differences between the orientation of the flexible conduits for the two doors, and the Safety Board has not become aware of problems associated with the flexible conduit for the forward door.

Nevertheless, because of the concerns about the chafed wires and possible electrical short circuits, on August 28, 1991, the Safety Board recommended that the FAA:

Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between the fuselage and aft cargo door to require an expedited inspection of:

(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test method or visual examination);

(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;
(3) the flexible conduit for the presence of cracking in the convoluted innercore.

Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an appropriate cyclic interval. (Class II, Priority Action) (A-91-83)

Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in A-91-83. (Class II, Priority Action) (A-91-84)

The FAA responded to these safety recommendations on November 1, 1991, stating that it agreed with the intent of the recommendations and that the issuance of an NPRM was being considered to address the issues in the safety recommendations. The Safety Board replied on November 27, 1991, classifying each of the recommendations as "Open--Acceptable Response," pending the completion of the rulemaking process. Since that exchange of correspondence, the FAA has published an NPRM which is now being reviewed by the Safety Board. Safety Recommendations A-91-83 and -84 will continue to be classified as "Open--Acceptable Response" until an acceptable final rule is published.

2. ANALYSIS

2.1 General

This analysis is based on the facts gathered during the initial investigation phase, without the benefit of the evidence from the cargo door, updated to include the findings from the subsequent

examinations of the door after it was recovered.
The flightcrew and flight attendants were trained and qualified in accordance with the applicable Federal regulations and UAL standards and requirements. There were no air traffic control or weather factors related to the cause of this accident.
The airplane had been properly maintained, with the exception of certain requirements pertaining to the cargo doors. Those discrepancies will be discussed in detail in this analysis.
The evidence examined by the Safety Board during its investigation revealed conclusively that this accident was precipitated by the sudden loss of the forward lower lobe cargo door, which led to an explosive decompression. There was no evidence of preexisting metal fatigue or corrosion in the structure surrounding the cargo door. All breaks were the result of overload at the time of the loss of the door. There was no evidence of a bomb or similar device that caused an explosion on the airplane.
The explosive decompression of the cabin when the cargo door separated caused the nine fatalities. The floor structure and seats where the nine fatally injured passengers had been seated were subjected to the destructive forces of the decompression and the passengers were lost through the hole in the fuselage. Their remains were not recovered. Most of the injuries sustained by the survivors were caused by the events associated with the decompression, such as baro-trauma to ears, and cuts and abrasions from the flying debris in the cabin. Other injuries were incurred during the emergency evacuation.
The loss of power to the Nos. 3 and 4 engines was caused by foreign object damage when debris were ejected from the cargo compartment and cabin during the explosive decompression. The debris also caused damage to the right wing leading edge flap pneumatic ducting, and other areas along the right side and empennage of the airplane.

During the approach to HNL, all of the leading edge flaps had extended, except the outboard sections 22 through 26 on the right wing. The reason that they failed to extend probably was the damage to the pneumatic duct caused by the ejected debris. The pneumatic pressure probably was too low to actuate the most outboard flaps to the extended position.

The failure of the flightcrew and passenger oxygen systems was caused by structural deformation and damage to the supply lines in the area adjacent to the cargo door and failed fuselage structure.

The Safety Board's analysis of this accident concentrated on the reasons for the loss of the cargo door and the events that led to its loss in flight. The analysis included an evaluation of the design, certification, and approval processes for the B-747 cargo doors, and the operational, maintenance, and inspection processes for the doors. Also, the analysis included an evaluation of the historical events that had occurred over the past months and years that eventually led to this accident.

2.2 Loss of the Cargo Door

The calculated pressure differential at the time of the loss was about 6.5 psi, which would have exerted a load on a properly closed and locked door that was substantial, but well within design limits.

There was no evidence of a structural problem with the cargo door that could have caused it to fail from metal fatigue or corrosion. Although the cargo door was recovered in two pieces on the floor of the ocean, there was no evidence of a preseparation structural failure of the door. All fractures and damage found on the door were determined to be the result of the sudden opening of the door rather than the cause. The evidence showed that the door was intact when it flew open violently and that its integrity was compromised when it struck the upper fuselage structure and most likely when it struck the water. The fracture in the cargo door occurred just below the midspan latch cams. Paint marks on the outer surface of the door that matched upper fuselage structure paint pattern, damage to the latch pins, pull-in hooks and hook pins, as well as damage to the floor structure near the upper door hinge area were consistent evidence that the door was intact when it flew open.

The evidence was also conclusive that the failure of the door did not result from the failure of the structure surrounding the door. The damage to the cabin floor beam structure, adjacent to the cargo door hinge area, showed that decompression loads in the cabin broke the beams downward when pressure was released from the cargo compartment. The fuselage skin above the door was torn away during the decompression as the door separated violently from the airplane. Unfortunately, the upper skin structure was not recovered from the sea.

There are no reasonable means by which the door could open in flight with the cams properly closed and locked. If the lock sectors were in proper condition, and were properly situated over the closed latch cams, the lock sectors had sufficient strength to prevent the cams from vibrating to the open position during ground operation and flight. Thus, the only ways in which the cargo door could open while in flight involve the placement of the cams in a partially latched or unlatched position. Either the latching mechanisms were forced open electrically through the lock sectors after the door was secured, or the door was not properly latched and locked before departure. Then the door opened when the pressurization loads reached a point at which the latches could not hold.

2.3 Partially Closed Door

Examination of the eight latch pins that had been removed from the lower sill of the forward cargo door revealed smooth wear patterns where the latch cams had normally rotated around the pins. These wear patterns indicate that interference had existed during normal operation between the cams and the pins over an extended period of time. All eight pins also had roughened areas from approximately the 6:15 position to the 7:30 position (clock references are as looking forward, 9:00 being directly inboard). The 7:30 position corresponds closely to the area where the lower surface of the cam first contacts the pin as the door reaches the nearly closed position, before the cams are rotated to the latched position.

The hoop stresses generated by pressurization of the airplane create a bearing load against the cam/pin contacting points. Even if the cams are in the unlatched position, and the airplane is pressurized, this bearing load could act as a frictional latch between the cams and the pins and would tend to keep the door in the closed position.

Transferred cam material and heat tinting of the pin surface was found to extend from the point where the cam-to-pin interface at the near fully open position of the latch cams (7:30 position) to a position corresponding to the bottom of the pin (6:15 position). This evidence was found on the roughened areas on all of the pins. The heat tinting and metal transfer are indicative of the high stress and rapid movement of the cam across the pin when the door separation occurred. Therefore, the location of this evidence indicates the probable location of the cams just before, and at the time of, separation of the door. The Safety Board concludes that these markings and their location on the pins resulted from a very fast, high bearing stress, separation of the cams across the pins, when the cams were in or very close to the unlatched position. Further, examination of the recovered cargo door confirmed that the latch cams were in a nearly unlatched position at the time the separation occurred. The lock sectors were found in the locked position jammed against the cams. Therefore, the cargo door latch cams had been closed, the master latch lock handle had been closed, and the lock sectors had moved to the locked position.

Subsequently, the cams had been back-driven to the near-open position, deforming the lock sectors.

The pull-in hooks and pull-in hook pins would also counteract the pressurization loads in the outward direction, providing that the latch cams were not engaged on the latch pins and carrying the pressurization loads. However, Boeing studies showed that the pull-in hooks would fail at a pressure differential of about 3.5 psi, assuming that the cams are in the unlatched position and that there is no bearing load on the pins. Therefore, based on the probable pressure differential of about 6.5 psi just before the door separated, it is concluded that forces other than the pull-in hooks/pins were holding the door closed. Since the flightcrew and passengers reported no pressurization difficulties until the explosive decompression, it is reasonable to conclude that the door was being held closed by the bearing stresses of the cam-to-pin interfaces as well as by the pull-in hooks.

The Safety Board believes that the approximate 1.5 to 2.0 seconds between the first sound (a thump) and the second very loud noise recorded on the CVR at the time of the door separation was probably the time difference between the initial failure of the latches at the bottom of the door, and the subsequent separation of the door, explosive decompression, and destruction of the cabin floor and fuselage structure. The door did not fail and separate instantaneously; rather, it first opened at the bottom and then flew open violently. As the door separated, it tore away the hinge and surrounding structure as the pressure in the cabin forced the floor beams downward in the area of the door to equalize with the loss of pressure in the cargo compartment.

Three possible theories to explain why the latch cams could have been in a partially latched condition during flight are examined: (1) they were never closed fully before the door was "locked" before takeoff. (2) they were backdriven manually after the door had been fully latched and locked or (3) they were back-driven electrically after the door had been fully latched and locked.

2.4 Incomplete Latching of the Door During Closure

The Safety Board considered the possibility that the master latch lock handle had not been closed before the airplane departed the gate, and the possibility that the shrouds recommended by SB-747-52-2097 for the cargo door pressure relief doors were not installed on the forward door. If this were the case, it is possible that this condition allowed the pressure relief doors to be rotated closed when the airplane pressurized.

The Safety Board believes that these events were very unlikely based on the statements of the ramp personnel, line maintenance personnel, and the flightcrew. The ramp and maintenance personnel would have to have missed seeing the master latch lock handle in the unstowed position and the pressure relief doors open before departure. Also, the flightcrew would have to have missed seeing the cockpit cargo door warning light indication.

The examination of the recovered forward cargo door did not provide confirmation that the pressure relief door shrouds were actually installed on the forward door, although UAL records showed that they had been installed on both cargo doors of N4713U, in accordance with SB-747-52-2097. However, the shrouds were found not to be installed on the aft door, contrary to UAL records, and therefore may not have been installed on the forward door. Without the shrouds, the pressure relief doors could have rotated shut during the pressurization cycle. Because the closure of the pressure relief doors would back-drive the lock sectors, this scenario would presume previous damage to the sectors, which would permit the sectors to move over the unlatched cams.

Before recovery of the cargo door, the Safety Board believed that the lock sectors might have been damaged some time prior to the accident flight to the extent that they could have been moved to the locked position even though the latching cams were not fully closed.

During closure of the door, the latch actuator may not be able to rotate the cams to the fully closed position because of excessive binding forces between the latch cams and pins. This could occur if the cargo door is misaligned (out of rig) or if the pull-in hooks do not pull the door in far enough to properly engage the cams around the pins. There is sufficient evidence of wear on the pins and from the previous discrepancies with the door to indicate that the door was misaligned and not properly rigged.

The smooth wear areas found on the pins from N4713U are signs of heavy contact (interference) between the cams and pins during numerous past closings and openings of the door. This wear, other evidence from the door, and the maintenance history of the door, suggest strongly that the door was out of rig during the weeks and months before the accident.

The wear pattern damage to the pull-in hook pins also showed interference during the normal ground operations prior to the accident. This is further evidence of an out-of-rig door. It is also possible that the excessive binding force acting over a period of time precipitated a failure of the latch actuator. Regardless of the reason(s), the conditions of the latch pins and pull-in hook pins showed prolonged out-of-rig operation.

Most of the previous discrepancies with the forward cargo door on N4713U during December 1988 involved problems with closing the door electrically. These problems always occurred when the airplane was fully or nearly fully loaded, just before departure. The trouble-shooting and corrective actions by UAL maintenance, which on some occasions only involved cycling the door and finding it functional, were performed when the airplane was not fully loaded, during overnight maintenance inspections. The flexing of the fuselage with a full load of fuel, cargo, and passengers could have caused distortion of the door frame and resulted in misalignment between the cams and pins. In this case, the pull-in hooks may not have pulled the door fully in before the cam actuator attempted to latch the door. The wear evidence on the latch pins from N4713U suggests that this event had been occurring before the accident.

Safety Board investigators also witnessed this event during inspection and operation of the aft door on another UAL B-747, N4718U, in HNL. It was noted that the door on N4718U was not being pulled in fully by the pull-in hooks, so the latch cams completed the closing cycle with significant interference and "thunking" sounds. In fact, the out-of-rig door on N4718U failed to operate electrically at one point during its examination.

By design, any attempt to close the master latch lock handle and move undamaged lock sectors into place would not be successful unless the cams were rotated to near the fully latched position. This condition was substantiated by Boeing tests. Even with severely damaged lock sectors, as found on the Pan Am B-747, if the cams were more than 20 turns from the fully closed position on the Pan Am airplane, the master latch lock handle could not be stowed. Examination of the recovered N4713U door indicated that the door lock sectors were generally intact and jammed against the cams that had been back-driven into the lock sectors. Consequently, if the latch cams had been in the nearly unlatched position as found on the recovered door at the time the cargo handler attempted to move the master latch lock handle, the interference between the cams and the lock sectors would have prevented the master latch lock handle from moving to the closed position. Furthermore, this interference would have prevented the closure of the pressure relief doors as the airplane pressurized, irrespective of the possible absence of the pressure relief door shrouds. This conclusion is supported by extensive testing of the latch/lock mechanisms following the recovery of the door.

Therefore, based upon the examination of the lock sectors and the tests that were conducted, the Safety Board concludes that the latches were fully closed and that the locking handle was placed in the stowed position after the cargo was loaded.

2.5 Manual Unlatching of the Door Following Closure

It is possible that the cams could have been manually back-driven (about 95 turns) after the door had been secured; however, the UAL ramp personnel involved with dispatching the flight stated that the door was operated electrically. Furthermore, it seems unlikely that the ramp personnel would have driven the manual latch actuator 95 turns toward the open position after the door was fully latched.

The placard/seal located over the latch actuator manual drive on the recovered door was found with damage that initially suggested it had been previously compromised. If this were the case, it would indicate that someone may have used the manual drive to operate the door latches on an earlier flight or possibly immediately before the accident flight. However, the Safety Board believes that an insertion of a screw driver and rotation of the plate retaining screw would have caused rotational tearing around the circumference of the screw head. There was no such tear. Rather, the damage to the placard/seal was more consistent with that which would occur from impact and underwater pressure forces. Therefore, the evidence strongly suggests that manual operation of the latch actuator by ground service personnel after the door was properly closed is unlikely.

2.6 Electrical Unlatching of the Door Following Closure

2.6.1 Conditions or Malfunctions Required to Support Hypothesis

It was determined in 1987, after the Pan Am incident, that the locking sectors for B-747's, including those installed on N4713U, could be overcome by the force of the latch cam actuator, electrically or mechanically. If the latch cam actuator had been energized for some reason with the originally designed unstrengthened lock sectors installed, the latch actuator motor was capable of driving the latch cams open through properly positioned lock sectors, whether they were damaged or undamaged. Therefore, the locking sectors installed as original equipment for B-747's, and those installed on N4713U, would not perform the locking function as intended by the design. They would not "lock" the latches in place as implied by the name "lock sectors."

The investigation has shown that there are several conditions that must be met before the latch actuator will electrically drive the latch cams to the unlatched position on the B-747 after the door has been properly closed and locked. First, the ground handling power bus must be energized by having external power connected, or the APU must be operating and the APU generator field switch in the cockpit must be set to power the bus via the No. 2 ground handling power relay. Second, the air/ground relay must be in the "airplane on the ground" position. These two conditions are normally present when the airplane is on the ground before engine startup. Third, there must be a signal to the door open position in one of the two door open/close switches. Fourth, the S2 master latch lock switch, which cuts off power to the door actuators when the handle is stowed, must sense "not locked."

Therefore, it would take several independent conditions and some failures to provide for electrical power to be available to drive the door open electrically once it is closed and locked. The number of conditions and combinations depend upon the phase of operation of the airplane.

While the airplane was on the ground, before engine startup, with the master latch lock handle stowed, the external power connected (or with the APU running), and the ground handling bus powered, an "open" signal to the cargo door latch actuator would have occurred if any of the following combinations of conditions had been met: (1) a malfunction of the S2 master latch lock switch and the placement by someone of one of the door control switches to the "open" position; (2) a malfunction of the S2 master latch lock switch and certain short circuits; or (3) a two-wire short circuit path consisting of wire 101-20 shorting with any of the following wires: 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

While the airplane was on the ground, after engine startup, and with the cargo door master latch lock handle stowed and the APU running, an "open" signal to the door latch actuator would have occurred if the following conditions had been met: (1) an energized ground handling bus resulting from the flightcrew reenergizing the APU generator field or failure of the No. 2 ground handling power relay; (2) a malfunction of the S2 master latch lock switch; (3) a malfunction of either of the door open/close switches or the placement of the switch in the "open" position by someone. An "open" signal would have also occurred had certain wire short circuits been present with condition (1) alone, or with conditions (1) and (2).

Regardless of the cause, electrical power to the latch actuator would have had to persist for the time necessary to rotate the cams to the nearly open position. If the electrical power had been applied for a longer time, the latch cams could have opened fully and caused the pull-in hooks to rotate open, a situation that would have prevented the airplane from pressurizing after takeoff. However, it is also possible that the latch actuator stalled before they opened fully because of the forces of the interference between the lock sectors and the cams as they were back-driven.

After takeoff, electrical operation of the door latch actuator would have required: (1) the APU to be running; (2) malfunction of the air/ground relay, (3) malfunction of the No. 2 ground handling power relay; and (4) malfunction of the S2 master latch lock switch and one of the cargo door open/close switches or a short circuit of the aforementioned wire pairs. Although the flightcrew could conceivably energize the ground handling bus from the APU by actuating the APU generator "field" switch, there was no evidence that they did so.

Thus, regardless of the phase of operation, either a wiring short circuit or a failure of the S2 master latch lock switch combined with some other anomaly or action would be required to cause the latches to move toward the open position. Before the recovery of the door, the Safety Board was able to examine two of the electrical relays and the door open/close switches from N4713U that would have to have failed to allow electrical operation of the cargo door in flight, with the APU running. These were the No. 2 ground handling power relay, the air/ground relay, and the internal and external door open/close switches. The examination of the relays and switches revealed no evidence of a single fault or conditions that might have caused an intermittent failure mode. The arcing noted on the No. 5 terminal of the outside door control switch was on the door "close" circuit and could not have been related to a short to the open mode. Further, because the flightcrew did not note a cargo door warning light, and the fact that the airplane was able to be pressurized, confirms that the master latch lock handle was in the closed position before takeoff. This position would actuate the master latch lock switch to disconnect power to the door opening actuators.

According to the flightcrew testimony and the pilots' comments recorded on the CVR during the flight, the APU was shut down shortly after takeoff and remained in that condition. Engine generators cannot power the ground handling bus from which the cargo door actuating mechanisms are powered. Once the APU was shut down, there was no power available to any of the cargo door electrical components. Therefore, an electrical actuation of the latch cam actuator at the time of the door loss was not possible.

The Safety Board believes that there is another reason why the opening of the door could not have been caused by electrical actuation shortly before the explosive decompression. Because the door carries the structural loads (hoop stresses) through its hinge and latches, the latch cams would be heavily loaded against the latch pins when the airplane was pressurized to the 6.5 psi differential pressure that was calculated to have been present at the time of the decompression. In that case, the torque limiter within the actuator would probably slip well before the actuator could achieve the torque necessary to drive the cams open against the frictional lock produced by the high bearing stresses resulting from pressurization.

2.6.2 Electrical Switches and Wiring Examinations--Recovered Door

All cargo door position sensing switches (S2 through S9) were found installed in their proper position. The cargo door recovery team found the S2 master latch lock switch in the "not-locked" position immediately after the door was aboard the recovery ship. This position would be consistent with the master latch lock handle being open. Further tests of the S2 switch revealed damage that probably resulted from the pressures under the sea. The only notable exception was a broken internal bracket that may have affected the operation of the switch prior to the accident. Other similar switches did not exhibit this failure. It is therefore possible that the S2 master latch lock switch failed prior to the accident, allowing more possibilities for electrical short circuits to power the latch actuator. Nevertheless, despite extensive testing, it could not be determined whether the S2 switch was functional before the accident.

The examination of 35 wires that remained with the recovered cargo door revealed several areas of damaged insulation that could have permitted an electrical short circuit to power the latch actuator. However, no evidence was noted of arcing that was indicative of short circuits. Furthermore, a significant number of the wires that had the potential for allowing for short circuits to power the latch actuator were not recovered. Testing conducted by Boeing and by UAL was inconclusive regarding whether a short circuit would have left detectable evidence of arcing. Therefore, the Safety Board was unable to determine whether the latch actuator was inadvertently powered by a short circuit in the cargo door wires.

The incident involving a UAL Boeing 747 at JFK Airport on June 13, 1991, confirmed that electrical short circuits in the cargo door wiring could cause the door to open. In this case, the short circuits were in the fuselage-to-cargo door wiring bundle where the bundle was covered by a flexible conduit. Although N4713U did not have a flexible conduit installed at the forward door position, its wiring was routed over the top of the door hinge where exposure to damage could occur. That portion of the wiring from N4713U was not recovered from the sea. The wires located at the door hinge area are more susceptible to in-service damage from movement during the open/close cycle, as compared with the wires mounted on the door that are normally static.

Following the incident at JFK, UAL directed that the circuit breaker that terminates power to the cargo doors be pulled after the door is closed and before departure of every B-747 flight. UAL obtained approval for this practice from the FAA and requested Boeing and the FAA to make such a practice part of the approved manual for the airplane. Neither Boeing nor the FAA acted on UAL's request.

Nevertheless, the Safety Board believes that the FAA should initiate rulemaking to include design considerations for nonplug transport category aircraft cargo doors that would deactivate the electrical circuitry to the door actuators after the doors are closed and locked. The catastrophic nature of the loss of a cargo door dictates the need to provide additional redundancies and fail-safe features in the door mechanisms to supplement the hardware safety features.

2.6.3 Possibility of Electrical Malfunction

Due to the lack of physical evidence, the Safety Board was unable to conclude that an electrical short caused the cargo door actuator to move the latch cams to the nearly open position, allowing the door to separate when the cabin pressure exceeded the load-carrying capability of the door latches. Neither could this possibility be eliminated. A momentary actuation of the door open switch by someone on the ground in the presence of a faulty S2 switch could also have caused the latches to open through the closed lock sectors. However, no evidence has been found that someone actuated the switch after the door was initially closed and locked.

The Safety Board concludes that it was not possible for the cargo door to have opened electrically at the time of the loss of the door. There was no power to the ground handling bus to power the actuator, even if there had been an electrical short. Further, the Safety Board concludes that it is highly improbable that an electrical short could have caused the latches to open after the airplane was airborne. Although the ground handling bus could conceivably have been powered, failures of other components that were tested as functional would also have been necessary.

The Safety Board believes that the electrical operation of the latch actuators from the fully closed and locked position most likely occurred before the engines were started when the ground handling bus was powered. The precise source of the electrical actuation could not be determined. Once the engines were started, the possibility of an electrical short decreases significantly because the ground handling bus is disengaged from the APU when the engines start. There was no evidence that the flightcrew reengaged the ground handling bus.

Because the preaccident condition of the S2 master latch lock switch could not be determined, it could also not be determined whether its proper functioning would have prevented the accident. The Safety Board did not determine whether damaged cargo door wires or a malfunctioning S2 switch could have been found by UAL maintenance had they been more aggressive in troubleshooting the cargo door problem in the weeks prior to the accident.

2.7 Design, Certification, and Continuing Airworthiness Issues

The Safety Board's analysis of this accident went beyond the conclusions about how the door failed. The Safety Board also examined the initial design and certification of the B-747 cargo door, and the continuing airworthiness system that should have prevented this accident, to identify the breakdowns in this system that led to the accident. As is the case with most aviation accidents, there are many factors that led up to the actual failure of the door on flight 811.

The Safety Board found that there were multiple opportunities during the design, certification, operation, and maintenance of the forward cargo door for N4713U for persons to have taken actions that could have precluded the accident involving flight 811. The circumstances that led to this accident exemplify the need for human factors considerations in the promulgation of regulations, the application of regulatory policies, the design of airplane systems, and the quality of airline operational and maintenance practices.

The first opportunity to prevent this accident occurred during the design and certification of the B-747 cargo door mechanical systems, when the design was chosen and approved, which allowed for the overriding of the lock sectors by either mechanical or electrical actuation. It is apparent that the original design was not tested sufficiently to verify that the locking sectors in fact "locked" the latch cams in the closed position. This shortcoming should have become apparent during the initial certification testing and approval process. Later, it should have become apparent when Boeing applied for, and the FAA granted, an alternative method of compliance with the certification regulations (25.783 [e]) that permitted the elimination of operational practices that included a visual verification of the cargo door latch positions via view ports in the doors.

The failure mode analysis performed by Boeing, and the FAA's acceptance of its content in granting the exemption, probably were based on the assumption that the lock sectors would always prevent the master latch lock handle from being in a stowed position when the latch cams were not fully closed. This assumption was not valid, as evidenced by the findings in 1987 following the Pan Am incident that the lock sectors could not prevent the latch cams from being driven from the fully latched position with the master latch lock handle stowed, while a false indication was provided to the flightcrew that the cargo door was properly latched and locked. At the time that Boeing sought approval of the alternative compliance, Boeing and the FAA should have reviewed the design and required testing of the door latch/lock mechanisms to verify their integrity. Thus, the procedure for direct viewing of the latches via the view ports before the airplane could be dispatched should not have been eliminated without adequate verification that the lock sectors were totally effective.

The next opportunity for the FAA and Boeing to have reexamined the original assumptions and conclusions about the B-747 cargo door design and certification was after the findings of the Turkish Airline DC-10 accident in 1974 near Paris, France. The concerns for the DC-10 cargo door latch/lock mechanisms and the human and mechanical failures, singularly and in combination, that led to that accident, should have prompted a review of the B-747 cargo door's continuing airworthiness. In the Turkish Airlines case, a single failure by a ramp service agent, who closed the door, in combination with a poorly designed latch/lock system, led to a catastrophic accident. The revisions to the DC-10 cargo door mechanisms mandated after that accident apparently were not examined and carried over to the design of the B-747 cargo doors.

Specifically, the mechanical retrofit of more positive locking mechanisms on the DC-10 cargo door to preclude an erroneous locked indication to the flightcrew, and the incorporation of redundant sensors to show the position of the latches/locks, were not required to be retrofitted at that time for the B-747. Of similar concern is the fact that the cargo doors for the L-1011 required redundant latch/lock indication sensors at initial certification, during the approximate same time frame the DC-10 and B-747 were certificated.

More recently, when Boeing and the FAA learned about the circumstances of the Pan Am cargo door opening incident in March 1987, more timely and positive corrective actions should have been taken. The Safety Board believes that the findings of that incident investigation should have called into question the assumptions and conclusions about the original design and certification of the B-747 cargo door, especially the alternative method for verifying that the door was latched and locked that was sought by Boeing and was granted by the FAA. Since a B-747 cargo door opening in flight was considered to be an "unacceptable event", once a door did come open in flight, the FAA and Boeing should have acted much quicker to prevent another failure.

It took nearly 16 months from the date of the Pan Am Incident

(March 10, 1987) until the FAA issued AD-88-12-04 (July 1, 1988). And then, the AD allowed 18 or 24 months, depending on the model B-747, from the date of its issuance for compliance with the terminating actions of the AD. The fact that Boeing had issued an Alert SB as a result of the Pan Am incident is an indication of the apparent urgency with which Boeing treated this issue. Alert SB's are issued for "safety of flight" reasons, while regular SB's deal with "reliability" and not necessarily safety of flight items. Despite this, the terminating action, issued as revision 3 to the Alert SB, on August 27, 1987, was not mandated by the FAA for 11 months.

The Safety Board found no evidence that the FAA or Boeing reassessed the original design and certification conclusions regarding the safety of the B-747 cargo door during this period. Several opportunities for preventive action were also missed by UAL during this period. First, UAL delayed the completion of the terminating actions of Alert SB 52A2206 (Rev 3 and AD-88-12-04. In fact, there was no evidence that UAL had intended to comply with the terminating action of the Alert SB, until it was mandated by the FAA.

It is understandable that an airline would not take its aircraft out of service to incorporate revisions that do not appear to be safety critical. Although by definition an Alert SB is safety related, there was no implication from Boeing's and FAA's actions regarding this matter that urgency was required. The airlines rely on the airframe manufacturers and the FAA to evaluate the need for urgent airworthiness actions that might take airplanes out of revenue service. In this case, UAL had scheduled completion of its B-747 fleet modifications in accordance with the terminating actions for AD-88-12-04 before the final allowable date; however, the schedule was based on other heavy maintenance schedules to prevent unnecessary down-time of its airplanes.

UAL personnel stated after the UAL 811 accident that its personnel did not fully appreciate the importance, or safety implications, of the terminating actions, or they would have incorporated the improvements much earlier. The usual difficulties in setting short suspense dates for performing terminating actions in AD's, such as parts availability, did not seem to exist in this case, because the parts were not complex components and probably could have been fabricated fairly quickly in-house by most airlines.

Human performance certainly contributed to UAL's failure to incorporate an important inspection step into its maintenance program as mandated by AD-88-12-04. When UAL obtained an advance draft copy of the forthcoming NPRM that eventually led to the AD, the airline began preparing its work orders to implement the forthcoming the AD requirements into its B-747 fleet (30 airplanes at the time). UAL developed its maintenance work sheets from the text of the draft NPRM, which was virtually identical to the text of the final rule. As a result of a clerical error, one of the important inspection steps required by the AD was omitted.

Apparently, UAL maintenance personnel never compared the work sheets they received with the actual requirements of the AD, or if they did, the omission was not detected. FAA inspectors responsible for oversight of UAL's maintenance program also did not detect this error because normal surveillance of AD compliance merely involved verifying the correctness of UAL's paperwork that listed the applicable AD's and compliance dates. The inspectors did not actually verify UAL's compliance action by shop visits, or by comparison of work sheets with AD provisions. These omissions by the UAL maintenance and quality assurance personnel, and the limitations of the FAA surveillance procedures were probably significant in setting the stage for the events that led to the actual cause of the door separation from N4713U.

Another matter of concern is the quality of UAL's trend analysis program. There was no indication that the repeated discrepancies with the forward cargo door on N4713U "raised a flag" within the UAL maintenance department. A quality assurance or trend analysis program should have detected an adverse trend and should have prompted efforts to resolve the repeated problems. If it had, any faults in the door electrical system or damage to mechanical components might have been detected.

In summary, the Safety Board concludes that there were several opportunities wherein Boeing, the FAA, and UAL could have taken action during the initial design and certification of the B-747 cargo door, as well as during the operation and maintenance of the cargo door installed on N4713U, to ensure the continuing airworthiness of the cargo door. The Safety Board further concludes that these deficiencies and oversights contributed to the cause of this accident.

2.8 Survival Aspects

The Hickam ARFF units and the airport's ARFF units operated on separate radio networks and thus they could not communicate directly on-scene by radio. This situation required them to communicate by voice. Although the two ARFF services had a common radio frequency (as per the Airport Emergency Plan), procedures for its use had not yet been developed. The Safety Board believes that such communication procedures should be expeditiously developed.

The use of camouflage paint schemes on military ARFF vehicles may be appropriate for military purposes; however, the Safety Board believes that camouflage is not appropriate for ARFF vehicles that are operated at a joint- use airport. It is obvious that these vehicles must be conspicuous to be seen by other responding vehicles and by persons who are involved in the accident, such as airport and airline personnel, crew and passengers, and off-airport firefighting and rescue vehicles.

The National Fire Protection Association Standards recommend for primary firefighting, rapid intervention and combined agent vehicles, that, "Paint finish shall be selected for maximum visibility and shall be resistant to damage from firefighting agents."4 Furthermore, Federal Aviation Regulation 14 CFR 139.319 (f) (2) requires emergency vehicles, "Be painted or marked in colors to enhance contrast with the background environment and optimize daytime and nighttime visibility and identification." Further guidance for the high visibility color of ARFF vehicles is provided in a Federal Aviation Administration Advisory Circular where the vehicle paint color is specified as, "lime yellow" Dupont No. 7744 UH or its equivalent.5

Because flight attendants are vital to the safety and survival of the passengers following a decompression, measures should be taken to prevent flight attendants from being incapacitated by hypoxia. The Safety Board believes that oxygen masks should be attached to the emergency oxygen bottles to avoid any delay in their use in order to be in compliance with the intent of 14 CFR 25.1447 (c)(4). Therefore, the FAA should direct its inspector staff to survey B-747 airplanes for compliance with 14 CFR 25.1447(c)(4), and correct deficiencies found.

In this accident, the use of megaphones was vital because of the inability to be heard over the public address (PA) system. Title 14CFR 121.309 (f)(1) requires one megaphone on each airplane with a seating capacity of more that 60 and less that 100 passengers; 14 CFR 121.309 (f)(2) requires two megaphones in the cabins on each airplane with a seating capacity of more than 99 passengers. As this decompression demonstrated, additional megaphones are necessary on wide-body and large narrow-body airplanes to ensure communication in the cabin during emergencies when the PA system is inoperative.

Had there been a need for an immediate evacuation, or a water ditching, rapid egress would not have been possible at doors 2-

left and 2-right because they were blocked by open storage compartments and spilled contents. The possibility also exists that a compartment door could release during a hard landing or turbulence and swing down and injure a flight attendant. Thus, the Safety Board believes that improved latches should be installed and the downward movement of stowage compartments doors should be restricted to prevent the doors from striking a seated flight attendant or block the exit door.

The Safety Board believes that the problems with life preserver donning and adjustment demonstrated in this accident should be addressed by the FAA. The straps and fittings on life preservers need to be evaluated to determine where improvements can be made, and clearer donning instructions should be developed.

TSO-C13d, Life Preservers 1/3/83 prescribes the minimum performance standards for life preservers. With regard to donning, the TSO requires:

Donning. It must be demonstrated that an adult, after receiving only the customary preflight briefing on the use of life preservers, can don the life preserver within 15 seconds unassisted while seated. It must be demonstrated that an adult can install the life preserver on another adult, a child, or an infant within 30 seconds unassisted. The donning demonstration is begun with the unpackaged life preserver in hand.

Based on flight attendant interviews and information obtained from passengers these donning times were exceeded in many instances.

The Safety Board has made numerous recommendations to the FAA in the past regarding needed improvements in life preserver donning instructions, donning procedures, and timing of donning.6 The FAA has adopted most of the Safety Board's recommendations in its April 23, 1986, revision to TSO-C13e, Life Preservers, which now requires the wearer to be able to secure the preserver with no more than one attachment and make no more than one adjustment for fit. Also, donning tests are required for age groups of users starting with 20-29 years and ending with 60-69 years. At least 60% of the test subjects in each age group must be able to don then life preserver within 25 seconds unassisted with their seatbelts fastened starting with the life preserver in its storage package. TSO-C13e contains requirements that would have eliminated some of the problems that passengers had in this accident in correctly donning and adjusting their life preservers.

The Safety Board has recommended (A-85-35 through-37) to the FAA to amend 14 CFR 121, 125, and 135 to require air carriers to install life preservers that meet TSO-C13e within a reasonable time. The FAA adopted TSO-C13e on April 23, 1986, and originally had specified an effective date of April 23, 1988, after which all newly manufactured life preservers approved under the TSO system would have to meet the requirements of TSO-C13e. The objective of the cut off date was to introduce life preservers into the fleets with the higher performance level as specified in TSO-C13e by assuring that replacement articles met the higher standards. On March 3, 1988, the FAA rescinded the cut off date to seek further public comments of fleet retrofit in accord with the proposed rulemaking. See Section 4.0 for FAA action and status of the recommendations.

3. CONCLUSIONS

3.1 Findings

1. There were no flightcrew or cabincrew factors in the cause of the accident or injuries.
2. There were no air traffic control or weather factors in the cause of the accident.
3. The airplane had not been maintained in accordance with the provisions of AD-88-12-04 that required an inspection of the cargo door locking mechanisms after each time the door was operated manually and restored to electrical operation. However, this

circumstance was determined not to be a factor in the accident.
4. All but one of the electrical components remaining with the airplane or found with the cargo door that were necessary to have malfunctioned in order to cause an inadvertent electrical opening of the cargo door after dispatch were found to function properly.
5. The forward cargo door lock sectors were found in the locked position (actually in an "over-locked" position) and jammed against the latch cams. The latch cams were found in the nearly open position.
6. The latch actuator manual drive port seal was found damaged from the forces involved in the separation of the door and did not indicate that the drive port had been used to open the door latches manually before the accident.
7. Electrical continuity tests indicated that the S2 master latch lock switch was in the "not locked" position when it was recovered with the cargo door. Because it had sustained damage from being submerged in the sea, its preaccident condition could not be determined.
8. An S2 switch functioning as found after recovery would permit electrical power to the door during ground operation so that additional failure modes or activation of the door control switch could result in movement of the latching cams.
9. All other switches associated with operation of the cargo door were found damaged from being submerged in the sea; however, they were determined to be properly installed and probably functional.
10. Short circuit paths in the cargo door circuit were identified that could have led to an uncommanded electrical actuation of the latch actuator; this situation occurred most likely before engine start, although limited possibilities for an uncommanded electrical actuation exist after engine start while an airplane is on the ground with the APU running.
11. It was not possible for electrical short circuits to command

the cargo door to open at the time of the loss of the door, and it is highly improbable that such an event occurred when the airplane was airborne during the short period while the APU was running.

12. Insulation breaches were found on recovered portions of the cargo door wires that could have allowed short circuiting and power to the latch actuator, although no evidence of arcing was noted. All of the wires were not recovered, and tests showed that arcing evidence may not be detectable.

13. An uncommanded movement of cargo door latches that occurred on another UAL B-747 on June 13, 1991, was attributed to insulation damage and a consequent short between wires in the wiring bundle between the fuselage and the moveable door. Because the S2 switch functioned properly on that airplane, movement of the latches would not have occurred after the door was locked.

14. UAL's maintenance trend analysis program was inadequate to detect an adverse trend involving the cargo door on N4713U. This circumstance was determined not to be a factor in the accident.

15. FAA oversight of the UAL maintenance and inspection program did not ensure adequate trend analysis and adherence to the provisions of airworthiness directives. This circumstance was determined not to be a factor in the accident.

16. The smooth wear patterns on the latch pins of the forward cargo door installed on N4713U were signs that the door was not properly aligned (out of rig) for an extended period of time, causing significant interference during the normal open/close cycle.

17. The rough heat-tinted wear areas on the latch pins of the forward cargo door installed on N4713U marked the positions of the cams at the time the door opened in flight.

18. The design of the B-747 cargo door locking mechanisms did

not provide for the intended "fail-safe" provisions of the locking and indicating systems for the door.

19. Boeing's Failure Analysis, which was the basis upon which the FAA granted an alternative method of compliance with the provisions of 14 CFR 25.783(e), was not valid as evidenced by the findings of the Pan Am incident in 1987, and the accident involving flight 811.

20. Boeing and the FAA did not take immediate action to require the use of the cam position view ports following the Pan Am incident, and did not include this requirement in the provisions of the Alert Service Bulletins or AD-88-12-04.

21. There were several opportunities for the manufacturer and the FAA to have taken action during the service life of the Boeing 747 that might have prevented this accident.

22. The fact that the crash fire rescue vehicles responding to this accident did not use a common radio frequency led to problems in communication among the responding vehicles.

23. The camouflage paint scheme of the military fire rescue units led to reduced visibility of these units and resulted in at least one near-collision.

24. Megaphones were used in flight to communicate with passengers because of the high ambient noise level. However, more megaphones would have afforded better communication in all parts of the cabin.

25. Some flight attendants and passengers had difficulties tightening straps of their life preservers around their waists because of the fabric used, the design of the adjustment fittings, and the angle the straps were pulled.

26. Articles that fell to the floor from stowage bins above the L-2 and R-2 exits and galley service items had to be cleared away from the exits before the emergency evacuation could be initiated.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

4. RECOMMENDATIONS

As a result of the investigation, including evidence from the recovered cargo door and a June 13, 1991, incident involving the uncommanded electrical operation of a cargo door on a UAL Boeing 747 at JFK Airport, the National Transportation Safety Board recommends that the FAA:

Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits. (Class II, Priority Action) (A-92-21)

As a result of this investigation, on August 23, 1989, the Safety Board issued the following safety recommendations to the FAA:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams. (Class II, Priority Action)(A-89-92)

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently. (Class II, Priority Action)(A-89-93)

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions. (Class II, Priority Action)(A-89-94)

The FAA responded to Safety Recommendations A-89-92 through -94 on November 3, 1989. During its evaluation of Safety Recommendation A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with AD 88-12-04, cannot be overridden during mechanical or

least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this, Safety Recommendation A-89-92 has been classified as "Closed--Reconsidered."

The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all jetpowered transport-category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight. The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for

FAA certification personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100 certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as "Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using nonplug doors and that the FAA should not be limiting this review to only those transports which are jetpowered.

On November 29, 1990, Boeing issued service bulletin number 747-52-2224 applicable to all 747-100, 747-200, and 747-300 airplanes to add a new "door latch" switch to all 747 cargo doors. In addition to the door warning switch that monitors the position of the pressure relief doors, the new door latch switch is activated by the latch cam bellcrank to separately sense the position of the latch cams. The existing "door closed" switch is also replaced with a double pole switch. The additional pole is used to separately sense the position of the door. Another single pole switch is also added to redundantly sense the position of the door. If any of these switches are not actuated, the warning light on the flight engineer's panel and a new light added to pilot's glareshield panel will be illuminated. The modification also requires installation of new cargo door control panels on the forward and aft lower cargo doors. The new panel incorporates an additional light to indicate proper door locking.

The FAA mandated the incorporation of this service bulletin within 18 months by AD 90-09-06, Amendment 39-6581, effective May 29, 1990.

Also, as a result of this accident, on May 4, 1990, the National Transportation Safety Board issued the following safety recommendations to the FAA:

Amend 14 CFR 25.1447(c)(4) to require that face masks be attached to the regulators of portable emergency oxygen bottles.

(Class II, Priority Action) (A-90-54)
Require, in accordance with the requirements of 14 CFR 25.1447 (c)(4), that a portable oxygen bottle be located at the flight attendant stations at exit door 5 right and at exit door 5 left in B-747 airplanes. (Class II, Priority Action) (A-90-55)
Require that no articles be placed in storage compartments that are located over emergency exit doors. (Class II, Priority Action) (A-90-56)
Amend 14 CFR 121.309(f) to require a readily accessible megaphone at each seat row at which a flight attendant is stationed. (Class II, Priority Action) (A-90-57)
Take corrective action to improve direct visibility to passengers from the upper level flight attendant jumpseat in the B-747 airplanes using eye reference data contained in Federal Aviation Administration report FAA-AM-75-2 "Anthropometry of Airline Stewardesses." (Class II, Priority Action) (A-90-58)
Issue an Airworthiness Directive to require that stronger latches be installed in oversized storage compartments that formerly held liferafts on all B-747 airplanes and also limit the distance that these compartments can be opened. (Class II, Priority Action) (A-90-59)
Demonstrate for each make and model of life preserver that it can be donned, adjusted, and tightened within the elapsed time required by TSO-C13d. Direct particular attention to the ease with which straps pass through adjustment fittings when the straps are pulled at all possible angles. (Class II, Priority Action) (A-90-60)
Establish a cutoff date of [within 1 year of this recommendation letter] after which all life preservers manufactured for passengercarrying aircraft would be required to meet the specifications of TSO-C13e. (Class II, Priority Action) (A-90-61)
The FAA first responded to these safety recommendations in a July 26, 1990, letter. Further responses to various safety recommendations in the group came in letters dated October 26,

1990 (A-90-59); May 13, 1991 (A-90-58); September 23, 1991 (A-90-55, -56, and -59); and March 9, 1992 (A-90-59). The current status of each safety recommendation is:

A-90-54: "Open--Acceptable Response," pending outcome of potential rulemaking initiative by the FAA.

A-90-55: "Open--Unacceptable Response," pending a review by the FAA of B-747 airplanes for compliance with portable oxygen bottle placement and securement requirements and for modifications that do not meet the intent of the type certification.

A-90-56: "Open--Unacceptable Response," pending a reexamination by the FAA of the potential for contents of compartments spilling out during an emergency and obstructing passengers.

A-90-57: "Open--Unacceptable Response," pending the FAA's review of its position regarding a requirement for multiple megaphones on passenger airplanes.

A-90-58: "Closed--Reconsidered" as a result of the Safety Board's acceptance of the FAA position that the cabin jumpseat design on B-747's does not constitute an unsafe condition.

A-90-59: "Open--Acceptable Response," pending the issuance of an Airworthiness Directive to require stronger latches on oversized storage compartments on B-747 airplanes.

A-90-60: "Open--Acceptable Response," pending the implementation of the latest iteration of TSO-C13.

A-90-61: "Open--Unacceptable Response," pending inclusion in TSO-C13 (latest iteration) of a cutoff date after which all life preservers manufactured for passenger-carrying aircraft would be required to meet the specifications of the TSO.

The FAA's March 9, 1992, response to Safety Recommendation A-90-59 included the final AD addressing this issue. The AD does meet the intent of the recommendation, which is now classified as "Closed--Acceptable Action."

Also as a result of this accident, on May 4, 1990, the Safety Board

reiterated the following recommendations to the FAA:
A-85-35
Amend 14 CFR 121 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; ensure that 14 CFR 25 is consistent with the amendments to Part 121.
A-85-36
Amend 14 CFR 125 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; amend Part 125 to require approved flotation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR 25 is consistent with the amendments of Part 125.
A-85-37
Amend 14 CFR 135 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; Amend Part 135 to require approved floatation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR SFAR No. 23 is consistent with the amendments to Part 135.

In a November 28, 1988, letter to the FAA, the Safety Board recommended that a cutoff date January 1, 1989, be reestablished. Based on this accident, the Safety Board's again urges the FAA to establish a cutoff date by which life preservers meeting TSO-C13e would be introduced into the fleets within a reasonable time (A-85-36). The Safety Board recognizes that the FAA has complied with the part of this recommendation pertaining to the flotation-type seat cushions.

Safety Recommendations A-85-35 and -37 are being held in an "Open--Acceptable Action" status pending the publication of the final rule. Safety Recommendation A-85-36 is being held in an "Open--Unacceptable Action" status because Part 125 operations were not included in the FAA rulemaking action.

As a result of its investigation, on May 4, 1990, the Safety Board also recommended that the State of Hawaii, Department of Transportation, Airports Division:

Develop, in cooperation with the Department of Defense, procedures for direct radio communication between aircraft rescue and fire fighting vehicles operated by the State of Hawaii and Hickam Air Force Base that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-62)

Additionally, as a result of its investigation, on May 4, 1990, the Safety Board recommended that the Department of Defense:

Develop, in cooperation with the State of Hawaii Department of Transportation, procedures for direct radio communication between aircraft rescue and firefighting vehicles operated by Hickam Air Force Base and the State of Hawaii that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-63)

Comply with Federal Regulation 14 CFR 139.319(f)(2) and the guidance contained in Federal Aviation Administration Advisory Circular 150/5220-14 by using high visibility color for aircraft rescue and firefighting vehicles that operate at Honolulu International Airport. (Class II, Priority Action) (A-90-64)

The Department of Defense responded to Safety Recommendations A-90-63 and -64 on August 17, 1990, citing the establishment of emergency radio communication ability between ARFF vehicles operated by Hickam Air Force Base and the State of Hawaii at Honolulu International Airport. Based on this action, Safety Recommendation A-90-63 was classified as "Closed--Acceptable Action" on December 12, 1990. With the establishment of the communications system as recommended, the Safety Board now classifies Safety Recommendation A-90-62 as "Closed--Acceptable Action."

Also, with regard to Safety Recommendation A-90-64, the Department of Defense pointed out that the Air Force has initiated a program to rep™ aint the vehicles over a 3-year period to spread out funding concerns. This safety recommendation is being held as "Open--Acceptable Response," pending the completion of the repainting program in 1993.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

SUSAN COUGHLIN

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Member

CHRISTOPHER A. HART

Member

JOHN HAMMERSCHMIDT

Member

JAMES L. KOLSTAD

Member

March 18, 1992

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Washington Headquarters of the National Transportation Safety Board was notified of the United Airlines accident within a short time after the occurrence. A full investigation team departed Washington, D.C. at 1400 eastern daylight time on the same day and arrived in Honolulu at 0030 Hawaiian standard time the next day.

The team was composed of the following investigation groups: Operations, Structures/Systems, Maintenance Records, Metallurgy, and Survival Factors. In addition, specialist reports were prepared relevant to the CVR, FDR and radar plots. Parties to the field investigation were United Airlines, the FAA, the Boeing Commercial Airplane Company, the Air Line Pilots Association, the International Association of Machinists, and the Association of Flight Attendants.

2. Public Hearing

A 3-day public hearing was held in Seattle, Washington, beginning on April 25, 1989. Parties represented at the hearing were the FAA, United Airlines, the Boeing Commercial Airplanes Company, the Air Line Pilots Association, and the International Association of Machinists.

APPENDIX B

PERSONNEL INFORMATION

Captain David Cronin

Captain David Cronin, 59, was hired by UAL on December 10, 1954. The captain holds Airline Transport Pilot (ATP) Certificate No. 1268493 with airplane multiengine land ratings and commercial privileges in airplane single-engine land, sea and gliders. The captain is type rated in the B747, DC10, DC8, B727, Convair (CV) 440, CV340, CV240 and the learjet. The captain was issued a first class medical certificate on November 1, 1988, with no limitations.

The captain's initial operating experience (IOE) check out in the B747 occurred in December, 1985. The captain's latest line and proficiency checks in the B747 were completed in August and December, 1988, respectively. Training in ditching and evacuation was included with the proficiency check. The captain had flown a total of about 28,000 hours, 1,600 to 1,700 hours of which were in the B747. During the 24-hour, 72-hour and 30-day periods, prior to the accident, the captain had flown: 1 hour, 5 minutes; 13

hours, 35 minutes; and 76 hours, 18 minutes, respectively.

First Officer Gregory Slader

First Officer Gregory Slader, 48, was hired by UAL on June 15, 1964. The first officer holds ATP Certificate No. 1528630 with airplane multiengine land ratings and commercial privileges in airplane single-engine land. The first officer is type rated in B747, DC10, B727, and B737. The first officer was issued a first class medical certificate on February 14, 1989, with no limitations.

The first officer's initial operating experience (IOE) check out in the B747 occurred in August, 1987. The first officer's latest proficiency check in the B747 was completed in October, 1988. Training on ditching and evacuation was included with the proficiency check. The first officer had flown a total of about 14,500 hours, 300 hours of which were in the B747. During the 24-hours, 72-hour and 30-day periods prior to the accident, the first officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Second Officer Randal Thomas

Second Officer Randal Thomas, 46, was hired by UAL on May 22, 1969. The second officer holds Flight Engineer Certificate No. 1947041 for turbo jet powered airplanes, issued July 18, 1969. The second officer holds commercial pilot certificate No. 1585899 with ratings and limitations of airplane single and multiengine land with instrument privileges. The second officer was issued a first class medical certificate on December 6, 1988, with no limitations.

The second officer's IOE check out in the B747 occurred in March, 1987. The second officer's latest proficiency check in the B747 was completed in October, 1988. Training in ditching and evacuation was included with the proficiency check. He had flown a total of about 20,000 hours, about 1,200 hours of which were as second officer on the B747. During his 24-hour, 72-hour and 30 day-periods, prior to the accident, the second officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes,

respectively.
Flight Attendant and Chief Purser Laura Brentlinger
Flight attendant Laura Brentlinger, 38, was employed by UAL in May 1982; and had completed B747 recurrent training on September 19, 1988.
Flight Attendant and AFT Purser Sarah Shanahan
Flight attendant Sarah Shanahan, 42, was employed by UAL in August 1967; and had completed B747 recurrent training on October 10, 1988.
Flight Attendant Richard Lam
Flight attendant Richard Lam, 41, was employed by UAL on April 1970; and had completed B747 recurrent training on September 16, 1988.
Flight Attendant John Horita
Flight attendant John Horita, 44, was employed by UAL in June 1970; and had completed B747 recurrent training on November 1, 1988.
Flight Attendant Curtis Christensen
Flight attendant Curtis Christensen, 34, was initially employed by PAA in May 1978. He was subsequently employed by UAL in February 1986 when UAL purchased PAA Pacific Division. Flight attendant Chrisensen had completed B747 recurrent training on December 12, 1988.
Flight Attendant Tina Blundy
Flight attendant Tina Blundy, 36, was employed by UAL in May 1973; and had completed B747 recurrent training on October 28, 1988.
Flight Attendant Jean Nakayama
Flight attendant Jane Nakayama, 37, was employed by UAL in August 1973; and had completed B747 recurrent training on December 6, 1988.
Flight Attendant Mae Sapolu
Flight attendant Mae Sapolu, 38, was initially employed by Pan

American Airlines (PAA) in March 1973. She was subsequently employed by UAL in February 1986; when UAL purchased PAA Pacific Division. Flight attendant Sapolu completed B747 recurrent training on October 13, 1988.

Flight Attendant Robyn Nakamoto

Flight attendant Robyn Nakamoto, 26, was employed by UAL in April, 1986, and transferred to the Inflight Service Division in May, 1988. She was initially trained on the B747 in May 1988; and had not attended recurrent training.

Flight Attendant Edward Lythgoe

Flight attendant Edward Lythgoe, 37, was employed by UAL in December 1978; and had completed B747 recurrent training on October 21, 1988.

Flight Attendant Sharol Preston

Flight attendant Sharol Preston, 39, was employed by UAL in July 1970; and had completed B747 recurrent training on July 29, 1988.

Flight Attendant Ricky Umehira

Flight attendant Ricky Umehira, 35, was employed by UAL in November 1983; and had completed B747 recurrent training on November 15, 1988.

Flight Attendant Darrell Blankenship

Flight attendant Darrell Blankenship, 28, was employed by UAL in February 1984; and had completed B747 recurrent training on February 10, 1988.

Flight Attendant Linda Shirley

Flight attendant Linda Shirley, 30, was employed by UAL in March 1979; and had completed B747 recurrent training on November 3, 1989.

Flight Attendant Ilona Benoit

Flight attendant Ilona Benoit, 48, was initially employed by PAA in November 1969. She was subsequently employed by UAL in February 1986; and had completed B747 recurrent training on November 17, 1988.

Lead Ramp Serviceman Paul Engalla
Lead ramp serviceman Paul Engalla was employed by UAL in 1959. Because of his extensive ramp service experience, Mr. Engalla was selected as a ramp service trainer in 1986.
Ramp Serviceman Daniel Sato
Ramp serviceman Daniel Sato was employed by UAL in May 1987. Company records indicate that his proficiency in the opening and closing of B747 cargo doors and the operation of container loads was attained in September 1988.
Ramp Serviceman Brian Kitaoka
Ramp serviceman Brian Kitaoka was employed by UAL in November 1986. Company records indicate that his proficiency in the operation of container loaders was attained in November 1987. His proficiency in the opening and closing of B747 cargo doors was attained in October 1988.
Dispatch Mechanic Steve Hajanos
Dispatch mechanic Steve Hajanos was employed as an airplane mechanic by UAL on October 30, 1986. He holds FAA Airplane and Powerplants Certificate No. 362583850, issued November 14, 1981. He was formerly employed by Aloha Airlines as a maintenance supervisor and by World Airways as a mechanic and maintenance supervisor. He began his aviation career as an airplane mechanic in the United States Air Force.
APPENDIX C
AIRPLANE INFORMATION

Type of Date of Maximum Inspection Inspection Cycles Interval Service No. 1 Current 02/23/89 58,814:24 15,027 Note 1 Previous 02/23/89 58,809:02 15,026 Service No. 2 Current 02/22/89 58,802:35 15,024 65 Hours Previous 02/18/89 58,747:12 15,016 Note 2 A Check Current 02/14/89 58,710:14 15,009 350 Hours Previous 01/16/89 58,368:57 14,947 B Check Current 11/28/88 57,751:44 14,839 131 Days Previous 07/28/88 56,635:36 14,632 C

Check Current 11/28/88 57,751:44 14,839 393 Days Previous 11/19/87 53,789:00 14,146 MPV Check Current 04/30/84 43,731:0 11,857 5 Years Previous 01/30/80 30,906:0
D Check Current 04/30/84 43,731 19,237 9 Years Previous 09/09/76 19,237 Note 1: Service No. 1 to be accomplished on through flights or at trip termination whenever time is less than 12 hours per Maintenance Manual Procedures BX 12-0-1-1.
Note 2: Aircraft with layover of 12 hours or more will receive a Service No. 2 not to exceed 65 flight hours between checks.

APPENDIX D

INJURY INFORMATION

Flight Crewmember.--The second officer sustained minor superficial brush burns to both elbows and forearms, during the evacuation.

Cabin Crewmembers.--The cabin crewmembers sustained the following injuries during the evacuation:

Flight attendant No. 1 sustained a strained left shoulder;

Flight attendant No. 2 sustained acute thoracic and lumbosacral strain;

Flight attendant No. 3 sustained a mild right bicep strain;

Flight attendant No. 4 sustained a left elbow contusion, left shoulder dislocation, and mild lumbosacral strain;

Flight attendant No. 5 sustained a left calf contusion;

Flight attendant No. 6 sustained a mild left elbow bruise;

Flight attendant No. 7 sustained mild left arm and lower back strain;

Flight attendant No. 8 sustained a soft tissue injury to the back;

Flight attendant No. 9 sustained abrasions to both palms and the left knee;

Flight attendant No. 10 sustained a fracture of the left tenth rib;

Flight attendant No. 11 sustained a minimal injury to the right middle finger PIP joint and left first MP joint;

Flight attendant No. 12 sustained a pulled muscle on the left side

of the neck;
Flight attendant No. 13 sustained a comminuted fracture of the right ulna and radius;
Flight attendant No. 14 sustained a mild thoracic back strain;
Flight attendant No. 15 sustained a non-displaced fracture of C-6, a cerebral concussion, a fracture of the proximal right humerus, and multiple lacerations;
A flight attendant, flying as a passenger, sustained mild lumbosacral strain, a laceration of the right little finger, and a left elbow abrasion.
Passengers.--Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH, and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally injured in the accident.
Passengers seated in the indicated seats sustained the following injuries:
Seat
7C - Barotrauma to both ears
9C - Half-inch laceration to the upper left arm, superficial abrasions to left arm and hand, barotrauma to both ears
9E - Superficial abrasions and contusions to the left hand, mild barotrauma to both ears
10B - Superficial abrasions to the left elbow and left middle finger
10E - Superficial abrasions to the torso and left forearm, bruising of the left hand and fingers
11E - Laceration on the right ankle tendon, multiple bruises
11F - Slight contusion of the right shoulder
13D - Barotrauma to both ears
13E - Bleeding in both ears
13H - Contusion to the left periorbital area
14A - Laceration in the parietal occipital area, barotrauma to both ears

15J - Comminuted fracture of the lateral epicondyle of the left distal humerus (about 5mm separation)
16B - Superficial abrasions to the right arm
16J - Barotrauma to both ears
16K - Right temporal abrasions
26A - Barotrauma to both ears
26B - barotrauma to both ears
26H - Barotitis to both ears, low back pain, irritation to the right eye due to foreign bodies
27A - Barotrauma to the right ear
28J - Superficial abrasions and a contusion to the left hand, mild barotrauma to both ears

1The flap track canoe fairings are numbered 1 through 8, from left outboard to right outboard.

2For ease in reference, the following numbering was used to relate forward cargo door frames to fuselage body stations (BS): frame 1--BS 567.10, frame 2--BS 580.95, frame 3--BS 596.75, frame 4--BS 608.15, frame 5--BS 623.96, frame 6--BS 636.02, frame 7--BS 651.50, frame 8--BS 662.90.

3 The "used" switch is the switch through which electricity passes; the "unused" switch does not have electricity pass through it.

4NFPA 414 - Aircraft Rescue and Fire Fighting Vehicles, National Fire Protection Association, 1984, Batterymarch Park, Quincy, MA 02269.

5Airport Fire and Rescue Vehicle Specification Guide, AC 150/5220-14, March 15, 1979, Federal Aviation Administration, Washington, D.C. 20591.

6 Air Carrier Overwater Emergency Equipment and Procedures" (NTSB/SS-85/02)

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:46 PM PDT

To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **PA 103 report**

To: aniljit singh uppal <aniljitsingh@hotmail.com>
From: John Barry Smith <barry@corazon.com>
Subject: PA 103 report
Cc:
Bcc:
X-Attachments:

http://www.open.gov.uk/aaib/n739pa.htm

Air Accidents Investigation Branch
Aircraft Accident Report No 2/90 (EW/C1094)

Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21December 1988

Contents

Operator: Pan American World Airways
Aircraft Type: Boeing 747-121
Nationality: United States of America

Registration: N 739 PA
Place of Accident Lockerbie, Dumfries, Scotland
Latitude 55¡ 07' N
Longitude 003¡ 21' W
Date and Time (UTC): 21 December 1988 at 19.02:50 hrs
All times in this report are UTC
SYNOPSIS

The accident was notified to the Air Accidents Investigation Branch at 19.40 hrs on the 21 December 1988 and the investigation commenced that day. The members of the AAIB team are listed at Appendix A.

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind. Major portions of the wreckage of the aircraft fell on the town of Lockerbie with other large parts landing in the countryside to the east of the town. Lighter debris from the aircraft was strewn along two trails, the longest of which extended some 130 kilometres to the east coast of England. Within a few days items of wreckage were retrieved upon which forensic scientists found conclusive evidence of a detonating high explosive. The airport security and criminal aspects of the accident are the subject of a separate investigation and are not covered in this report which concentrates on the technical aspects of the disintegration of the aircraft.

The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie. Five recommendations are made of which four concern flight recorders, including the funding of a study to devise methods of recording violent positive and negative pressure pulses associated with explosions. The final recommendation is that Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft's structure and systems to explosive damage.

1. FACTUAL INFORMATION

1.1 History of the Flight

Boeing 747, N739PA, arrived at London Heathrow Airport from San Francisco and parked on stand Kilo 14, to the south-east of Terminal 3. Many of the passengers for this aircraft had arrived at Heathrow from Frankfurt, West Germany on a Boeing 727, which was positioned on stand Kilo 16, next to N739PA. These passengers were transferred with their baggage to N739PA which was to operate the scheduled Flight PA103 to New York Kennedy. Passengers from other flights also joined Flight PA103 at Heathrow. After a 6 hour turnround, Flight PA103 was pushed back from the stand at 18.04 hrs and was cleared to taxy on the inner taxiway to runway 27R. The only relevant Notam warned of work in progress on the outer taxiway. The departure was unremarkable.

Flight PA103 took-off at 18.25 hrs. As it was approaching the Burnham VOR it took up a radar heading of 350¡ and flew below the Bovingdon holding point at 6000 feet. It was then cleared to climb initially to flight level (FL) 120 and subsequently to FL 310. The aircraft levelled off at FL 310 north west of Pole Hill VOR at 18.56 hrs. Approximately 7 minutes later, Shanwick Oceanic Control transmitted the aircraft's oceanic clearance but this transmission was not acknowledged. The secondary radar return from Flight PA103 disappeared from the radar screen during this transmission. Multiple primary radar returns were then seen fanning out downwind for a considerable distance. Debris from the aircraft was strewn along two trails, one of which extended some 130 km to the east coast of England. The upper winds were between 250¡ and 260¡ and decreased in strength from 115 kt at FL 320 to 60 kt at FL 100 and 15 to 20 kt at the surface.

Two major portions of the wreckage of the aircraft fell on the town of Lockerbie; other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Residents of Lockerbie reported that, shortly after 19.00 hrs, there was a rumbling noise like thunder which rapidly increased to deafening proportions like the roar of a jet engine under power. The noise appeared to come from a meteor-like object which was trailing flame and came down in the north-eastern part of the town. A larger, dark, delta shaped object, resembling an aircraft wing, landed at about the same time in the Sherwood area of the town. The delta shaped object was not on fire while in the air, however, a very large fireball ensued which was of short duration and carried large amounts of debris into the air, the lighter particles being deposited several miles downwind. Other less well defined objects were seen to land in the area.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others

Fatal	16	243	11
Serious	-	-	2
Minor/None	-	-	3

CLICK HERE TO RETURN TO INDEX

1.3 Damage to aircraft

The aircraft was destroyed

1.4 Other damage

The wings impacted at the southern edge of Lockerbie, producing a crater whose volume, calculated from a photogrammetric survey, was approximately 560 cubic metres. The weight of material displaced by the wing impact was estimated to be well in excess of 1500 tonnes. The wing impact created a fireball, setting fire to neighbouring houses and carrying aloft debris which was then blown downwind for several miles. It was subsequently established that domestic properties had been so seriously damaged as a result of fire and/ or impact that 21 had to be demolished and an even greater number of homes required substantial repairs. Major portions of the aircraft, including the engines, also landed on the town of Lockerbie and other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Lighter debris from the aircraft was strewn as far as the east coast of England over a distance of 130 kilometres.

1.5 Personnel information

1.5.1 Commander: Male, aged 55 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 720, Lockheed L1011 and Douglas DC3
Medical Certificate: Class 1,valid to April 1989, with the limitation that the holder shall wear lenses that correct for distant vision and possess glasses that correct for near vision

Flying experience:
Total all types: 10,910 hours
Total on type: 4,107 hours
Total last 28 days 82 hours
Duty time: Commensurate with company requirements
Last base check: 11 November 1988
Last route check: 30 June 1988

Last emergencies check: 8 November 1988

1.5.2 Co-pilot: Male, aged 52 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 727
Medical Certificate: Class 1, valid to April 1989, with the limitation that the holder shall possess correcting glasses for near vision
Flying experience:
Total all types: 11,855 hours
Total on type: 5,517 hours
Total last 28 days: 51 hours
Duty time: Commensurate with company requirements
Last base check: 30 November 1988
Last route check: Not required
Last emergencies check: 27 November 1988

1.5.3 Flight Engineer: Male, aged 46 years
Licence: USA Flight Engineer's Licence
Aircraft ratings: Turbojet
Medical certificate: Class 2, valid to June 1989, with the limitation that the holder shall wear correcting glasses for near vision
Flying experience:
Total all types: 8,068 hours
Total on type: 487 hours
Total last 28 days: 53 hours
Duty time: Commensurate with company requirements
Last base check: 30 October 1988
Last route check: Not required
Last emergencies check: 27 October 1988

1.5.4 Flight Attendants: There were 13 Flight Attendants on the aircraft, all of whom met company proficiency and medical requirements
CLICK HERE TO RETURN TO INDEX

1.6 Aircraft information

1.6.1 Leading particulars

Aircraft type: Boeing 747-121
Constructor's serial number: 19646
Engines: 4 Pratt and Whitney JT9D-7A turbofan

1.6.2 General description

The Boeing 747 aircraft, registration N739PA, was a conventionally designed long range transport aeroplane. A diagram showing the general arrangement is shown at Appendix B, Figure B-1 together with the principal dimensions of the aircraft.

The fuselage of the aircraft type was of approximately circular section over most of its length, with the forward fuselage having a diameter of 21† feet where the cross-section was constant. The pressurised section of the fuselage (which included the forward and aft cargo holds) had an overall length of 190 feet, extending from the nose to a point just forward of the tailplane. In normal cruising flight the service pressure differential was at the maximum value of 8.9 pounds per square inch. The fuselage was of conventional skin, stringer and frame construction, riveted throughout, generally using countersunk flush riveting for the skin panels. The fuselage frames were spaced at 20 inch intervals and given the same numbers as their stations, defined in terms of the distance in inches from the datum point close to the nose of the aircraft [Appendix B, Figure B-2]. The skin panels were joined using vertical butt joints and horizontal lap joints. The horizontal lap joints used three rows of rivets together with a cold bonded adhesive.

Accommodation within the aircraft was predominately on the main deck, which extended throughout the whole length of the pressurised compartment. A separate upper deck was incorporated in the forward part of the aircraft. This upper deck was reached by means of a spiral staircase from the main deck and incorporated the flight crew compartment together with additional passenger accommodation. The cross-section of the forward fuselage differed considerably from the near circular section of the remainder of the aircraft, incorporating an additional smaller radius arc above the upper deck section joined to the main circular arc of the lower cabin portion by elements of straight fuselage frames and flat skin.

In order to preserve the correct shape of the aircraft under pressurisation loading, the straight portions of the fuselage frames in the region of the upper deck floor and above it were required to be much stiffer than the frame portions lower down in the aircraft. These straight sections were therefore of very much more substantial construction than most of the curved sections of frames lower down and further back in the fuselage. There was considerable variation in the gauge of the fuselage skin at various locations in the forward fuselage of the aircraft.

The fuselage structure of N739PA differed from that of the majority of Boeing 747 aircraft in that it had been modified to carry special purpose freight containers on the main deck, in place of seats. This was known as the Civil Reserve Air Fleet (CRAF) modification and enabled the aircraft to be quickly converted for carriage of military freight containers on the main deck during times of national emergency. The effect of this modification on the structure of the fuselage was mainly to replace the existing main deck floor beams with beams of more substantial cross-section than those generally found in passenger carrying Boeing 747 aircraft. A large side loading door, generally known as the CRAF door, was also incorporated on the left side of the main deck aft of the wing.

Below the main deck, in common with other Boeing 747 aircraft, were a number of additional compartments, the largest of which were the forward and aft freight holds used for the storage of cargo and baggage in standard air-transportable containers. These containers were placed within the aircraft hold by means of a freight handling system and were carried on a system of rails approximately 2 feet above the outer skin at the bottom of the aircraft, there being no continuous floor, as such, below these baggage containers. The forward freight compartment had a length of approximately 40 feet and a depth of approximately 6 feet. The containers were loaded into the forward hold through a large cargo door on the right side of the aircraft.

1.6.3 Internal fuselage cavities

Because of the conventional skin, frame and stringer type of construction, common to all large public transport aircraft, the fuselage was effectively divided into a series of 'bays'. Each bay, comprising two adjacent fuselage frames and the structure between them, provided, in effect, a series of interlinking cavities bounded by the frames, floor beams, fuselage skins and cabin floor panels etc. The principal cavities thus formed were:

(i) A semi-circular cavity formed in between the fuselage frames in the lower lobe of the hull, i.e. from the crease beam (at cabin floor level) on one side down to the belly beneath the containers and up to the opposite crease beam, bounded by the fuselage skin on the outside and the containers/cargo liner on the inside [Appendix B, Figure B-3, detail A].

(ii) A horizontal cavity between the main cabin floor beams, the cabin floor panels and the cargo bay liner. This extended the full width of the fuselage and linked the upper ends of the lower lobe cavity [Appendix B, Figure B-3, detail B].

(iii) A narrow vertical cavity between the two containers [Appendix B, Figure B-3, detail C].

(iv) A further narrow cavity around the outside of the two containers, between the container skins and the cargo bay liner, communicating with the lower lobe cavity [Appendix B, Figure B-3, detail D].

(v) A continuation of the semi-circular cavity into the space behind the cabin wall liner [Appendix B, Figure B-3, detail E]. This space was restricted somewhat by the presence of the window assembly, but nevertheless provided a continuous cavity extending upwards to the level of the upper deck floor. Forward of station 740, this cavity was effectively terminated at its upper end by the presence of diaphragms which formed extensions of the upper deck floor panels; aft of station 740, the cavity communicated with the ceiling space and the cavity in the fuselage crown aft of the upper deck.

All of these cavities were repeated at each fuselage bay (formed between pairs of fuselage frames), and all of the cavities in a given bay were linked together, principally at the crease beam area [Appendix B, Figure B-3, region F]. Furthermore, each of the set of bay cavities was linked with the next by the longitudinal cavities formed between the cargo hold liner and the outer hull, just below the crease beam [Appendix B, Figure B-3, detail F]; i.e. this cavity formed a manifold linking together each of the bays within the cargo hold.

The main passenger cabin formed a large chamber which communicated directly with each of the sub floor bays, and also with the longitudinal manifold cavity, via the air conditioning and cabin/cargo bay de-pressurisation vent passages in the crease beam area. (It should be noted that a similar communication did not exist between the upper and lower cabins because there were no air conditioning/depressurisation passages to bypass the upper deck floor.)

1.6.4 Aircraft weight and centre of gravity

The aircraft was loaded within its permitted centre of gravity limits as follows:

Loading:	lb	kg
Operating empty weight	366,228	166,120
Additional crew	130	59
243 passengers (1)	40,324	18,291
Load in compartments:		
1	11,616	5,269
2	20,039	9,090
3	15,057	6,830
4	17,196	7,800
5	2,544	1,154
Total in compartments (2)	66,452	30,143
Total traffic load	106,776	48,434
Zero fuel weight	472,156	214,554
Fuel (Take-off)	239,997	108,862
Actual take-off weight(4)	713,002	323,416
Maximum take-off weight	733,992	332,937

Note 1:
Calculated at standard weights and including cabin baggage.

Note 2:
Despatch information stated that the cargo did not include dangerous goods, perishable cargo, live animals or known security exceptions.

1.6.5 Maintenance details

N739PA first flew in 1970 and spent its whole service life in the hands of Pan American World Airways Incorporated. Its Certificate of Airworthiness was issued on 12 February 1970 and remained in force until the time of the accident, at which time the aircraft had completed a total of 72,464 hours flying and 16,497 flight cycles. Details of the last 4 maintenance checks carried out during the aircraft's life are shown below:

DATE	SERVICE	HOURS	CYCLES
27 Sept 88	C Check (Interior upgrade)	71,502	16,347
2 Nov 88	B Service Check	71,919	16,406
27 Nov 88	Base 1	72,210	16,454
13 Dec 88	Base 2	72,374	16,481

The CRAF modification programme was undertaken in September 1987. At the same time a series of modifications to the forward fuselage from the nose back to station 520 (Section 41) were carried out to enable the aircraft to continue in service without a continuing requirement for structural inspections in certain areas.

All Airworthiness Directives relating to the Boeing 747 fuselage structure between stations 500 and 1000 have been reviewed and their applicability to this aircraft checked. In addition, Service Bulletins relating to the structure in this area were also reviewed. The applicable Service Bulletins, some of which implement the Airworthiness Directives are listed below together with their subjects. The dates, total aircraft times and total aircraft cycles at which each relevant inspection was last carried out have been reviewed and their status on aircraft N739PA at the time of the accident has been established.

N739PA Service Bulletin compliance:

SB 53-2064 Front Spar Pressure Bulkhead Chord Reinforcement and Drag Splice Fitting Rework.
Modification accomplished on 6 July 1974.
Post-modification repetitive inspection IAW (in accordance with) AD 84-18-06 last accomplished on 19 November 1985 at 62,030 TAT hours (Total Aircraft Time) and 14,768 TAC (Total Aircraft Cycles).
SB 53-2088 Frame to Tension Tie Joint Modification - BS760 to 780.
Repetitive inspection IAW AD 84-19-01 last accomplished on 19 June 1985 at 60,153 hours TAT and 14,436 TAC.
SB 53-2200 Lower Cargo Doorway Lower Sill Truss and Latch Support Fitting Inspection Repair and Replacement.
Repetitive inspection IAW AD 79-17-02 R2 last accomplished 2 November 1988 at 71,919 hours TAT and 16,406 TAC.
SB 53-2234 Fuselage - Auxiliary Structure - Main Deck Floor - BS 480 Floor Beam Upper Chord Modification.
Repetitive inspection per SB 53A2263 IAW AD 86-23-06 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
SB 53-2237 Fuselage - Main Frame - BS 540 thru 760 and 1820 thru 1900 Frame Inspection and Reinforcement.
Repetitive inspection IAW AD 86-18-01 last accomplished on 27 February 1987 at 67,088 hours TAT and 15,627 TAC.
SB 53-2267 Fuselage - Skin - Lower Body Longitudinal Skin Lap Joint and Adjacent Body Frame Inspection and Repair.
Terminating modification accomplished 100% under wing-to-body fairings

and approximately 80% in forward and aft fuselage sections on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
Repetitive inspection of unmodified lap joints IAW AD 86-09-07 R1 last accomplished on 18 August 1988 at 71,043 hours TAT and 16,273 TAC.
SB 53A2303 Fuselage - Nose Section - station 400 to 520 Stringer 6 Skin Lap Splice Inspection, Repair and Modification.
Repetitive inspection IAW AD 89-05-03 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.

This documentation, when viewed together with the detailed content of the above service bulletins, shows the aircraft to have been in compliance with the requirements laid down in each of those bulletins. Some maintenance items were outstanding at the time the aircraft was despatched on the last flight, however, none of these items relate to the structure of the aircraft and none had any relevance to the accident.

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1.7 Meteorological Information

1.7.1 General weather conditions

An aftercast of the general weather conditions in the area of Lockerbie at about 19.00 hrs was obtained from the Meteorological Office, Bracknell. The synoptic situation included a warm sector covering northern England and most of Scotland with a cold front some 200 nautical miles to the west of the area moving eastwards at about 35 knots. The weather consisted of intermittent rain or showers. The cloud consisted of 4 to 6 oktas of stratocumulus based at 2,200 feet with 2 oktas of altocumulus between 15,000 and 18,000 feet. Visibility was over 15 kilometers and the freezing level was at 8,500 feet with a sub-zero layer between 4,000 and 5,200 feet.

1.7.2 Winds

There was a weakening jet stream of around 115 knots above Flight Level 310. From examination of the wind profile (see below), there appeared to be insufficient shear both vertically and horizontally to produce any clear air turbulence but there may have been some light turbulence.

Flight Level	Wind
320	260¡/115 knots

300	260¡/ 90 knots
240	250¡/ 80 knots
180	260¡/ 60 knots
100	250¡/ 60 knots
050	260¡/ 40 knots
Surface	240¡/ 15 to 20 gusting 25 to 30 knots

1.8 Aids to navigation

Not relevant.

1.9 Communications

The aircraft communicated normally on London Heathrow aerodrome, London control and Scottish control frequencies. Tape recordings and transcripts of all radio telephone (RTF) communications on these frequencies were available.

At 18.58 hrs the aircraft established two-way radio contact with Shanwick Oceanic Area Control on frequency 123.95 MHz. At 19.02:44 hrs the clearance delivery officer at Shanwick transmitted to the aircraft its oceanic route clearance. The aircraft did not acknowledge this message and made no subsequent transmission.

1.9.1 ATC recording replay

Scottish Air Traffic Control provided copy tapes with time injection for both Shanwick and Scottish ATC frequencies. The source of the time injection on the tapes was derived from the British Telecom "TIM" signal.

The tapes were replayed and the time signals corrected for errors at the time of the tape mounting.

1.9.2 Analysis of ATC tape recordings

From the cockpit voice recorder (CVR) tape it was known that Shanwick was transmitting Flight PA103's transatlantic clearance when the CVR stopped. By synchronising the Shanwick tape and the CVR it was possible to establish that a loud sound was heard on the CVR cockpit area microphone (CAM) channel at 19.02:50 hrs ±1 second.

As the Shanwick controller continued to transmit Flight PA103's clearance instructions through the initial destruction of the aircraft it would not have been possible for a distress call to be received from N739PA on the Shanwick frequency. The Scottish frequency tape recording was listened to from 19.02 hrs until 19.05 hrs for any unexplained sounds indicating an attempt at a distress call but none was heard.

A detailed examination and analysis of the ATC recording together with the flight recorder, radar, and seismic recordings is contained in Appendix C.

1.10 Aerodrome information

Not relevant

1.11 Flight recorders

The Digital Flight Data Recorder (DFDR) and the Cockpit Voice Recorder (CVR) were found close together at UK Ordnance Survey (OS) Grid Reference 146819, just to the east of Lockerbie, and recovered approximately 15 hours after the accident. Both recorders were taken directly to AAIB Farnborough for replay. Details of the examination and analysis of the flight recorders together with the radar, ATC and seismic recordings are contained in Appendix C.

1.11.1 Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded and that the recorder had simply stopped at 19.02:50 hrs ±1 second.

1.11.2 Cockpit voice recorder

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The

CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1 Flight Engineer's RTF.
Channel 2 Co-Pilot's RTF.
Channel 3 Pilot's RTF.
Channel 4 Cockpit Area Microphone.

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings were audible on the RTF channels. The CAM channel was particularly noisy, probably due to the combination of the inherently noisy flight deck of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high flight deck noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified and could have been of either acoustic or electrical origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19.02:50 hrs ±1 second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC.

1.12 Wreckage and impact information

1.12.1 General distribution of wreckage in the field

The complete wing primary structure, incorporating the centre section, impacted at the southern edge of Lockerbie. Major portions of the aircraft, including the engines, also landed in the town. Large portions of the aircraft fell in the countryside to the east of the town and lighter debris was strewn to the east as far as the North Sea. The wreckage was distributed in two trails which became known as the northern and southern trails respectively and these are shown in Appendix B, Figure B-4. A computer database of approximately 1200 significant items of wreckage was compiled and included a brief description of each item and the location where it was found

Appendix B, Figures B-5 to B-8 shows photographs of a model of the aircraft on which the fracture lines forming the boundaries of the separate items of structure have been marked. The model is colour coded to illustrate the way in which the wreckage was distributed between the town of Lockerbie and the northern and southern trails.

1.12.1.1 The crater

The aircraft wing impacted in the Sherwood Crescent area of the town leaving a crater approximately 47 metres (155 feet) long with a volume calculated to be 560 cubic metres.

The projected distance, measured parallel from one leading edge to the other wing tip, of the Boeing 747-100 was approximately 143 feet, whereas the span is known to be 196 feet. This suggests that impact took place with the wing structure yawed. Although the depth of the crater varied from one end to the other, its widest part was clearly towards the western end suggesting that the wing structure impacted whilst orientated with its root and centre section to the west.

The work carried out at the main crater was limited to assessing the general nature of its contents. The total absence of debris from the wing primary structure found remote from the crater confirmed the initial impression that the complete wing box structure had been present at the main impact.

The items of wreckage recovered from or near the crater are coloured grey on the model at Appendix B, Figures B-5 to B-8.

1.12.1.2 The Rosebank Crescent site

A 60 feet long section of fuselage between frame 1241 (the rear spar attachment) and frame 1960 (level with the rear edge of the CRAF cargo door) fell into a housing estate at Rosebank Crescent, just over 600 metres from the crater. This section of the fuselage was that situated immediately aft of the wing, and adjoined the wing and fuselage remains which produced the crater. It is colour coded yellow on the model at Appendix B, Figures B-5 to B-8. All fuselage skin structure above floor level was missing except for the following items:

Section containing 3 windows between door 4L and CRAF door;
The CRAF door itself (latched) apart from the top area containing the hinge;
Window belt containing 8 windows aft of 4R door aperture

Window belt containing 3 windows forward of 4R door aperture;
Door 4R.

Other items found in the wreckage included both body landing gears, the right wing landing gear, the left and right landing gear support beams and the cargo door (frames 1800-1920) which was latched. A number of pallets, luggage containers and their contents were also recovered from this site.

1.12.1.3 Forward fuselage and flight deck section.

The complete fuselage forward of approximately station 480 (left side) to station 380 (right side) and incorporating the flight deck and nose landing gear was found as a single piece [Appendix B, Figure B-9] in a field approximately 4 km miles east of Lockerbie at OS Grid Reference 174808. It was evident from the nature of the impact damage and the ground marks that it had fallen almost flat on its left side but with a slight nose-down attitude and with no discernible horizontal velocity. The impact had caused almost complete crushing of the structure on the left side. The radome and right nose landing gear door had detached in the air and were recovered in the southern trail.

Examination of the torn edges of the fuselage skin did not indicate the presence of any pre-existing structural or material defects which could have accounted for the separation of this section of the fuselage. Equally so, there were no signs of explosive blast damage or sooting evident on any part of the structure or the interior fittings. It was noted however that a heavy, semi-eliptical scuff mark was present on the lower right side of the fuselage at approximately station 360. This was later matched to the intake profile of the No 3 engine.

The status of the controls and switches on the flight deck was consistent with normal operation in cruising flight. There were no indications that the crew had attempted to react to rapid decompression or loss of control or that any emergency preparations had been actioned prior to the catastrophic disintegration.

1.12.1.4 Northern trail

The northern trail was seen to be narrow and clearly defined, to emanate from a point very close to the main impact crater and to be orientated in a direction which agreed closely with the mean wind aftercast for the height band from sea level to 20,000 ft. Also at the western end of the northern trail were the lower rear fuselage at Rosebank Crescent, and the group of Nos. 1, 2 and 4 engines which fell in Lockerbie.

The trail contained items of structure distributed throughout its length, from the area slightly east of the crater, to a point approximately 16 km east, beyond which only items of low weight / high drag such as insulation, interior trim, paper etc, were found. For all practical purposes this trail ended at a range of 25 km.

The northern trail contained mainly wreckage from the rear fuselage, fin and the inner regions of both tailplanes together with structure and skin from the upper half of the fuselage forward to approximately the wing mid-chord position. A number of items from the wing were also found in the northern trail, including all 3 starboard Kreuger flaps, most of the remains of the port Kreuger flaps together with sections of their leading edge attachment structures, one portion of outboard aileron approximately 10 feet long, the aft ends of the flap-track fairings (one with a slide raft wrapped around it), and fragments of glass reinforced plastic honeycombe structure believed to be from the flap system, i.e. fore-flaps, aft-flaps, mid-flaps or adjacent fairings. In addition, a number of pieces of the engine cowlings and both HF antennae (situated projecting aft from the wing-tips) were found in this trail.

All items recovered from the northern trail, with the exception of the wing, engines, and lower rear fuselage in Rosebank Crescent, are coloured red on the model of the aircraft in Appendix B, Figures B-5 to B-8.

1.12.1.5 Southern trail

The southern trail was easily defined, except within 12 km of Lockerbie where it tended to merge with the northern trail. Further east, it extended across southern Scotland and northern England, essentially in a straight band as far as the North Sea. Most of the significant items of wreckage were found in this trail within a range of 30 km from the main impact crater. Items recovered from the southern trail are coloured green on the model of the aircraft at Appendix B, Figures B-5 to B-8.

The trail contained numerous large items from the forward fuselage. The flight deck and nose of the aircraft fell in the curved part of this trail close to Lockerbie. Fragments of the whole of the left tailplane and the outboard portion of the right tailplane were distributed almost entirely throughout the southern trail. Between 21 and 27 km east of the main impact point (either side of Langholm) substantial sections of tailplane skin were found, some bearing distinctive signs of contact with debris moving outwards and backwards relative to the fuselage. Also found in this area were numerous isolated sections of fuselage frame, clearly originating from the crown region above the forward upper deck.

1.12.1.6 Datum line

All grid references relating to items bearing actual explosive evidence, together with those attached to heavily distorted items found to originate immediately adjacent to them on the structure, were plotted on an Ordnance Survey (OS) chart. These references, 11 in total, were all found to be distributed evenly about a mean line orientated 079¡(Grid) within the southern trail and were spread over a distance of 12 km. The distance of each reference from the line was measured in a direction parallel to the aircraft's track and all were found to be within 500 metres of the line, with 50% of them being within 250 metres of the line. This line is referred to as the datum line and is shown in Appendix B, Figure B-4.

1.12.1.7 Distribution of wreckage within the southern trail

North of the datum line and parallel to it were drawn a series of lines at distances of 250, 300, 600 and 900 metres respectively from the line, again measured in a direction parallel to the aircraft's track. The positions on the aircraft structure of specific items of wreckage, for which grid references were known with a high degree of confidence, within the bands formed between these lines, are shown in Appendix B, Figures B-10 to 13. In addition, a separate assessment of the grid references of tailplane and elevator wreckage established that these items were distributed evenly about the 600 metre line.

1.12.1.8 Area between trails

Immediately east of the crater, the southern trail converged with the northern trail such that, to an easterly distance of approximately 5 km, considerable wreckage existed which could have formed part of either trail. Further east, between 6 and 11 km from the crater, a small number of sections and fragments of the fin had fallen outside the southern boundary of the northern trail. Beyond this a large area existed between the trails in which there was no wreckage.

1.12.2 Examination of wreckage at CAD Longtown

The debris from all areas was recovered by the Royal Air Force to the Army Central Ammunition Depot Longtown, about 20 miles from Lockerbie.

Approximately 90% of the hull wreckage was successfully recovered, identified, and laid out on the floor in a two-dimensional reconstruction [Appendix B, Figure B-14]. Baggage container material was incorporated into a full three-dimensional reconstruction. Items of wreckage added to the reconstructions was given a reference number and recorded on a computer database together with a brief description of the item and the location where it was found.

1.12.2.1 Fuselage

The reconstruction revealed the presence of damage consistent with an explosion on the lower fuselage left side in the forward cargo bay area. A small region of structure bounded approximately by frames 700 & 720 and stringers 38L & 40L, had clearly been shattered and blasted through by material exhausting directly from an explosion centred immediately inboard of this location. The material from this area, hereafter referred to as the 'shatter zone', was mostly reduced to very small fragments, only a few of which were recovered, including a strip of two skins [Appendix B, Figure B-15] forming part of the lap joint at the stringer 39L position.

Surrounding the shatter zone were a series of much larger panels of torn fuselage skin which formed a 'star-burst' fracture pattern around the shatter zone. Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range. In contrast, the star-burst fractures, outside the boundary of the shatter zone, displayed evidence of more typical overload tearing, though some tears appeared to be rapid and, in the area below the missing panels, were multi-branched. These surrounding skin panels were moderately sooted in the regions adjacent to the shatter zone, but otherwise were lightly sooted or free of soot altogether. (Forensic analysis of the soot deposits on frame and skin material from this area confirmed the presence of explosive residues.) All of these skin panels had pulled away from the supporting structure and had been bent and torn in a manner which indicated that, as well as fracturing in the star burst pattern, they had also petalled outwards producing characteristic, tight curling of the sheet material.

Sections of frames 700 and 720 from the area of the explosion were also recovered and identified. Attached to frame 720 were the remnants of a section of the aluminium baggage container (side) guide rail, which was heavily distorted and displayed deep pitting together with very heavy sooting, indicating that it had been very close to the explosive charge. The pattern of distortion and damage on the frames and guide rail segment matched the overall pattern of damage observed on the skins.

The remainder of the structure forming the cargo deck and lower hull was, generally, more randomly distorted and did not display the clear indications of explosive processes which were evident on the skin panels and frames nearer the focus of the explosion. Nevertheless, the overall pattern of damage was consistent with the propagation of explosive pressure fronts away from the focal area inboard of the shatter zone. This was particularly evident in the fracture and bending characteristics of several of the fuselage frames ahead of, and behind station 700.

The whole of the two-dimensional fuselage reconstruction was examined for general evidence of the mode of disintegration and for signs of localised damage, including overpressure damage and pre-existing damage such as corrosion or fatigue. There was some evidence of corrosion and dis-bonding at the cold-bond lap joints in the fuselage. However, the corrosion was relatively light and would not have compromised significantly the static strength of the airframe. Certainly, there was no evidence to suggest that corrosion had affected the mode of disintegration, either in the area of the explosion or at areas more remote. Similarly, there were no indications of fatigue damage except for one very small region of fatigue, involving a single crack less than 3 inches long, which was remote from the bomb location. This crack was not in a critical area and had not coincided with a fracture path.

No evidence of overpressure fracture or distortion was found at the rear pressure bulkhead. Some suggestion of 'quilting' or 'pillowing' of skin panels between stringers and frames, indicative of localised overpressure, was evident on the skin panels attached to the larger segments of lower fuselage wreckage aft of the blast area. In addition, the mode of failure of the butt joint at station 520 suggested that there had been a rapid overpressure load in this area, causing the fastener heads to 'pop' in the region of stringers 13L to 16L, rather than producing shear in the fasteners. Further evidence of localised overpressure damage remote from the source of the explosion was found during the full three-dimensional reconstruction, detailed later in paragraph 1.12.3.2.

An attempt was made to analyse the fractures, to determine the direction and sequence of failure as the fractures propagated away from the region of the explosion. It was found that the directions of most of the fractures close to the explosion could be determined from an analysis of the fracture surfaces and other features, such as rivet and rivet hole distortions. However, it was apparent that beyond the boundary of the petalled region, the disintegration process had involved multiple fractures taking place simultaneously - extremely complex parallel processes which made the sequencing of events not amenable to conventional analysis.

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1.12.2.2 Wing structure and adjacent fuselage area

On completion of the initial layout at Longtown it became evident that, in the area from station 1000 to approximately station 1240 the only identifiable fuselage structure consisted of elements of fuselage skin, stringers and frames from above the cabin window belts. The wreckage from in and around the crater was therefore sifted to establish more accurately what sections of the aircraft had produced the crater. All of the material was highly fragmented, but it was confirmed that the material comprised mostly wing structure, with a few fragments of fuselage sidewall and passenger seats. The badly burnt state of these fragments made it clear that they were recovered from the area of the main impact crater, the only scene of significant ground fire. Amongst these items a number of cabin window forgings were recovered with sections of thick horizontal panelling attached having a length equivalent to the normal window spacing/frame pitch. This arrangement, with skins of this thickness, is unique to the area from station 1100 to 1260. It is therefore reasonable to assume that these fragments formed parts of the missing cabin sides from station 1000 to station 1260, which must have remained attached to the wing centre section at the time of its impact. Because of the high degree of fragmentation and the relative insignificance of the wing in terms of the overall explosive damage pattern, a reconstruction of the wing material was not undertaken. The sections of the aircraft which went into the crater are colour coded grey in Appendix B, Figures B-5 to B-8.

1.12.2.3 Fin and aft section of fuselage

Examination of the structure of the fin revealed evidence of in-flight damage to the leading edge caused by the impact of structure or cabin contents. This damage was not severe or extensive and the general break-up of the fin did not suggest either a single readily defined loading direction, or break-up due to the effects of leading edge impact. A few items of fin debris were found between the northern and southern trails.

A number of sections of fuselage frame found in the northern trail exhibited evidence of plastic deformation of skin attachment cleats and tensile overload failure of the attachment rivets. This damage was consistent with that which would occur if the skin had been locally subjected to a high loading in a direction normal to its plane. Although this was suggestive of an internal overpressure condition, the rear fuselage revealed no other evidence to support this possibility. Examination of areas of the forward fuselage known to have been subjected to high blast overpressures revealed no comparable evidence of plastic deformation in the skin attachment cleats or rivets, most skin attachment failures appearing to have been rapid.

Calculations made on the effects of internal pressure generated by an open ended fuselage descending at the highest speed likely to have been experienced revealed that this could not generate an internal pressure approaching that necessary to cause failure in an intact cabin structure.

1.12.2.4 Baggage containers

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited damage consistent with being close to a detonating high explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence of explosive damage. It was evident, from the main wreckage layout, that the explosion had occurred in the forward cargo hold and, although all baggage container wreckage was examined, only items from this area which showed the relevant characteristics were considered for the reconstruction. Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to Lockerbie, whilst that from the forward hold was scattered along the southern wreckage trail.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this, two adjacent containers, one of metal construction the other fibreglass, were identified as exhibiting damage likely to have been caused by the explosion. Those parts which could be positively identified as being from these two containers were assembled onto one of three simple wooden frameworks, one each for the floor and superstructure of the metal container and one for the superstructure of the fibreglass container. From this it was positively determined that the explosion had occurred within the metal container (serial number AVE 4041 PA), the direct effects of this being evident also on the forward face of the adjacent fibreglass container (serial number AVN 7511 PA) and on the local airframe on the left side of the aircraft in the region of station 700. It was therefore confirmed that this metal container had been loaded in position 14L in agreement with the aircraft loading records. While this work was in progress a buckled section of the metal container skin was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device (IED).

The reconstruction of these containers and their relationship to the aircraft structure is described in detail in Appendix F. Examination of all other components of the remaining containers revealed only damage consistent with ejection into the high speed slipstream and/or ground impact, and that only one device had detonated within the containers on board the aircraft.

1.12.3 Fuselage three-dimensional reconstruction

1.12.3.1 The reconstruction

The two-dimensional reconstruction successfully established that there had been an explosion in the forward hold; its location was established and the general damage characteristics in the vicinity of the explosion were determined. However, the mechanisms by which the failure process developed from local damage in the immediate vicinity of the explosion to the complete structural break-up and separation of the whole forward section of the fuselage, could not be adequately investigated without recourse to a more elaborate reconstruction.

To facilitate this additional work, wreckage forming a 65 foot section of the fuselage (approximately 30 feet each side of the explosion) was transported to AAIB Farnborough, where it was attached to a specially designed framework to form a fully three-dimensional reconstruction [Appendix B, Figures B-16 and B-17] of the complete fuselage between stations 360 & 1000 (from the separated nose section back to the wing cut out). The support framework was designed to provide full and free access to all parts of the structure, both internally and externally. Because of height constraints, the reconstruction was carried out in two parts, with the structure divided along a horizontal line at approximately the upper cabin floor level. The previously reconstructed containers were also transported to AAIB Farnborough to allow correlation of evidence with, and partial incorporation into, the fuselage reconstruction.

Structure and skin panels were attached to the supporting framework by their last point of attachment, to provide a better appreciation of the modes and direction of curling, distortion, and ultimate separation. Thus, the panels of skin which had petalled back from the shatter zone were attached at their outer edges, so as to identify the bending modes of the panels, the extent of the petalled region, and also the size of the resulting aperture in the hull. In areas more remote from the explosion, the fracture and tear directions were used together with distortion and curling directions to determine the mode of separation, and thus the most appropriate point of attachment to the reconstruction. Cabin floor beam segments were supported on a steel mesh grid and a plot of the beam fractures is shown at Appendix B, Figure B-18.

The cargo container base elements were separated from the rest of the container reconstruction and transferred to the main wreckage reconstruction, where the re-assembled container base was positioned precisely onto the cargo deck. To assist in the correlation of the initial shatter zone and petalled-out regions with the position of the explosive device, the boundaries of the skin panel fractures were marked on a transparent plastic panel which was then attached to the reconstruction to provide a transparent pseudo-skin showing the positions of the skin tear lines. This provided a clear visual indication of the relationship between the skin panel fractures and the explosive damage to the container base, thus providing a more accurate indication of the location of the explosive device.

1.12.3.2 Summary of explosive features evident

The three-dimensional reconstruction provided additional information about the region of tearing and petalling around the shatter zone. It also identified a number of other regions of structural damage, remote from the explosion, which were clearly associated with severe and rapidly applied pressure loads acting normal to the skin's internal surface. These were sufficiently sharp-edged to pre-empt the resolution of pressure induced loads into membrane tension stresses in the skin: instead, the effect was as though these areas of skin had been struck a severe 'pressure blow' from within the hull.

The two types of damage, i.e. the direct blast/tearing/petalling damage and the quite separate areas of 'pressure blow' damage at remote sites were evidently caused by separate mechanisms, though it was equally clear that each was caused by explosive processes, rather than more general disintegration.

The region of petalling was bounded (approximately) by frames 680 and 740, and extended from just below the window belt down nearly to the keel of the aircraft [Appendix B, Figure B-19, region A]. The resulting aperture measured approximately 17 feet by 5 feet. Three major fractures had propagated beyond the boundary of the petalled zone, clearly driven by a combination of hull pressurisation loading and the relatively long term (secondary) pressure pulse from the explosion. These fractures ran as follows:

(i) rearwards and downward in a stepped fashion, joining the stringer 38L lap joint at around station 840, running aft along stringer 38L to around station 920, then stepping down to stringer 39L and running aft to terminate at the wing box cut-out [Appendix B, Figure B-19, fracture 1].
(ii) downwards and forward to join the stringer 44L lap joint, then running forward along stringer 44L as far as station 480 [Appendix B, Figure B-19, fracture 2].
(iii) downwards and rearward, joining the butt line at station 740 to run under the fuselage and up the right side to a position approximately 18 inches above the cabin floor level [Appendix B, Figures B-19 and B-20, fracture 3].

The propagation of tears upwards from the shatter zone appeared to have taken the form of a series of parallel fractures running upwards together before turning towards each other and closing, forming large flaps of skin which appear to have separated relatively cleanly.

Regions of skin separation remote from the site of the explosion were evident in a number of areas. These principally were:

(i) A large section of upper fuselage skin extending from station 500 back to station 760, and from around stringers 15/19L up as far as stringer 5L [Appendix B, Figures B-19 and B-20, region B], and probably extending further up over the crown. This panel had separated initially at its lower forward edge as a result of a pressure blow type of impulse loading, which had popped the heads from the rivets at the butt joint on frame 500 and lifted the skin flap out into the airflow. The remainder of the panel had then torn away rearwards in the airflow.
A region of 'quilting' or 'pillowing', i.e. spherical bulging of skin panels between frames and stringers, was evident on these panels in the region between station 560 and 680, just below the level of the upper deck floor, indicative of high internal pressurisation loading [Appendix B, Figure B-19, region C].
(ii) A smaller section of skin between stations 500 and 580, bounded by stringers 27L and 34L [Appendix B, Figure B-19, region D], had also been

'blown' outwards at its forward edge and torn off the structure rearwards. A characteristic curling of the panel was evident, consistent with rapid, energetic separation from the structure.
(iii) A section of thick belly skin extending from station 560, stringers 40R to 44R, and tapering back to a point at stringer 45R/station720 [Appendix B, Figure B-19 and B-20, region E], had separated from the structure as a result of a very heavy 'pressure blow' load at its forward end which had popped the heads off a large number of substantial skin fasteners. The panel had then torn away rearwards from the structure, curling up tightly onto itself as it did so - indicating that considerable excess energy was involved in the separation process (over and above that needed simply to separate the skin material from its supporting structure).
(iv) A panel of skin on the right side of the aircraft, roughly opposite the explosion, had been torn off the frames, beginning at the top edge of the panel situated just below the window belt and tearing downwards towards the belly [Appendix B, Figure B-20, region F]. This panel was curled downwards in a manner which suggested significant excess energy.

Appendix B, Figure B-21 shows a plot of the fractures noted in the fuselage skins between stations 360 and 1000.

The cabin floor structure was badly disrupted, particularly in the general area above the explosion, where the floor beams had suffered localised upward loading sufficient to fracture them, and the floor panels were missing. Elsewhere, floor beam damage was mainly limited to fractures at the outer ends of the beams and at the centreline, leaving sections of separated floor structure comprising a number of half beams joined together by the Nomex honeycomb floor panels.

1.12.3.3 General damage features not directly associated with explosive forces.

A number of features appeared to be a part of the general structural break-up which followed on from the explosive damage, rather than being a part of the explosive damage process itself. This general break-up was complex and, to a certain extent, random. However, analysis of the fractures, surface scores, paint smears and other features enabled a number of discreet elements of the break-up process to be identified. These elements are summarised below.

(i) Buckling of the window belts on both sides of the aircraft was evident between stations 660 and 800. That on the left side appeared to be the result of in-plane bending in a nose up sense, followed by fracture. The belt on the right side had a large radius curve suggesting lateral deflection of the fuselage possibly accompanied by some longitudinal compression. This terminated in a peeling failure of the riveted joint at station 800.

(ii) On the left side three fractures, apparently resulting from in-plane bending/buckling distortion, had traversed the window belt [Appendix B, Figure B-21, detail G]. Of these, the forward two had broken through the window apertures and the aft fracture had exploited a rivet line at the region of reinforcement just forward of the L2 door aperture. On the right side, the window belt had peeled rearwards, after buckling had occurred, separating from the rest of the fuselage, following rivet failure, at the forward edge of the R2 door aperture.

(iii) All crown skins forward of frame 840 were badly distorted and a number of pieces were missing. It was clearly evident that the skin sections from this region had struck the empennage and/or other structure following separation.

(iv) The fuselage left side lower lobe from station 740 back to the wing box cut-out, and from the window level down to the cargo deck floor (the fracture line along stringer 38L), had peeled outwards, upwards and rearwards - separating from the rest of the fuselage at the window belt. The whole of this separated section had then continued to slide upwards and rearwards, over the fuselage, before being carried back in the slipstream and colliding with the outer leading edge of the right horizontal stabiliser, completely disrupting the outer half. A fragment of horizontal stabiliser spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door [Appendix B, Figure B-22].

(v) A large, clear, imprint of semi-eliptical form was apparent on the lower right side at station 360 which had evidently been caused by the separating forward fuselage section striking the No 3 engine as it swung rearwards and to the right (confirmed by No 3 engine fan cowl damage).

1.12.3.4 Tailplane three-dimensional reconstruction

The tailplane structural design took the form of a forward and an aft torque box. The forward box was constructed from light gauge aluminium alloy sheet skins, supported by closely pitched, light gauge nose ribs but without lateral stringers. The aft torque box incorporated heavy gauge skin/stringer panels with more widely spaced ribs. The front spar web was of light gauge material. Leading edge impacts inflicted by debris would therefore have had the capacity to reduce the tailplane's structural integrity by passing through the light gauge skins and spar web into the interior of the aft torque box, damaging the shear connection between top and bottom skins in the process and thereby both removing the bending strength of the box and opening up the weakened structure to the direct effects of the airflow.

Examination of the rebuilt tailplane structure at AAIB Farnborough left little doubt that it had been destroyed by debris striking its leading edges. In addition, the presence on the skins of smear marks indicated that some unidentified soft debris had contacted those surfaces whilst moving with both longitudinal and lateral velocity components relative to the aircraft.

The reconstructed left tailplane [Appendix B, Figure B-23] showed evidence that disruption of the inboard leading edge, followed respectively by the forward torque box, front spar web and main torque box, occurred as a result of frontal impact by the base of a baggage container. Further outboard, a compact object appeared to have struck the underside of the leading edge and penetrated to the aft torque box. In both cases, the loss of the shear web of the front spar appeared to have permitted local bending failure of the remaining main torque box structure in a tip downwards sense, consistent with the normal load direction. For both events to have occurred it would be reasonable to assume that the outboard damage preceded that occurring inboard.

The right tailplane exhibited massive leading edge impact damage on the outboard portion which also appeared to have progressed to disruption of the aft torsion box. A fragment of right tailplane spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door and it is clear that this area of forward left fuselage had travelled over the top of the aircraft and contributed to the destruction of the outboard right tailplane.

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1.12.4 Examination of engines

All four engines had struck the ground in Lockerbie with considerable velocity and therefore sustained major damage, in particular to most of the fan blades. The No 3 engine had fallen 1,100 metres north of the other three engines, striking the ground on its rear face, penetrating a road surface and coming to rest without any further change of orientation i.e. with the front face remaining uppermost. The intake area contained a number of loose items originating from within the cabin or baggage hold. It was not possible initially to determine whether any of the general damage to any of the engine fans or the ingestion noted in No 3 engine intake occurred whilst the relevant engines were delivering power or at a later stage.

Numbers 1, 2 and 3 engines were taken to British Airways Engine Overhaul

Limited for detailed examination under AAIB supervision in conjunction with a specialist from the Pratt and Whitney Engine Company. During this examination the following points were noted:

(i) No 2 engine (situated closest to the site of the explosion) had evidence of blade "shingling" in the area of the shrouds consistent with the results of major airflow disturbance whilst delivering power. (This effect is produced when random bending and torsional deflection occurs, permitting the mid-span shrouds to disengage and repeatedly strike the adjacent aerofoil surfaces of the blades). The interior of the air intake contained paint smears and other evidence suggesting the passage of items of debris. One such item of significance was a clear indentation produced by a length of cable of diameter and strand size similar to that typically attached to the closure curtains on the baggage containers.

(ii) No 3 engine, identified on site as containing ingested debris from within the aircraft, nonetheless had no evidence of the type of shingling seen on the blades of No 2 engine. Such evidence is usually unmistakable and its absence is a clear indication that No 3 engine did not suffer a major intake airflow disturbance whilst delivering significant power. The intake structure was found to have been crushed longitudinally by an impact on the front face although, as stated earlier, it had struck the ground on its rear face whilst falling vertically.

(iii) All 3 engines had evidence of blade tip rubs on the fan cases having a combination of circumference and depth greater than hitherto seen on any investigation witnessed on Boeing 747 aircraft by the Pratt and Whitney specialists. Subsequent examination of No 4 engine confirmed that it had a similar deep, large circumference tip rub. These tip-rubs on the four engines were centred at slightly different clock positions around their respective fan cases.

The Pratt and Whitney specialists supplied information which was used to interpret the evidence found on the blades and fan cases including details of engine dynamic behaviour necessary to produce the tip rub evidence. This indicated that the depth and circumference of tip rubs noted would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left.

Pratt and Whitney also advised that:

(i) Airflow disruption such as that presumed to have caused the shingling

observed on No 2 engine fan blades was almost invariably the result of damage to the fan blade aerofoils, resulting from ingestion or blade failure.
(ii) Tip rubs of a depth and circumference noted on all four engines could be expected to reduce the fan rotational energy on each to a negligible value within approximately 5 seconds.
(iii) Airflow disruption sufficient to cause the extent of shingling noted on the fan blades of No 2 engine would also reduce the rotational fan energy to a negligible value within approximately 5 seconds.

1.13 Medical and pathological information

The results of the post mortem examination of the victims indicated that the majority had experienced severe multiple injuries at different stages, consistent with the in-flight disintegration of the aircraft and ground impact. There was no pathological indication of an in-flight fire and no evidence that any of the victims had been injured by shrapnel from the explosion. There was also no evidence which unequivocally indicated that passengers or cabin crew had been killed or injured by the effects of a blast. Although it is probable that those passengers seated in the immediate vicinity of the explosion would have suffered some injury as a result of blast, this would have been of a secondary or tertiary nature.

Of the casualties from the aircraft, the majority were found in areas which indicated that they had been thrown from the fuselage during the disintegration. Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section. The fragmented remains of 13 passengers who had been allocated seats around the eight missing persons were found in or near the crater formed by the wing. Whilst there is no unequivocal proof that the missing people suffered the same fate, it would seem from the pattern that the missing passengers remained attached to the wing structure until impact.

1.14 Fire

Of the several large pieces of aircraft wreckage which fell in the town of Lockerbie, one was seen to have the appearance of a ball of fire with a trail of flame. Its final path indicated that this was the No 3 engine, which embedded itself in a road in the north-east part of the town. A small post impact fire posed no hazard to adjacent property and was later extinguished with water from a hosereel. The three remaining engines landed in the Netherplace area of the town. One severed a water main and the other two, although initially on fire, were no risk to persons or property and the fires were soon extinguished.

A large, dark, delta shaped object was seen to fall at about the same time in the Sherwood area of the town. It was not on fire while in the air, however, a fireball several hundred feet across followed the impact. It was of relatively short duration and large amounts of debris were thrown into the air, the lighter particles being carried several miles downwind, while larger pieces of burning debris caused further fires, including a major one at the Townfoot Garage, up to 350 metres from the source. It was determined that the major part of both wings, which included the aircraft fuel tanks, had formed the crater. A gas main had also been ruptured during the impact.

At 19.04 hrs the Dumfries Fire Brigade Control received a call from a member of the public which indicated that there had been a "huge boiler explosion" at Westacres, Lockerbie, however, subsequent calls soon made it clear that it was an aircraft which had crashed. At 19.07 hrs the first appliances were mobile and at 1910 hrs one was in attendance in the Rosebank area. Multiple fires were identified and it soon became apparent that a major disaster had occurred in the town and the Fire Brigade Major Incident Plan was implemented. During the initial phase 15 pumping appliances from various brigades were deployed but this number was ultimately increased to 20.

At 22.09 hrs the Firemaster made an assessment of the situation. He reported that there was a series of fires over an area of the town centre extending 1† by € mile. The main concentration of the fire was in the southwest of the town around Sherwood Park and Sherwood Crescent. Appliances were in attendance at other fires in the town, particularly in Park Place and Rosebank Crescent. Water and electricity supplies were interrupted and water had to be brought into the town.

By 02.22 hrs on 22 December, all main seats of fire had been extinguished and the firemen were involved in turning over and damping down. At 04.42 hrs small fires were still occurring but had been confined to the Sherwood Crescent area.

1.15 Survival aspects

1.15.1 Survivability

The accident was not survivable.

1.15.2 Emergency services

A chronology of initial responses by the emergency services is listed below:-

Time	Event
19.03 hrs	Radio message from Police patrol in Lockerbie to Dumfries and Galloway Constabulary reporting an aircraft crash at Lockerbie.
19.04 hrs	Emergency call to Dumfries and Galloway Fire Brigade.
19.37 hrs	First ambulances leave for Dumfries and Galloway Royal Infirmary with injured town residents. (2- serious; 3- minor)
19.40 hrs	Sherwood Park and Sherwood Crescent residents evacuated to Lockerbie Town Hall.
20.25 hrs	Nose section of N739PA discovered at Tundergarth (approximately 4 km east of Lockerbie).

During the next few days a major emergency operation was mounted using the guidelines of the Dumfries and Galloway Regional Peacetime Emergency Plan. The Dumfries and Galloway Constabulary was reinforced by contingents from Strathclyde and Lothian & Borders Constabularies. Resources from HM Forces were made available and this support was subsequently authorised by the Ministry of Defence as Military Aid to the Civil Power. It included the provision of military personnel and a number of helicopters used mainly in the search for and recovery of aircraft wreckage. It was apparent at an early stage that there were no survivors from the aircraft and the search and recovery of bodies was mainly a Police task with military assistance.

Many other agencies were involved in the provision of welfare and support services for the residents of Lockerbie, relatives of the aircraft's occupants and personnel involved in the emergency operation.

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1.16 Tests and research

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity spherically propagating shock wave which will expand outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant because it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter, irrespective of charge size, thus providing a means of calculating the standoff distance of the explosive charge from the fuselage skin. Calculations suggest that a charge standoff distance of aproximately 25 inches would result in a shattered region approximately 18 to 20 inches in diameter, comparable to the size of the shattered region evident in the wreckage. This aspect is covered in greater detail in [Appendix G].

1.17 Additional information

1.17.1 Recorded radar information

Recorded radar information on the aircraft was available from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen from which it was clear that the flight had progressed in a normal manner until secondary surveillance radar (SSR) was lost.

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. The last secondary return from the aircraft was recorded at 19.02:46.9 hrs, identifying N739PA at Flight Level 310, and at the next radar return there is no SSR data, only 4 primary returns. It was concluded that the aircraft was, by this time, no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items had been ejected at high speed probably to both right and left of the aircraft.

Each rotation of the radar head thereafter showed the number of returns increasing, with those first identified across track having slowed down very quickly and followed a track along the prevailing wind line. The radar evidence then indicated that a further break-up of the aircraft had occurred and formed a parallel wreckage trail to the north of the first. From the absence of any returns travelling along track it was concluded that the main wreckage was travelling almost vertically downwards for much of the time.

A detailed analysis of the recorded radar information, together with the radar, ATC and seismic recordings is contained in Appendix C.

1.17.2 Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event measuring 1.6 on the Richter scale and, with appropriate corrections for the times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

An analysis of the seismic recording, together with the radar, ATC and radar information is contained in Appendix C.

1.17.3 Trajectory analysis

A detailed trajectory analysis was carried out by Cranfield Institute of Technology in an effort to provide a sequence for the aircraft disintegration. This analysis comprised several separate processes, including individual trajectory calculations for a limited number of key items of wreckage and mathematical modelling of trajectory paths adopted by a series of hypothetical items of wreckage encompassing the drag/weight spectrum of the actual wreckage.

The work carried out at Cranfield enabled the reasons for the two separate trails to be established. The narrow northern trail was shown to be created by debris released from the aircraft in a vertical dive between 19,000 and 9,000 feet overhead Lockerbie. The southern trail, longer and straight for most of its length, appeared to have been created by wreckage released during the initial disintegration at altitude whilst the aircraft was in level flight. Those items falling closest to Lockerbie would have been those with higher density which would travel a significant distance along track before losing all along-track velocity, whilst only drifting a small distance downwind, owing to the high speed of their descent. The most westerly items thus showed the greatest such effect. The southern trail therefore had curved boundaries at its western end with the curvature becoming progressively less to the east until the wreckage essentially fell in a straight band. Thus wreckage in the southern trail positioned well to the east could be assumed to have retained negligible velocity along aircraft track after separation and the along-track distribution could be used to establish an approximate sequence of initial disintegration.

The analysis calculated impact speeds of 120 kts for the nose section weighing approximately 17,500 lb and 260 kts for the engines and pylons which each weighed about 13,500 lb. Based on the best available data at the time, the analysis showed that the wing (approximately 100,000 lb of structure containing an estimated 200,000 lb of fuel) could have impacted at a speed, in theory, as high as 650 kts if it had 'flown' in a streamlined attitude such that the drag coefficient was minimal. However, because small variations of wing incidence (and various amounts of attached fuselage) could have resulted in significant increases in drag coefficient, the analysis also recognized that the final impact speed of the wing could have been lower.

1.17.4 Space debris re-entry

Four items of space debris were known to have re-entered the Earth's atmosphere on 21 December 1988. Three of these items were fragments of debris which would not have survived re-entry, although their burn up in the upper atmosphere might have been visible from the Earth's surface. The fourth item landed in the USSR at 09.50 hrs UTC.

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2 ANALYSIS

2.1 Introduction

The airport security and criminal aspects of the destruction of Boeing 747 registration N739PA near Lockerbie on 21 December 1988 are the subjects of a separate investigation and are not covered in this report. This analysis discusses the technical aspects of the disintegration of the aircraft and considers possible ways of mitigating the effects of an explosion in the future.

2.2 Explosive destruction of the aircraft

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in

Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage, including those exhibiting positive evidence of a detonating high performance plastic explosive. The scatter of these items about the datum line may have been due partly to velocities imparted by the force of the detonating explosive and partly by the difficulty experienced in pinpointing the location of the wreckage accurately in relatively featureless terrain and poor visibility. However, the random nature of the scatter created by these two effects would have tended to counteract one another, and a major error in any one of the eleven grid references would have had little overall effect on the whole line. There is, therefore, good reason to have confidence in the validity of the datum line.

The items used to define the datum line, included those exhibiting positive evidence of a detonating high performance plastic explosive, would have been the first pieces to have been released from the aircraft. The datum line was projected westwards until it intersected the known radar track of the aircraft in order to derive the position of the aircraft along track at which the explosive items were released and therefore the position at which the IED had detonated. This position was OS grid reference 146786 and is annotated Point C in Appendix B, Figure B-4. Point C was well within the circle of accuracy (±525 metres) of the position at which the loud noise was heard on the CVR (Point B). There can, therefore, be no doubt that the loud noise on the CVR was directly associated with the detonation of the IED and that this explosion initiated the disintegration process and directly caused the loss of the aircraft.

2.3 Flight recorders

2.3.1 Digital flight data recordings

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data

Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to € second. These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the recording from the DFDR fitted to N739PA, which is detailed in Appendix C, showed that the recorded data simply stopped. Following careful examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19.02:50 hrs ±1 second. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or was old data from a previous recording.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when the aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

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2.3.2 Cockpit voice recorders

The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the CVR when it stopped at 19.02:50 hrs ±1 second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

2.3.3 Detection of explosive occurrences

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985, RARDE were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems. This recommendation was accepted.

Preliminary results from the trials indicate that, if a suitable sensor can be developed, its output will need to be recorded in real time and therefore it may require wiring to the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

2.4 IED position within the aircraft

From the detailed examination of the reconstructed luggage containers, discussed at paragraph 1.12.2.4 and in Appendix F, it was evident that the IED had been located within a metal container (serial number AVE 4041 PA), near its aft outboard quarter as shown in Appendix F, Figure F-13. It was also clear that the container was loaded in position 14L of the forward hold which placed the explosive charge approximately 25 inches inboard from the fuselage skin at frame 700. There was no evidence to indicate that there was more than one explosive charge.

2.5 Engine evidence

To produce the fan blade tip rub damage noted on all engines by means of airflow inclined to the axes of the nacelles would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left while all of the engines were attached to the wing.

The shingling damage noted on the fan blades of No 2 engine can only be attributed to airflow disturbance caused by ingestion related fan blade damage occurring when substantial power was being delivered. This is readily explained by the fact that No 2 engine intake is positioned some 27 feet aft and 30 feet outboard of the site of the explosion and that the interior of the intake exhibited a number of prominent paint smears and general foreign object damage. This damage included evidence of a strike by a cable similar to that forming part of the closure curtain of a typical baggage container. It is inconceivable that an independent blade failure could have occurred in the short time frame of this event. By similar reasoning, the absence of such shingling damage on blades of No 3 engine was a reliable indication that it suffered no ingestion until well into the accident sequence.

The combination of the position of the explosive device and the forward speed of the aircraft was such that significant sized debris resulting from the explosion would have been available to be ingested by No 2 engine within milliseconds of the explosion. In view of the fact that the tip rub damage observed on the fan case of No 2 engine is of similar magnitude to that observed on the other three engines it is reasonable to deduce that a manoeuvre of the aircraft occurred before most of the energy of the No 2 engine fan was lost due to the effect of ingestion (seen only in this engine). Since this shingling effect could only readily be produced as a by-product of ingestion whilst delivering considerable power, it is reasonable to assume that this was also occurring before loss of major fan energy due to tip rubbing took place. Hence both phenomena must have been occurring simultaneously, or nearly so, to produce the effects observed and must have occupied a time frame of substantially less than 5 seconds. The onset of this time period would have been the time at which debris from the explosion first inflicted damage to fan blades in No 3 engine and, since the fan is only approximately 40 feet from the location of the explosive device, this would have been an insignificant time interval after the explosion.

It was therefore concluded from this evidence that the wing with all of the engines attached had achieved a marked nose down and left roll attitude change well within 5 seconds of the explosion.

2.6 Detachment of forward fuselage

Examination of the three major structural elements either side of the region of station 800 on the right side of the fuselage makes it clear that to produce the curvature of the window belt and peeling of the riveted joint at the R2 door aperture requires the door pillar to be securely in position and able to react longitudinal and lateral loads. This in turn requires the large section of fuselage on the right side between stations 760 and 1000 (incorporating the right half of the floor) to be in position in order to locate the lower end of the door pillar. Thus both these sections must have been in position until the section from station 560 to 800 (right side) had completed its deflection to the right and peeled from the door pillar. Separation of the forward fuselage must thus have been complete by the time all three items mentioned above had fallen free.

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2.7 Speed of initial disintegration

The distribution of wreckage in the bands between the datum line and the 250, 300, 600 and 900 metre lines was examined in detail. The positions of these items of structure on the aircraft are shown in Appendix B, Figures B-10 to B-13. It should be noted that the position on the ground of these items, although separated by small distances when measured in a direction along aircraft track, were distributed over large distances when measured along the wreckage trail. All were recovered from positions far enough to the east to be in that part of the southern trail which was sufficiently close, theoretically, to a straight line for any curvature effect to be neglected.

The wreckage found in each of the bands enabled an approximate sequence of break-up to be established. It was clear that as the distance travelled from the datum line increased, items of wreckage further from the station of the IED were encountered. The items shown on the diagram as falling on the 250 metre band also include those fragments of lower forward fuselage skin having evidence of explosive damage and presumed to have separated as a direct result of the blast. However, a few portions of the upper forward fuselage were also found within the 250 metre band, suggesting that these items had also separated as a result of the blast.

By the time the 300 metre line was reached much of the structure from the right side in the region of the explosive device had been shed. This included the area of window belt, referred to in paragraph 2.6 above, which gave clear indications that the forward structure had detached to the right and finally peeled away at station 800. It also included the areas of adjacent structure immediately to the rear of station 800 about which the forward structure would have had to pivot. By the time the 600 metre line was reached, there was clearly insufficient structure left to connect the forward fuselage with the remainder of the aircraft. Wreckage between the 600 and 900 metre lines consisted of structure still further from the site of the IED.

There is evidence that a manoeuvre occurred at the time of the explosion which would have produced a significant change of the aircraft's flight path, however, it is considered that the change in the horizontal velocity component in the first few seconds would not have been great. The original groundspeed of the aircraft was therefore used in conjunction with the distribution of wreckage in the successive bands to establish an approximate time sequence of break-up of the forward fuselage. Assuming the original ground speed of 434 Kts, the elapsed flight times from the datum to each of the parellel lines were calculated to be:

Distance (metres)	250	300	600	900
Time (seconds)	1.1	1.3	2.7	4.0

Thus, there is little doubt that separation of the forward fuselage was complete within 2 to 3 seconds of the explosion.

The separate assessment of the known grid references of tailplane and elevator wreckage in the southern trail revealed that those items were evenly distributed about the 600 metre line and therefore that most of the tailplane damage occurred after separation of the forward fuselage was complete.

2.8 The manoeuvre following the explosion

The engine evidence, timing and mode of disintegration of the fuselage and tailplane suggests that the latter did not sustain significant damage until the forward fuselage disintegration was well advanced and the pitch/roll manoeuvre was also well under way.

Examination of the three dimensional reconstruction makes it clear that both main and upper deck floors were disrupted by the explosion. Since pitch control cables are routed through the upper deck floor beams and the roll control cables through the main deck beams, there is a strong possibility that movement of the beams under explosive forces would have applied inputs to the control cables, thus operating control surfaces in both axes.

2.9 Secondary disintegration

The distribution of fin debris between the trails suggests that disintegration of the fin began shortly before the vertical descent was established. No single mode of failure was identified and the debris which had struck the leading edge had not caused major disruption. The considerable fragmentation of the thick panels of the aft torque box was also very different from that noted on the corresponding structure of the tailplanes. It was therefore concluded that the mode of failure was probably flutter.

The finding, in the northern trail, of a slide raft wrapped around a flap track fairing suggests that at a later stage of the disintegration the rear of the aircraft must have experienced a large angle of sideslip. The loss of the fin would have made this possible and also subjected the structure to large side loads. It is possible that such side loading would have assisted the disintegration of the rear fuselage and also have caused bending failure of the pylon attachments of the remaining three engines.

2.10 Impact speed of components

The trajectory analysis carried out by Cranfield Institute of Technology calculated impact speeds of 120 kts for the nose section, and 260 kts for the engines and pylons. These values were considered to be reliable because the drag coefficients could be estimated with a reasonable degree of confidence. Based on the best available data at the time, the analysis also showed that the wing could have impacted at a speed, in theory, as high as 650 kts if it had flown in a streamlined attitude such that the drag coefficient was minimal. However, it was also recognized that relatively small changes in the angle of incidence of the wing would have produced a significant increase in drag with a consequent reduction in impact speed. Refinement of timing information and radar data subsequent to the Cranfield analysis has enabled a revised estimate to be made of the mean speed of the wing during the descent.

The engine evidence indicated that there had been a large nose down attitude change of the aircraft early in the event. The Cranfield analysis also showed that the rear fuselage had disintegrated while essentially in a vertical descent between 19,000 and 9,000 feet over Lockerbie. Assuming that, following the explosion, the wing followed a straight line descending flight profile from 31,000 feet to 19,000 feet directly overhead Lockerbie and then descended vertically until impact, the wing would have travelled the minimum distance practicable. The ground distance between the geographical position at which the disintegration started (Figure B-4, Point B) and the crater made by the wing impact was 2997 ±525 metres (9833 ±1722 feet). The time interval between the explosion and the wing impact was established in Appendix C as 46.5 ±2 seconds. Based on the above times and distances the mean linear speed achieved by the wing would have been about 440 kts.

The impact location of Nos 1, 2, and 4 engines closely grouped in Lockerbie was consistent with their nearly vertical fall from a point above the town. If they had separated at about 19,000 feet and the wing had then flown as much as one mile away from the overhead position before tracking back to impact, the total flight path length of the wing would not have required it to have achieved a mean linear speed in excess of 500 kts.

Any speculation that the flight path of the wing could have been longer would have required it to have undergone manoeuvres at high speed in order to arrive at the 19,000 feet point. The manoeuvres involved would almost certainly have resulted in failure of the primary wing structure which, from distribution of wing debris, clearly did not occur. Alternatively the wing could have travelled more than one mile from Lockerbie after reaching the 19,000 feet point, but this was considered unlikely. It is therefore concluded that the mean speed of the wing during the descent was in the region of 440 to 500 kts.

2.11 Sequence of disintegration

Analysis of wreckage in each of the bands, taken in conjunction with the engine evidence and the three-dimensional reconstruction, suggests the following sequence of disintegration:

(i) The initial explosion triggered a sequence of events which effectively destroyed the structural integrity of the forward fuselage. Little more then remained between stations 560 and 760 (approximately) than the window belts and the cabin sidewall structure immediately above and below the windows, although much of the cargo-hold floor structure appears to have remained briefly attached to the aircraft. [Appendix B, Figure B-24]

(ii) The main portion of the aircraft simultaneously entered a manoeuvre involving a marked nose down and left roll attitude change, probably as a result of inputs applied to the flying control cables by movement of structure.

(iii) Failure of the left window belt then occurred, probably in the region of station 710, as a result of torsional and bending loads on the fuselage imparted by the manoeuvre (i.e. the movement of the forward fuselage relative to the remainder of the aircraft was an initial twisting motion to the right, accompanied by a nose up pitching deflection).
(iv) The forward fuselage deflected to the right, pivoting about the starboard window belt, and then peeled away from the structure at station 800. During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation was apparently complete within 3 seconds of the explosion.
(v) Structure and contents of the forward fuselage struck the tail surfaces contributing to the destruction of the outboard starboard tailplane and causing substantial damage to the port unit. This damage occurred approximately 600 metres track distance after the explosion and therefore appears to have happened after the fuselage separation was complete.
(vi) Fuselage structure continued to break away from the aircraft and the separated forward fuselage section as they descended.
(vii) The aircraft maintained a steepening descent path until it reached the vertical in the region of 19,000 feet approximately over the final impact point. Shortly before it did so the tail fin began to disintegrate.
(viii) The mode of failure of the fin is not clear, however, flutter of its structure is suspected.
(ix) Once established in the vertical dive, the fin torque box continued to disintegrate, possibly permitting the remainder of the aircraft to yaw sufficiently to cause side load separation of Nos 1, 2 and 4 engines, complete with their pylons.
(x) Break-up of the rear fuselage occurred during the vertical descent, possibly as a result of loads induced by the yaw, leaving a section of cabin floor and baggage hold from approximately stations 1241 to 1920, together with 3 landing gear units, to fall into housing at Rosebank Terrace.
(xi) The main wing structure struck the ground with a high yaw angle at Sherwood Crescent.
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2.12 Explosive mechanisms and the structural disintegration

The fracture and damage pattern analysis was mainly of an interpretive nature involving interlocking pieces of subtle evidence such as paint smears, fracture and rivet failure characteristics, and other complex features. In the interests of brevity, this analysis will not discuss the detailed interpretation of individual fractures or damage features. Instead, the broader 'damage picture' which emerged from the detailed work will be discussed in the context of the explosive mechanisms which might have produced the damage, with a view to identifying those features of greatest significance.

It is important to keep in mind that whilst the processes involved are considered and discussed separately, the timescales associated with shock wave propagation and the high velocity gas flows are very short compared with the structural response timescales. Consequently, material which was shattered or broken by the explosive forces would have remained in place for a sufficiently long time that the structure can be considered to have been intact throughout much of the period that these explosive propagation phenomena were taking place.

2.12.1 Direct blast effect

2.12.1.1 Shock wave propagation

The direct effect of the explosive detonation within the container was to produce a high intensity spherically propagating shock wave which expanded from the centre of detonation close to the side of the container, shattering part of the side and base of the container as it passed through into the gap between the container and the fuselage skin. In breaking out of the container, some internal reflection and Mach stem interaction would have occurred, but this would have been limited by the absorptive effect of the baggage inboard, above, and forward of the charge. The force of the explosion breaking out of the container would therefore have been directed downwards and rearwards.

The heavy container base was distorted and torn downwards, causing buckling of the adjoining section of frame 700, and the container sides were blasted through and torn, particularly in the aft lower corner. Some of the material in the direct path of the explosive pressure front was reduced to shrapnel sized pieces which were rapidly accelerated outwards behind the primary shock front. Because of the overhang of the container's sloping side, fragments from both the device itself and the container wall impacted the projecting external flange of the container base edge member, producing micro cratering and sooting. Metallurgical examination of the internal surfaces of these craters identified areas of melting and other features which were consistent only with the impact of very high energy particles produced by an explosion at close quarters. Analysis of material on the crater surfaces confirmed the presence of several elements and compounds foreign to the composition of the edge member, including material consistent with the composition of the sheet aluminium forming the sloping face of the container.

On reaching the inner surface of the fuselage skin, the incident shock wave energy would partially have been absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of its energy would have been transmitted, as a shock wave, through the skin and into the atmosphere [Appendix B, Figure B-25], but a significant amount of energy would have been returned as a reflected shock wave, back into the cavity between the container and the fuselage skin where Mach stem shock waves would have been formed. Evidence of rapid shattering was found in a region approximately bounded by frames 700 & 720 and stringers 38L & 40L, together with the lap joint at 39L.

The shattered fuselage skin would have taken a significant time to move, relative to the timescales associated with the primary shock wave propagation. Clear evidence of soot and small impact craters were apparent on the internal surfaces of all fragments of container and structure from the shatter zone, confirming that the this material had not had time to move before it was hit by the cloud of shrapnel, unburnt explosive residues and sooty combustion products generated at the seat of the explosion.

Following immediately behind the primary shock wave, a secondary high pressure wave - partly caused by reflections off the baggage behind the explosive material but mainly by the general pressure rise caused by the chemical conversion of solid explosive material to high temperature gas - emerged from the container. The effect of this second pressure front, which would have been more sustained and spread over a much larger area, was to cause the fuselage skin to stretch and blister outwards before bursting and petalling back in a star-burst pattern, with rapidly running tear fractures propagating away from a focus at the shatter zone. The release of stored energy as the skin ruptured, combined with the outflow of high pressure gas through the aperture, produced a characteristic curling of the skin 'petals' - even against the slipstream. For the most part, the skins which petalled back in this manner were torn from the frames and stringers, but the frames and stringers themselves were also fractured and became separated from the rest of the structure, producing a very large jagged hole some 5 feet longitudinally by 17 feet circumferentially (upwards to a region just below the window belt and downwards virtually to the centre line).

From this large jagged hole, three of the fractures continued to propagate away from the hole instead of terminating at the boundary. One fracture propagated longitudinally rearwards as far as the wing cut-out and another forwards to station 480, creating a continuous longitudinal fracture some 43 feet in length. A third fracture propagated circumferentially downwards along frame 740, under the belly, and up the right side of the fuselage almost as far as the window belt - a distance of approximately 23 feet.

These extended fractures all involved tearing or related failure modes, sometimes exploiting rivet lines and tearing from rivet hole to rivet hole, in other areas tearing along the full skin section adjacent to rivet lines, but separate from them. Although the fractures had, in part, followed lap joints, the actual failure modes indicated that the joints themselves were not inherently weak, either as design features or in respect of corrosion or the conditions of the joints on this particular aircraft.

Note: The cold bond process carried out at manufacture on the lap joints had areas of disbonding prior to the accident. This disbonding is a known feature of early Boeing 747 aircraft which, by itself, does not detract from the structural integrity of the hull. The cold bond adhesive was used to improve the distribution of shear load across the joint, thus reducing shear transfer via the fasteners and improving the resistance of the joint to fatigue damage; the fasteners were designed to carry the full static loading requirements of the joint without any contribution from the adhesive. Thus, the loss of the cold bond integrity would only have been significant if it had resulted in the growth of fatigue cracks, or corrosion induced weaknesses, which had then been exploited by the explosive forces. No evidence of fatigue cracking was found in the bonded joints. Inter-surface corrosion was present on most lap joints but only one very small region of corrosion had resulted in significant material thinning; this was remote from the critical region and had not played any part in the break-up.

The cracks propagating upwards as part of the petalling process did not extend beyond the window line. The wreckage evidence suggests that the vertical fractures merged, effectively closing off the fracture path to produce a relatively clean bounding edge to the upper section of the otherwise jagged hole produced by the petalling process. There are at least two probable reasons for this. Firstly the petalling fractures above the shattered zone did not diverge, as they had tended to do elsewhere. Instead, it appears that a large skin panel separated and peeled upwards very rapidly producing tears at each side which ran upwards following almost parallel paths. However, there are indications that by the time the fractures had run several feet, the velocity of fracture had slowed sufficiently to allow the free (forward) edge of the skin panel to overtake the fracture fronts, as it flexed upwards, and forcibly strike the fuselage skin above, producing clear witness marks on both items. Such a tearing process, in which an approximately rectangular flap of skin is pulled upwards away from the main skin panel, is likely to result in the fractures merging. Secondly, this merging tendency would have been reinforced in this particular instance by the stiff window belt ahead of the fractures, which would have tended to turn the fractures towards the horizontal.

It appears that the presence of this initial ('clean') hole, together with the stiff window belt above, encouraged other more slowly running tears to break into it, rather than propagating outwards away from the main hole.

2.12.1.2 Critical crack considerations

The three very large tears extending beyond the boundary of the petalled region resulted in a critical reduction of fuselage structural integrity.

Calculations were carried out at the Royal Aerospace Establishment to determine whether these fractures, growing outwards from the boundary of the petalled hole, could have occurred purely as a result of normal differential pressure loading of the fuselage, or whether explosive forces were required in addition to the pressurisation loads.

Preliminary calculations of critical crack dimensions for a fuselage skin punctured by a 20 by 20 inches jagged hole indicated that unstable crack growth would not have occurred unless the skin stress had been substantially greater than the stress level due to normal pressurisation loads alone. It was therefore clear that explosive overpressure must have produced the gross enlargement of the initially small shattered hole in the hull. Furthermore, it was apparent from the degree of curling and petalling of the skin panels within the star-burst region that this overpressure had been relatively long term, compared with the shock wave overpressure which had produced the shatter zone. A more refined analysis of critical crack growth parameters was therefore carried out in which it was assumed that the long term explosive overpressure was produced by the chemical conversion of solid explosive material into high temperature gas.

An outline of the fracture propagation analysis is given at Appendix D. This analysis, using theoretical fracture mechanics, showed that, after the incident shock wave had produced the shatter zone, significant explosive overpressure loads were needed to drive the star-burst fractures out to the boundary of the petalled skin zone. Thereafter, residual gas overpressure combined with fuselage pressurisation loads were sufficient to produce the two major longitudinal cracks and a single major circumferential crack, extending from the window belt down to beyond the keel centreline.

2.12.1.3 Damage to the cabin floor structure

The floor beams in the region immediately above the baggage container in which the explosive had detonated were extensively broken, displaying clear indications of overload failure due to buckling caused by localised upward loading of the floor structure.

No direct evidence of bruising was found on the top panel of the container. It therefore appears that the container did not itself impact the floor beams, but instead the floor immediately above the container was broken through as a result of explosive overpressure as gases emerged from the ruptured container and loaded the floor panels. Data on floor strengths, provided by Boeing, indicated that the cabin floor (with the CRAF modification) would fail at a uniform static differential pressure of between 3.5 and 3.9 psi (high pressure below the cabin floor), and that the floor panel to floor beam attachments would not fail before the floor beams. Whilst there is no direct evidence of the pressure loading on the floor structure immediately following detonation, there can be no doubt that in the region of station 700 it would have exceeded the ultimate failure load by a large margin.

2.12.2 Indirect explosive damage (damage at remote sites)

All of the damage considered in the foregoing analysis, and the mechanisms giving rise to that damage, resulted from the direct impact of explosive shock waves and/or the short-term explosive overpressure on structure close to the source of the explosion. However, there were several regions of skin separation at sites remote from the explosion (see para 1.12.3.2) which were much more difficult to understand. These remote sites formed islands of indirect explosive damage separated from the direct damage by a sea of more generalised structural failure characterised by the progressive aerodynamic break-up of the weakened forward fuselage. All of these remote damage sites were consistent with the impact of very localised pressure impulses on the internal surfaces of the hull -effectively high energy 'pressure blows' against the inner surfaces produced by explosive shock waves and/or high pressure gas flows travelling through the interior spaces of the hull.

The propagation of explosive shock waves and supersonic gas flows within multiple, interlinking, cavities having indeterminate energy absorption and reflection properties, and ill-defined structural response, is extremely complex. Work has been initiated in an attempt to produce a three-dimensional computer analysis of the shock wave and supersonic flow propagation inside the fuselage, but full theoretical analysis is beyond present resources.

Because of the complexity of the problem, the following analysis will be restricted to a qualitative consideration of the processes which were likely to have taken place. Whilst such an approach is necessarily limited, it has identified a number of propagation mechanisms which appear to have been of fundamental importance to the break-up of Flight PA103, and which are likely to be critical in any future incident involving the detonation of high explosive inside an aircraft hull.

2.12.2.1 Shock wave propagation through internal cavities

When Mach stem shocks are produced not only are the shock pressures very high but they propagate at very high velocity parallel to the reflecting surface. In the context of the lower fuselage structure in the region of Mach stem formation, it can readily be seen that the Mach stem will be perfectly orientated to enter the narrow cavity formed between the outer skin and the cargo liner/containers, bounded by the fuselage frames [Appendix B, Figure B-25]. This cavity enables the Mach stem shock wave to propagate, without causing damage to the walls (due to the relatively low pressure where the Mach stem sweeps their surface), and reach regions of the fuselage remote from the source of the explosion. Furthermore, energy losses in the cavity are likely to be less than would occur in the 'free' propagation case, resulting in the efficient transmission of explosive energy. The cavity would tend to act like a 'shock tube', used for high speed aerodynamic research, confining the shock wave and keeping it running along the cavity axis, with losses being limited to kinetic heating due to friction at the walls.

Paragraph 1.6.3 contains a general description of the structural arrangements in the area of the cargo hold. Before proceeding further and considering how the shock waves might have propagated through this network of cavities, it should be pointed out that the timescale associated with the propagation of the shock waves is very short compared with the timescale associated with physical movement and separation of skin and structure fractured or damaged by the shock. Therefore, for the purpose of assessing the shock propagation through the cavities, the explosive damage to the hull can be ignored and the structure regarded as being intact. A further simplification can usefully be made by considering the structure to be rigid. This assumption would, if the analysis were quantitative, result in over-estimations of the shock strengths. However, for the purposes of a purely qualitative assessment, the assumption should be valid, in that the general trends of behaviour should not be materially altered.

It has already been argued that the shock wave emerging from the container was, in part, reflected back off the inner surface of the fuselage skin, forming a Mach stem shock wave which would then have tended to travel into the semi-circular lower lobe cavity. The Mach stem waves would have propagated away through this cavity in two directions:

(i) under the belly, between the frames [Appendix B, Figure B-3, detail A], and
(ii) up the left side, expanding into the cavity formed by the longitudinal manifold chamber where it joins the lower lobe cavity.
As the shock waves travelled along the cavity, little attenuation or other change of characteristic was likely to have occurred until the shocks passed the entrances to other cavities, or impinged upon projections and other local changes in the cavity. A review of the literature dealing with propagation of blast waves within such cavities provides useful insights into some of the physical mechanisms involved.

As part of a research program carried out into the design of ventilation systems for blast hardened installations intended to survive the long duration blast waves following the detonation of nuclear weapons, the propagation of blast waves along the primary passages and into the side branches of ventilation ducts was studied. The research showed that 90¡ bends in the ducts produced very little attenuation of shock wave pressure; a series of six right angle bends produced only a 30% pressure attenuation, together with an extension of the shock duration. It is therefore evident that the attenuation of shock waves propagating through the fuselage cavities, all of which were short with hardly any right angle turns, would have been minimal.

It was also demonstrated that secondary shock waves develop within the entrance to any side branch from the main duct, produced by the interaction of the primary shock wave with the geometric changes in the duct walls at the side-branch location. These secondary shock waves interact as they propagate into the side branch, combining together within a relatively short distance (typically 7 diameters) to produce a single, plane shock wave travelling along the duct axis. In a rigid, smooth walled structure, this mechanism produces secondary shock overpressures in the side branch of between 30% and 50% of the value of the primary shock, together with a corresponding attenuation of the primary shock wave pressure by approximately 20% to 25%.

This potential for the splitting up and re-transmission of shock wave energy within the lower hull cavities is of extreme importance in the context of this accident. Though the precise form of the interactions is too complex to predict quantitatively, it is evident that the lower hull cavities will serve to convey the overpressure efficiently to other parts of the aircraft. Furthermore, the cavities are not of serial form, i.e. they do not simply branch (and branch again) in a divergent manner, but instead form a parallel network of short cavities which reconnect with each other at many different points, principally along the crease beams. Thus, considerable scope exists for: the additive recombination of blast waves at cavity junctions; for the sustaining of the shock overpressure over a greater time period; and, for the generation of multiple shocks produced by the delay in shock propagation inherent in the different shock path (i.e. cavity) lengths.

Whilst it has not been possible to find a specific mechanism to explain the regions of localised skin separation and peel-back (i.e. the 'pressure blow' regions referred to in para 2.12.2), they were almost certainly the result of high intensity shock overpressures produced locally in those regions as a result of the additive recombination of shock waves transmitted through the lower hull cavities. It is considered that the relatively close proximity of the left side region of damage just below floor level at station 500, [Appendix B, Figure B-19, region D] to the forward end of the cargo hold may be significant insofar as the reflections back from the forward end of the hold would have produced a local enhancement of the shock overpressure. Similarly, 'end blockage effects' produced by the cargo door frame might have been responsible for local enhancements in the area of the belly skin separation and curl-back at station 560 [Appendix B, Figure B-19 and B-20, region E].

The separation of the large section of upper fuselage skin [Appendix B, Figure B-19 and B-20, detail B] was almost certainly associated with a local overpressure in the side cavities between the main deck window line and the upper deck floor, where the cavity is effectively closed off. It is considered that the most probable mechanism producing this region of impulse overpressure was a reflection from the closed end of the cavity, possibly combined with further secondary reflections from the window assembly, the whole being driven by reflective overpressures at the forward end of the longitudinal manifold cavity caused by the forward end of the cargo hold. The local overpressure inside the sidewall cavity would have been backed up by a general cabin overpressure resulting from the floor breakthrough, giving rise to an increased pressure acting on the inner face of the cabin side liner panels. This would have provided pseudo mass to the panels, effectively preventing them from moving inwards and allowing them to react the impulse pressure within the cavity, producing the region of local high pressure evidenced by the region of quilting on the skin panels [Appendix B, Figure B-19, region C].

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2.12.2.2 Propagation of shock waves into the cabin

The design of the air-conditioning/depressurisation-venting systems on the Boeing 747 (and on most other commercial aircraft) is seen as a significant factor in the transmission of explosive energy, as it provides a direct connection between the main passenger cabin and the lower hull at the confluence of the lower hull cavities below the crease beam. The floor level air conditioning vents along the length of the cabin provided a series of apertures through which explosive shock waves, propagating through the sub floor cavities, would have radiated into the main cabin.

Once the shock waves entered the cabin space, the form of propagation would have been significantly different from that which occurred in the cavities in the lower hull. Again, the precise form of such radiation cannot be predicted, but it is clear that the energy would potentially have been high and there would also (potentially) have been a large number of shock waves radiating into the cabin, both from individual vents and in total, with further potential to recombine additively or to 'follow one another up' producing, in effect, sustained shock overpressures.

Within the cabin, the presence of hard, reflective, surfaces are likely to have been significant. Again, the precise way in which the shock waves interacted is vastly beyond the scope of current analytical methods and computing power, but there clearly was considerable potential for additive recombination of the many different shock waves entering at different points along the cabin and the reflected shock waves off hard surfaces in the cabin space, such as the toilet and galley compartments and overhead lockers. These recombination effects, though not understood, are known phenomena. Appendix B, Figure B-26 shows how shock waves radiating from floor level might have been reflected in such a way as produce shock loading on a localised area of the pressure hull.

2.12.2.3 Supersonic gas flows

The gas produced by the explosive would have resulted in a supersonic flow of very high pressure gas through the structural cavities, which would have followed up closely behind the shock waves. Whilst the physical mechanisms of propagation would have been different from those of the shock wave, the end result would have been similar, i.e. there would have been propagation via multiple, linked paths, with potential for additive recombination and successive pressure pulses resulting from differing path lengths. Essentially, the shock waves are likely to have delivered initial 'pressure blows' which would then have been followed up immediately by more sustained pressures resulting from the high pressure supersonic gas flows.

2.13 Potential limitation of explosive damage

Quite clearly the detonation of high explosive material anywhere on board an aircraft is potentially catastrophic and the most effective means of protecting lives is to stop such material entering the aircraft in the first place. However, it is recognised that such risks cannot be eliminated entirely and it is therefore essential that means are sought to reduce the vulnerability of commercial aircraft structures to explosive damage.

The processes which take place when an explosive detonates inside an aircraft fuselage are complex and, to a large extent, fickle in terms of the precise manner in which the processes occur. Furthermore, the potential variation in charge size, position within the hull, and the nature of the materials in the immediate vicinity of the charge (baggage etc) are such that it would be unrealistic to expect to neutralise successfully the effect of every potential explosive device likely to be placed on board an aircraft. However, whilst the problem is intractable so far as a total solution is concerned, it should be possible to limit the damage caused by an explosive device inside a baggage container on a Boeing 747 or similar aircraft to a degree which would allow the aircraft to land successfully, albeit with severe local damage and perhaps resulting in some loss of life or injuries.

In Appendix E the problem of reducing the vulnerability of commercial aircraft to explosive damage is discussed, both in general terms and in the context of aircraft of similar size and form to the Boeing 747. In that discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution.

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2.14 Summary

It was established that the detonation of an IED, loaded in a luggage container positioned on the left side of the forward cargo hold, directly caused the loss of the aircraft. The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential. The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion. The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage, allow the nose and flight deck area to detach within a period of 2 to 3 seconds, and subsequently allow most of the remaining aircraft to disintegrate while it was descending nearly vertically from 19,000 to 9,000 feet.

The investigation has enabled a better understanding to be gained of the explosive processes involved in such an event and to suggest ways in which the effects of such an explosion might be mitigated, both by changes to future design and also by retrospective modification of aircraft. It is therefore recommended that Regulatory Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft structure and systems to explosive damage.

3. CONCLUSIONS

(a) Findings

(i) The crew were properly licenced and medically fit to conduct the flight.

(ii) The aircraft had a valid Certificate of Airworthiness and had been maintained in compliance with the regulations.

(iii) There was no evidence of any defect or malfunction in the aircraft that could have caused or contributed to the accident.

(iv) The structure was in good condition and the minimal areas of corrosion did not contribute to the in-flight disintegration.

(v) One minor fatigue crack approximately 3 inches long was found in the fuselage skin but this had not been exploited during the disintegration.

(vi) An improvised explosive device detonated in luggage container serial number AVE 4041 PA which had been loaded at position 14L in the forward hold. This placed the device approximately 25 inches inboard from the skin on the lower left side of the fuselage at station 700.

(vii) The analysis of the flight recorders, using currently accepted

techniques, did not reveal positive evidence of an explosive event.
(viii) The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential.
(ix) The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion.
(x) The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage.
(xi) Containers and items of cargo ejected from the fuselage aperture in the forward hold, together with pieces of detached structure, collided with the empennage severing most of the left tailplane, disrupting the outer half of the right tailplane, and damaging the fin leading edge structure.
(xii) The forward fuselage and flight deck area separated from the remaining structure within a period of 2 to 3 seconds.
(xiii) The No 3 engine detached when it was hit by the separating forward fuselage.
(xiv) Most of the remaining aircraft disintegrated while it was descending nearly vertically from 19,000 to 9,000 feet.
(xv) The wing impacted in the town of Lockerbie producing a large crater and creating a fireball.

(b) Cause

The in-flight disintegration of the aircraft was caused by the detonation of an improvised explosive device located in a baggage container positioned on the left side of the forward cargo hold at aircraft station 700.

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4. SAFETY RECOMMENDATIONS

The following Safety Recommendations were made during the course of the investigation :

4.1 That manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and the data recoverable after power loss.
4.2 That Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.
4.3 That Airworthiness Authorities consider requiring the CVR system to

contain a short duration, i.e. no greater than 1 minute, back-up power supply to enable the CVR to respond to events that result in the almost immediate loss of the aircraft's electrical power supply.

4.4 That the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

4.5 That Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of aircraft structure and systems to explosive damage.

M M Charles
Inspector of Accidents
Department of Transport

July 1990

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APPENDIX A

PERSONNEL CONDUCTING THE INVESTIGATION

The following Inspectors of the Air Accidents Investigation Branch conducted the investigation:

Mr M M Charles	Investigator-in-Charge
Mr D F King	Principal Inspector (Engineering)
Mr P F Sheppard	Assistant Principal Inspector (Engineering)
Mr A N Cable	Senior Inspector (Engineering)
Mr R G Carter	Senior Inspector (Engineering)
Mr P T Claiden	Senior Inspector (Engineering)
Mr P R Coombs	Senior Inspector (Engineering)
Mr S R Culling	Senior Inspector (Engineering)
Miss A Evans	

Senior Inspector (Engineering)

Mr B M E Forward

Senior Inspector (Operations)

Mr P N Giles

Senior Inspector (Operations)

Mr S W Moss

Senior Inspector (Engineering)

Mr R Parkinson

Senior Inspector (Engineering)

Mr J D Payling

Senior Inspector (Operations)

Mr C G Pollard

Senior Inspector (Engineering)

Mr C A Protheroe

Senior Inspector (Engineering)

Mr A H Robinson

Senior Inspector (Engineering)

Mr A P Simmons

Senior Inspector (Engineering)

Mr R G Vance

Senior Inspector (Engineering)

Mr R StJ Whidborne

Senior Inspector (Operations)

The Air Accidents Investigation Branch would like to thank the following organisations from the United Kingdom, United States of America, France, and Canada who participated in the investigation:

Air Line Pilot's Association International

Boeing Commercial Airplane Company

British Airways

British Army

British Geological Survey

Bureau Enquete Accidents

Canadian Aviation Safety Bureau

Civil Aviation Authority

Cranfield Institute of Technology

Federal Aviation Administration

Federal Bureau of Investigation

Independent Union of Flight Attendants

National Transportation Safety Board

Pan American World Airways

Police Service

Royal Aerospace Establishment

Royal Air Force

Royal Armaments Research and Development Establishment

Royal Navy

Royal Ordnance

Royal Signals and Radar Establishment

United Technologies International Operations (Pratt and Whitney)

The Air Accidents Investigation Branch would also like to acknowledge the excellent work of the Dumfries & Galloway Regional Council and to thank all the many voluntary organisations who gave such unstinting support to the investigation.

APPENDIX C

ANALYSIS OF RECORDED DATA

1. Introduction

This appendix describes and analyses the different types of recorded data which were examined during the investigation of the accident to Boeing 747 registration N739PA at Lockerbie on 21 December 1988.
The recorded data consists of that from the Cockpit Voice Recorder (CVR), the Digital Flight Data Recorder (DFDR), Air Traffic Control (ATC) radio telephony (RTF), ATC radar, and British Geological Survey seismic records. The time correlation of the records is also discussed.

2. Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 analogue parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

2.1 DFDR strip and examination

Internal inspection of the DFDR showed that there was considerable disruption to the control electronics circuits. The crash protection was removed and the plastic recording tape was found detached from its various guide rollers and tangled in the tape spools. There was no tension in the negator springs. This indicated that the tape had probably moved since electrical power was removed from the recorder. The position of the tape in relation to the record/replay heads was marked with a piece of splicing tape in order to quantify the movement. To ensure that no additional damage was caused to the tape it was necessary to cut the negator springs to separate the upper and lower tape reels.

The crinkling and stretching of the tape and the damage to the control electronics meant that the tape had to be replayed outside the recorder. AAIB experience has shown that the most efficient method of replaying stretched Lockheed recorder tapes is to re-spool the tape into a known serviceable recorder, in this case a Plessey 1584G.

2.2 DFDR replay

The 25 hour duration of the DFDR was satisfactorily replayed. Data relating to the accident flight was recorded on track 2. The only significant defect in the recording system was that normal acceleration was inoperative. There was one area on the tape, 2 minutes from the end, where data synchronisation was lost for 1 second.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded. The recorded data simply stopped. Figure C-1 is a graphical representation of the main flight parameters.

2.3 DFDR analysis

In order to ensure that all recorded data from the accident flight had been decoded and to examine the quality of the data at the end of the recording, a section of tape, including both the most recently recorded data and the oldest data (data from 25 hours past), was replayed through an ultra-violet (UV) strip recorder. The data was also digitised and the resulting samples used to reconstruct the tape signal on a VDU.

Both methods of signal representation were used to determine the manner by which the recorder stopped. There was no gap between the most recently recorded data and the 25 hour old data. This showed that the recorder stopped while there was an incoming data stream from the FDAU. The recorder, therefore, stopped because its electrical supply was disconnected. The tape signal was examined for any transients or noise signals that would have indicated the presence of electrical disturbances prior to the recorder stopping. None was found and this indicated that there had been a quick clean break of the electrical supply.

The last seconds of data were decoded independently using both the UV record and the digitised signal. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or if it was old data from a previous recording.

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between

parameter input and recording (buffering) of up to ? second.
These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when tha aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

3. Cockpit voice recorder (CVR)

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1
Flight Engineer's RTF.
Channel 2
Co-Pilot's RTF.
Channel 3
Pilot's RTF.
Channel 4
Cockpit Area Microphone.

3.1 CVR strip and examination

To gain access to the recording tape it was necessary to cut away the the outer case and saw through part of the crash protected enclosure. No damage to the tape transport or the recording tape was found. The endless loop of tape was cut and the tape transferred to the replay equipment. The electronic modules in the CVR were crushed and there was evidence of long term overheating of the dropper resistors on the power supply module. The CAM had been crushed breaking internal wiring and damaging components on the printed circuit board.

3.2 CVR replay

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings was audible on the RTF channels. The CAM channel was particularly noisy, this was probably due to the combination of the inherently noisy cockpit of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high cockpit noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified as of either acoustic or electrical in origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual in crew behaviour. The tape record ended with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording. The sound occurred whilst the crew were copying their transatlantic clearance from Shanwick ATC.

3.3 Analysis of the CVR record

3.3.1 The stopping of the recorder

To determine the mechanism that stopped the recorder a bench test rig was constructed utilizing an A100 CVR and an A152 CAM. Figures C-2 to C-5 show the effect of shorting, earthing or disconnecting the CAM signal wires. Figure C-8 shows the CAM channel signal response to the event which occurred on Flight PA103. From this it can be seen that there are no characteristic transients similar to those caused by shorting or earthing the CAM signal wires. Neither does the signal stop cleanly and quickly as shown in Figure C-5, indicating that the CAM signal wires were not interrupted. The UV trace shows the recorded signal decaying in a manner similar to that shown in Figure C-6, which demonstrates the effect of disconnecting electrical power from the recorder. The tests were repeated on other CVRs with similar results and it is therefore concluded that Flight PA103's CVR stopped because its electrical power was removed.

Figures C-9A to C-9D show the recorded signals for the Air India B747 (AI 182) accident in the North Atlantic on 23 June 1985. These show that there is a large transient on the CAM track indicating earthing or shorting of the CAM signal wires and that recorder power-down is more prolonged, indicating attempts to restore the electrical power supply either by bus switching or healing of the fault. The Flight PA103 CVR shows no attempts at power restoration with the break being clean and final.

In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

3.3.2 Information concerning the event

Figure C-8 is an expanded UV trace of the final milliseconds of the CVR record. Three tracks have been used, the flight engineer's RTF channel which contained similar information to the P2's channel has been replaced with a timing signal. Individual sections of interest are identified by number. On the bottom trace, the P1 RTF track, section 1 is part of the Shanwick transatlantic clearance. During this section the loud sound on the CAM channel is evident.

Examination of the DFDR event recordings shows that the Shanwick oceanic clearance was being received on VHF2, the aerial for which is on the underside of the fuselage close to the seat of the explosion.
Section 2 identifies a transient, on the P1 channel, typical of an end of ATC transmission transient for this CVR. The start and finish of most of the recorded ATC transmissions were analysed and they
produce a similar signature to the three shown in Figure C-10. The signature on the P1 channel more closely resembles the end of transmission signature and it is open to conjecture that this transient was
caused by the explosion damaging the aerial feeder and/or its supporting structure.

Section 3 shows what is considered to be a high speed power supply transient which is evident on all the RTF channels and is probably on the CAM channel, but cannot be identified because of the automatic
gain control (AGC), limiting the audio event. This transient is considered to coincide with the loss of electrical power to the CVR. Section 5 identifies the period to the end of recording and this agrees well
with tests carried out by AAIB and independently by Fairchild as part of the AI 182 investigation. The typical time from removal of the electrical supply until end of recording is 110 milliseconds.

During the period identified as section 4 it is considered that the disturbances on the RTF channels are electrical transients probably channelled through the communications equipment. Section 6 identifies the
170 millisecond period from the point when the sound was first heard on the CAM until the recording stopped.

The CAM unit is of the old type which has a frequency response of 350 to 3500 Hz. The useable duration of the signal is probably confined to the first 60 milliseconds of the final 170 milliseconds and even
during this period the AGC is limiting the signal. In the remaining time the sound is being distorted because power to the recorder has been disconnected. The ambient cockpit noise may have been high
enough to have caused the AGC to have been active prior to the event and in this event the full volume of the sound would not be audible. Distortion from the incomplete erasure of the last recording may
form part of the recorded signal.

It is not clear if the recorded sound is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case.

Additionally some of the frequencies present on the recording were not present in the original sound, but are the result of the rise in total harmonic distortion caused by the increased amplitude of the incoming signal. Outputs from a frequency analysis of the recorded signal for the same frequency of input to the CVR, but at two input amplitudes, are shown in Figures C-11 and C-12. These illustrate the effects on harmonic distortion as the signal level is increased. Finally the recorded signal does not lend itself to analysis by a digital spectrum analyser as it is, in a large measure, aperiodic and most digital signal analysis algorithms are unable to deal with a short duration signal of this type, however, it is hoped that techniques being developed in Canada will enable more information to be deduced from the end of the recording.

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985 the Royal Armaments Research and Development Establishment (RARDE) were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

Preliminary results from these trials indicates that if a suitable sensor can be developed its output will need to be recorded in real time and therefore it may require wiring into the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

4. Flight recorder electrical system

4.1 CVR/DFDR electrical wiring.

The flight recorders were located in the left rear fuselage just forward of the rear pressure bulkhead. Audio information to the CVR ran along the left hand side of the aircraft, at stringer 11. Electrical power to the CVR followed a similar route on the right hand side of the aircraft crossing to the left side above the rear passenger toilets. DFDR electrical power and signal information followed the same route as the CVR audio information.

4.2 Flight recorder power supply

The DFDR, CVR and the transponders were all powered from the essential alternating current (AC) bus. This bus was capable of being powered by any generator, however, in normal operation the selector switch on the flight engineers panel is selected to "normal" connecting the essential bus to number 4 generator. When the cockpit of Flight PA103 was examined the selector switch was found in the normal position.

4.3 Aircraft alternating current power supplies

AC electrical power to the aircraft was provided by 4 engine driven generators, see Figure C-13. Each generator was driven at constant speed through a constant speed drive (CSD) and connected to a separate bus-bar through a generator control breaker (GCB). The 4 generators were connected to a parallel bus-bar (sync bus) by individual bus tie breakers (BTBs). Control and monitoring of the AC electrical system was achieved through the flight engineer's instrument panel. In normal operation the generators operated in parallel, i.e with the BTBs closed.

4.4 Fault conditions

Analysis of the CVR CAM channel signal indicated that approximately 60 milliseconds after the sound on the CAM channel an electrical transient was recorded on all 4 channels and that approximately 110 milliseconds later the CVR had ceased recording. Within the accuracy of the available timing information it is believed that the incoming VHF was lost at the same time, indicating an AC power supply fault.

The AC electrical system was protected from faults in individual systems or equipment by fuses or circuit breakers. Faults in the generators or in the distribution bus-bars and feeders were dealt with automatically by opening of the GCBs and opening or closing of the BTBs. In the event of fault conditions causing the disconnection of all 4 generators electrical power for essential services, including VHF radio, was provided by a battery located in the cockpit.

The short time interval of 55 milliseconds after which the AC supply to the flight recorders was lost limits the basis on which a fault path analysis of the AC electrical system can be undertaken. On the available information only a differential (feeder) fault could have isolated the bus-bar this quickly, with the generator field control relay taking 20 milliseconds to trip. However, in normal operation, the generators would have been operating in parallel and the essential AC bus-bar would have been supplied via the number 4 BTB from the sync bus. If the fault conditions had continued, a further 40 to 100 milliseconds would have elapsed before the BTB opened. If the BTB was open prior to the fault it would have attempted to close and restore the supply to the essential bus. Any automatic switching causes electrical transients to appear on the CVR and data losses on the FDR. Both the CVR and the FDR indicate that a clean break of the AC supply occurred with no electrical transients associated with BTBs open or closing in an attempt to restore power. In the absence of any additional information only two possibilities are apparent:

i) That all 4 generators were simultaneously affected causing a total loss of AC electrical power. The feeders for the left and right side generators run on opposite sides of the aircraft under the passenger cabin floor. The only situation envisaged that could cause simultaneous loss of all 4 generators is the disruption of the passenger cabin floor across its entire width.

ii) That disruption of the main equipment centre, housing the control units for the AC electrical system, caused the loss of all AC power. However, again it would have to affect both the left and right sides of the aircraft as the control equipment is located at left and right extremes of the main equipment centre.

The nature of the event may also produce effects that are not understood. It is also to be noted that a sudden loss of electrical power to the flight recorders has been reported in other B747 accidents, e.g. Air India, AI 182.

5. Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event caused by the wing section crashing on Lockerbie. The seismic monitors are time correlated with the British Telecom Rugby standard. Using this and calculating the time for the various waves to reach the recording stations it was possible for the British Geological Survey to conclude that the event occurred at 19.03:36.5 hrs ± 1 second.

Attempts were made to correlate various smaller seismic events with other wreckage impacts. However, this was not conclusive because the nearest recording station was above ground and due to the high winds at the time of the accident had considerable noise on the trace. In addition, little of the other wreckage had the mass or impact velocity to stimulate the sensors.

6. Time correlation

6.1 Introduction

The sources of each time encoded recording were asked to provide details of their time standard and any known errors in the timings on their recordings. Although the resolution of the recorded time sources is high it was not possible to attach an accuracy of better than ±1 second due to possible errors in synchronising the recorded time with the associated standard. The following time sources were available and used in determining the significant events in the investigation:-

i) ATC

ATC communications were recorded along with a time signal. The time source for the ATC tape was the British Telecom "Tim" signal. Any error in setting the time when individual tapes are mounted was logged.

ii) Recorded rada data

A time signal derived from the British Telecom "Rugby" standard was included on radar recordings. The Rugby and Tim times were assumed to be of equal accuracy for timing purposes.

iii) The DFDR had UTC recorded.

The source of this time was the flight engineer's clock. This clock was set manually and therefore this time was subject to a significant fixed error as well any inaccuracy in the clock.

iv) The CVR had no time signal.

However, the CVR was correlated with the ATC time through the RTF and with the DFDR, by correlating the press to talk events on the FDR with the press to talk signature on the CVR.

v) Seismic recordings

Seismic recordings included a timing signal derived from the British Telecom Rugby standard.

6.2 Analysis and correlation of times

The Scottish and Shanwick ATC tapes were matched with each other and with the CVR tape. The CVR recording speed was adjusted by peaking its recorded 400 Hz AC power source frequency. This correlation served as a double check on any fixed errors on the ATC recordings and to fix events on the CVR to UTC. The timing of the sound on the CAM channel of the CVR was made simpler because Shanwick was transmitting when it occurred. From this it was possible to determine that the sound on the CVR occurred at 19.02:50 hrs ±1 second.

With the CVR now tied to the Tim standard it was possible to match the RTF keying on the CVR with the RTF keying events on the FDR. These events on the FDR were sampled and recorded once per second, it was therefore possible for a 1 second delay to be present on the FDR. This potential error was reduced by obtaining the best fit between a number of RTF keyings and a time correlation between the FDR and CVR of ±? second was achieved. From this it was determined, within this accuracy, that electrical power was removed from the CVR and FDR at the same time.

From the recorded radar data it was possible to determine that the last recorded SSR return was at 19.02:46.9 hrs and that by the next rotation of the radar head a number of primary returns, some left and right of track, were evident. Time intervals between successive rotations of the radar head became more difficult to use as the head painted more primary returns.

The point at which aircraft wreckage impacted Lockerbie was determined using the time recorded by seismic activity detectors. A seismic event measuring 1.6 on the Richter scale was detected and, with appropriate time corrections for times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

7. Recorded radar information

7.1 Introduction

Recorded radar information on the aircraft was available from from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen, from this it was clear that the flight had progressed in a normal manner until Secondary Surveillance Radar (SSR) was lost. There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost. The Lowther Hill and St. Annes radars did not see this return. The Great Dun Fell radar recording was watched for 1 hour both before and after this single return for any signs of other spurious returns, but none was seen. The return was only present for one paint and no explanation can be offered for its presence.

7.2 Limitations of recorded radar data

Before evaluating the recorded radar data it is important to highlight limitations in radar performance that must be taken into account when interpreting primary radar data. The radar system used for both primary and secondary radar utilised a rotating radar transmitter/receiver (Head). This means that a return was only visible whilst the radar head was pointing at the target, commonly called painting or illuminating the target. In the case of this accident the rotational speeds of the radar heads varied from approximately 10 seconds for the Lowther Hill Radar to 8 Seconds for the Great Dun Fell Radar.

Whilst it was possible to obtain accurate positional information within a resolution of 0.09¡ of bearing and ± 1/16 nautical mile range for an aircraft from SSR, incorporating mode C height encoding, primary radar provided only slant range and bearing and therefore positional information with respect to the ground was not accurate.

The structural break-up of an aircraft releases many items which were excellent radar reflectors eg. aluminium cladding, luggage containers, sections of skin and aircraft structure. These and other debris with reflective properties produce "clutter" on the radar by confusing the radar electronics in a manner similar to chaff ejected by military aircraft to avoid radar detection.

Even when the target is not masked by clutter repetitive detection of individual targets may not be possible because detection is a function of the target effective area which, for wreckage with its irregular shape, is not constant but fluctuates wildly. These factors make it impossible to follow individual returns through successive sweeps of the radar head.

7.3 Analysis of the radar data

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. This information was correlated with the CVR and ATC times to establish a time and position for the aircraft at the initial disintegration.

For the purposes of this analysis the data from Great Dun Fell Radar has been presented. Figures C-14 to C-23 show a mosaic picture of the radar data i.e. each figure contains the information on the preceding figure together with more recently recorded information. Figure C-14 shows the radar returns from an aircraft tracking 321¡(Grid) with a calculated ground speed of 434 kts. Reading along track (towards the top left of Figure C-14) there are 6 SSR returns with the sixth and final SSR return shown decoded: squawk code 0357 (identifying the aircraft as N739PA); mode C indicating FL310; and the time in seconds (68566.9 seconds from 00:00, i.e. 19.02:46.9 hrs).

At the next radar return there is no SSR data, only 4 primary returns. One return is along track close to the expected position of the aircraft if it had continued at its previous speed and heading. There are 2 returns to the left of track and 1 to the right of track. Remembering the point made earlier about clutter, it is unlikely that each of these returns are real targets. It can, however, be concluded that the aircraft is no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items have been ejected at high speed probably to both right and left of the aircraft. Figure C-15 shows the situation after the next head rotation. There is still a return along track but it has either slowed down or the slant range has decreased due to a loss of altitude.

Each rotation of the radar head thereafter shows the number of returns increasing with those first identified across track in Figure C-14 having slowed down very quickly and followed a track along the prevailing wind line. Figure C-20 shows clearly that there has been a further break-up of the aircraft and subsequent plots show a rapidly increasing number of returns, some following the wind direction and forming a wreckage trail parallel to and north of the original break-up debris. Additionally it is possible that there was some break-up between these points with a short trail being formed between the north and south trails. From the absence of any returns travelling along track it can be concluded that the main wreckage was travelling almost vertically downwards for much of the time.

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

8. Conclusions

The almost instant destruction of Flight PA103 resulted in no direct evidence on the cause of the accident being preserved on the DFDR. The CVR CAM track contained a loud sound 170 milliseconds before recording ceased. Sixty milliseconds of this sound were while power was applied to the recorder; after this period the amplitude decreased. It cannot be determine whether the decrease was because of reducing recorder drive or if the sound itself decreased in amplitude. Analysis of both flight recorders shows that they stopped because the electrical supply was removed and that there were valid signals available to both recorders at that time.

The most important contribution to the investigation that the flight recorders could make was to pinpoint the time and position of the event. As the timescale involved was so small in relation to the resolution and accuracy of many of the recorded time sources it was necessary to analyse collectively all the available recordings. From the analysis of the CVR, DFDR, ATC tapes, radar data and the seismic records it was concluded that the loud sound on the CVR occurred at 19.02:50 hrs ±1 second and wreckage from the aircraft crashed on Lockerbie at 19.03:36.5 hrs ±1 second, giving a time interval of 46.5 ±2 seconds between these two events. When the loud sound was recorded on the CVR, the geographical position of the aircraft, based on the evidence of recorded data, was calculated to be within 525 metres of OS Grid Reference 14827826.

Eight seconds after the sound on the CVR the Great Dun Fell radar showed 4 primary radar returns. The returns indicated a spread of wreckage in the order of 1 nautical mile across track. On successive returns of the radar, two parallel wreckage trails are seen to develop with the second trail, to the north, becoming evident 30 to 40 seconds after the first.

APPENDIX D

CRITICAL CRACK CALCULATIONS

It was assumed that the fuselage rupture and associated star-burst petalling process was driven by an expanding 'bubble' of high pressure gas, produced by the conversion of solid explosive material into gas products. As the explosive gas pressures reduced due to dissipation through the structure and external venting, the service differential pressure loading would have taken over from the explosive pressures as the principal force driving the skin fractures.

The high temperature gas would initially have been confined within the container where, because of the low volume, the pressure would have been extremely high (too high for containment) and the gas bubble would have expanded violently into the cavities of the fuselage between the outer skin and the container. This gas bubble would have continued to expand, with an accompanying fall in pressure due to the increasing volume combined with a corresponding drop in temperature.

The precise nature of the gas expansion process could not be determined directly from the evidence and it was therefore necessary to make a number of assumptions about its behaviour, based on the geometry of the hull and the area of fuselage skin which the high pressure bubble would have ruptured. Essentially, it was assumed that the gas bubble would expand freely in the circumferential direction, into the cavity between the fuselage skin and the container. In contrast, the freedom for the bubble to expand longitudinally would have been restricted by the presence of the fuselage frames, which would have partially blocked the passage of gas in the fore and aft directions. However, the pressures acting on the frames would have been such that they would have buckled and failed, allowing the gas to vent into the next 'bay', producing failure of the next frame. This sequential frame-failure process would have continued until the pressure had fallen to a level which the frames could withstand. During the period of frame failure and the associated longitudinal expansion of the gas bubble, this expansion rate was assumed to be half that of the circumferential rate.

It was assumed that venting would have taken place through the ruptured skin and that the boundary of the petalled hole followed behind the expanding gas bubble, just inside its outer boundary, i.e. the expanding gas bubble would have stretched and 'unzipped' the skins as it expanded. This process would have continued until the gas bubble had expanded/vented to a level where the pressure was no longer able to drive the petalling mechanism because the skin stresses had reduced to below the natural strength of the material.

The following structural model was assumed:

(i) The pressurised hull was considered to be a cylinder of radius 128 inches, divided into regular lengths by stiff frames.

(ii) The contributions of the stringers and frames beyond the petalled region were considered to be the equivalent of a reduction of stress in the skins by 20%, corresponding to an increase in skin thickness from 0.064 inches to 0.080 inches.

(iii) Standing skin loads were assumed to be present due to the service differential pressure, i.e.. it was assumed that no significant venting of internal cabin pressure occurred within the relevant timescale.

(iv)

The mechanism of bubble pressure load transfer into the skins was:

a)

Hoop direction -conventional membrance reaction into hoop stresses

b)

Longitudinal direction - reaction of pressures locally by the frames, restrained by the skins.

The critical crack calculations were based upon the generalised model of a plate under biaxial loading in which there was an elliptical hole with sharp cracks emanating from it. This is a good approximation of the initial condition, i.e.. the shattered hole, and an adequate representation of the subsequent phase, when the hole was enlarging in its star-burst, petalling, mode.

The analyses of critical crack dimensions in the circumferential and longitudinal directions were based on established Fracture Resistance techniques. The method utilises fracture resistance data for the material in question to establish the critical condition at which the rate of energy released by the crack just balances the rate of energy absorbed by the material in the cracking process, i.e. the instantaneous value of the parameter Kr, commonly referred to as the fracture toughness Kc. From this, the relationship between critical stress and crack length can be determined.

Using conventional Linear Elastic Fracture Mechanics (LEFM) with fracture toughness data from RAE experimental work and published geometric factors relating to cracks emanating from elliptical holes, the stress levels required to drive cracks of increasing lengths in both circumferential and longitudinal directions were calculated. The skin stresses at sequential stages of the expanding gas bubble/skin petalling process were then calculated and compared with these data.

The results of the analysis indicated that, once the large petalled hole had been produced by explosive gas overpressure, the hoop stresses generated by fuselage pressurisation loads acting alone would have been sufficient to drive cracks longitudinally for large distances beyond the boundaries of the petalled hole. Thus, with residual gas overpressure acting as well, the 43 feet (total length) longitudinal fractures observed in the wreckage are entirely understandable. The calculations also suggested that the hoop fractures, due to longitudinal stresses in the skins, would have extended beyond the boundary of the petalled hole, though the excess stress driving the fractures in this direction would have been much smaller than for the longitudinal fractures, and the level of uncertainty was greater due to the difficulty of producing an accurate model reflecting the diffusion of longitudinal loads into the skins. Nevertheless, the results suggested that the circumferential cracks would extend downwards just beyond the keel, and upwards as far as the window belt - conclusions which accord reasonably well with the wreckage evidence.

APPENDIX E

POTENTIAL REMEDIAL MEASURES

1. Introduction

In the following discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution. On the basis of the Flight PA103 investigation, damage is likely to fall into two categories: direct explosive damage, and indirect explosive damage.

2. Direct explosive damage

The most serious aspect of the direct explosive damage on the structure is the large, jagged aperture in the pressure hull, combined with frame and stringer break-up, which results from the star-burst rupture of the fuselage skin. Because of its uncontrolled size and position, and the naturally radiating cracks which form as part of the petalling process, the skin's critical crack length (under pressurisation loading) is likely to be exceeded, resulting in unstable crack propagation away from the boundary of the aperture. Such cracks can lead to a critical loss of structural integrity at a time when additional loads are likely to be imposed on the structure due to reflected blast pressure and/or aircraft aerodynamic and inertial loading.

A further complicating factor is that the size of this aperture is likely to be sufficiently large to allow complete cargo containers and other debris to be ejected into the airstream, with a high probability of causing catastrophic structural damage to the empennage.

3. Indirect explosive damage

Indirect explosive damage (channelling or ducting of explosive energy in the form of both shock waves and supersonic gas flows) is likely to occur because of the network of interlinked cavities which exist, in various forms, in all large commercial aircraft, particularly below cabin floor level. This channeling mechanism can produce critical damage at significant distances from the source of the explosion.

In addition to the structural damage, aircraft flight control and other critical systems will potentially be disrupted, both by the explosive forces and as a result of structural break-up and distortions. The discussion which follows focuses on possible means of limiting structural damage of the kind which occurred on Flight PA103. Undoubtedly, such measures will also have beneficial effects in limiting systems damage. However, system vulnerability can further be reduced by applying, wherever possible, those techniques used on military aircraft to reduce vulnerability to battle damage; multiplexed, multiply redundant systems using distributed hardware to minimise risk of a single area of damage producing major system disruption. Fly by wire flight control systems potentially offer considerable scope to achieve these goals, but the same distributed approach would also be required for the electronic and other equipment which, in current aircraft, tends to be concentrated into a small number of 'equipment centres'.

4. Remedial measures to reduce structural damage

Whilst pure containment of the explosive energy is theoretically possible, in an aviation context such a scheme would not be viable. Any unsuccessful attempt to contain the explosive will probably produce greater devastation than the original (uncontained) explosion since all the explosive energy would merely be stored until the containment finally ruptured, when the stored energy would be released together with massive fragmentation of the containment.

However, a mixed approach involving a combination of containment, venting, and energy absorption should provide useful gains provided that a systematic rather than piecemeal approach is adopted, and that the scheme also addresses blast channelling. The following scheme is put forward for discussion, primarily as means of identifying, by example, how the various elements of the problem might be approached at a conceptual level and to provide a stimulus for debate. No detailed engineering solutions are offered, but it is firmly believed that the requirements of such a scheme could be met from a technical standpoint. The proposed scheme is based on the need to counter a threat similar to that involving Flight PA103, i.e. a high explosive device placed within a baggage container, however, the principles should be applicable to other aircraft types.

Such a scheme might comprise several 'layers' of defence. The first two layers, one within the other, are essentially identical and provide partial containment of the explosive energy and the redirection of blast out from the compartment via pre-determined vent paths. Although the containment is temporary, it must provide an effective barrier to uncontrolled venting, preventing the escape of blast except via the pre-designated paths.

The third layer comprises a pre-determined area of fuselage skin, adjoining the outer end of the vent path, designed to rupture or burst in a controlled manner, providing a large vent aperture which will not tend to crack or rupture beyond the designated boundaries.

A fourth layer of protection has two elements, both intended to limit the propagation of shock waves through the internal cavities in the hull. The first element comprises the closure of any gaps between the vent apertures in the two innermost containment layers and the vent aperture in the outer skin. This effectively provides an exhaust duct connecting the inner and outer vent apertures to minimise leakage into the intervening structure and cavities around the cargo hold. The second element comprises the incorporation of an energy absorbing lining material within all the cavities in the lower hull, to absorb shock energy, limit shock reflection and limit the propagation of pressure waves which might enter the cavities, for example because of containment layer breakthrough.

5 Possible application to Boeing 747 type aircraft

5.1 Container Modification

The obvious candidates for the inner containment layer are the baggage containers themselves. Existing containers are of crude construction, typically comprising aluminium sheet sides and top attached to an aluminium frame with a fabric reinforced access curtain, or have sides and top of fibreglass laminate attached to a robust aluminium base section.

These containers are stacked in the aircraft in such a manner that on three sides (except for the endmost containers) the baggage within the adjoining containers provides an already highly effective energy absorbing barrier. If the container is modified so that loading access is via the outboard side of the container rather than at the end, i.e. the curtain is put on the faces shown in Figure E-1, then only the top and base are 'unbacked' by other containers, leaving the outboard face as a vent region.

The proposal is therefore that a modified container is developed in which the access is changed from the end to the outside face only, and which is modified to improve the resistance to internal pressures and thus encourage venting via the new access curtain only. How the container is actually modified to achieve the containment requirement is a matter of detail design, but two approaches suggest themselves, both involving the use of composite type materials. The first approach is to adopt a scheme for a rigid container which relies on a combination of energy absorption and burst strength to prevent uncontrolled breakout of explosive energy. The second approach is to use a 'flexible' container, i.e. rigid enough for normal use, but sufficiently flexible to allow gross deformation of shape without rupture. This, particularly if used with a backing blanket made from high performance material to resist fragmentation, could deform sufficiently to allow the container to bear against, and partially crush, adjoining containers. In this way, the shock energy transmission should be significantly reduced and the inherent energy absorption capability and mass of the baggage in adjoining containers could be utilised, whilst still retaining the high pressure gas for long enough to allow venting via the side face. Clearly, care would need to be taken to ensure that the container vent aperture remained as undistorted as possible, to ensure minimal leakage at the interface.

5.2 Cargo bay liner

The existing cargo bay liner is a thin fibreglass laminate which lines the roof and sidewalls of the cargo hold. There is no floor as such; instead, the containers are supported on rails running fore and aft on the tops of the fuselage frame lower segments. In a number of areas, there are zipped fabric panels let into the liner to provide access to equipment located behind. The liner 'ceiling' is suspended on plastic pillars approximately 2 centimeters below the bottom of the main cabin floor beams. The purpose of the liner is solely to act as a general barrier to protect wiring looms and systems components.

The proposal is to produce a new liner designed to provide the second level of containment, essentially at 'floor' and 'roof' level only [Figure E-1]. The dimensional constraints are such that potentially quite thick material could be incorporated (leaving aside the weight problem), permitting not only a rigid liner design, but semi-rigid or flexible linings backed by energy absorbing blanket materials.

The liner would be designed to provide an additional barrier at the base and roof of the containers, which unlike the sides, are not protected by adjoining containers. The outside ends of these barrier elements must effectively seal against the vent apertures in the containers, to minimise leakage into the fuselage cavities.

5.3 Structural blow-out regions.

The final element in the containment/venting part of the scheme is a line of blow-out regions in the fuselage skins, coinciding exactly with the positions of the vent apertures in the cargo containers and cargo bay liner. These should extend along the length of the cargo hold, zoned in such a way that rupture due to rapid overpressure will occur in a controlled manner. The primary function of the blow-out regions would be to provide immediate pressure relief by allowing the inevitable skin rupture to take place only within pre-determined zones, limiting the extent of the skin tearing by means of careful stiffness control at the boundary of the blow-out regions.

The structural requirements of such panels are perhaps the most difficult challenge to meet, particularly for existing designs. However, it is believed that by giving appropriate consideration to the directionality of fastening strengths, and the use of external tear straps, it should be possible to design the structure to carry the normal service loads whilst creating a pre-disposition to rupturing in a controlled manner in response to gross pressure impulse loading.

The implementation of such features will need carefully balanced design in order to provide local stiffening, sufficient to control and direct the tear processes, without creating stiffness discontinuities which could lead to fatigue problems during extended service. However, the degree of reinforcement needed at the blow-out aperture need only be sufficient to limit tearing and to sustain the aircraft long enough to complete the flight unpressurised.

All aircraft have pre-existing strength discontinuities, despite the efforts of the designers to eliminate them. By choosing the positions of butt joints, lap joints, anti-tear straps and similar structural features in future designs, so as to incorporate them into the boundary of the blow-out panel region, the natural "tear here" tendencies of such features could possibly be turned to advantage. In the case of current generation aircraft, the positions of existing lines of weakness at such features will determine the optimum position for structural blow-out areas, and hence the positions of the container and cargo bay liner blow-out panels. A limited amount of local structural reinforcement (e.g. in the form of external anti-tear straps), carried out as part of a modification program, could perhaps fine tune the tearing properties of existing lines of weakness, potentially producing significant improvements.

5.4 Closure of cavities

There are four main classes of cavity which will need to be addressed on the Boeing 747, and most other modern aircraft. These are:

(i) The channels formed between fuselage frames

(ii) The cross-ship cavities between cabin floor beams

(iii) Longitudinal 'manifold' cavities on each side of the cargo deck, running fore and aft in the space behind the upper sidewall areas of the cargo bay liner.

(iv) Air conditioning vents along the bottom of the cabin side-liner panels, which connect the side cavities below cabin floor level with the main passenger cabin.

If the containment barriers (i.e. modified cargo containers and cargo hold liner) can be made to prevent blast breakthrough into these cavities directly, then the only area where transfer can occur is at the interface between the container/cargo hold liner vent apertures and the fuselage skins at the blow-out region. This short distance will need to be sealed in order to form a short 'exhaust duct' between the container vent aperture and the fuselage skin. Since the shock and general explosive pressure will act mainly along the vent-duct axis, the pressure loading on the vent duct walls should not be excessive.

5.5 Attenuation of shock waves in structural cavities

To prevent the 'ducting' of any blast which does enter the fuselage cavities, either because of partial penetration of the containment barriers or leakage at the vent duct interfaces, the scheme requires the provision of lightweight energy absorbing material within the cavities to limit reflection and propagation of pressure waves within the cavities, and radiation of shock waves into the cabin from the conditioning air vents. Materials such as vermiculite, which are of low density yet have excellent explosive energy absorption properties, may have application in this area, perhaps in lieu of the existing insulation material.

Since the existing cavities often serve as part of the air conditioning outflow circuit, some consideration will need to be given to finding an alternative route. However, the flow rates are small compared with the total cross-sectional flow potential of the cavities and this function could be served by separate air conditioning ducts, or perhaps by restricting access to one or two cavities only (thus limiting the risk), or by using some form of blast valve to close off the air conditioning vents. Similarly, the requirement to vent pressure from the cabin in the event of a cargo bay decompression would also need to be addressed.

APPENDIX F

BAGGAGE CONTAINER EXAMINATION, RECONSTRUCTION AND RELATIONSHIP TO THE AIRCRAFT STRUCTURE

1. Introduction

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited blast damage. It was confirmed by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE), after detailed physical and chemical examination, that these items showed conclusive evidence of a detonating high performance plastic explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence from the effect of Improvised Explosive Device (IED). It was evident, from the main wreckage layout that the IED had been located in the forward cargo hold and, although all baggage container wreckage was examined, only items from the forward hold showing the relevant characteristics were considered for the reconstruction. This Appendix documents the reconstruction of two particular containers and, from their position within the forward fuselage, defines the location of the IED.

2 Container Arrangement

Information supplied by Pan Am showed that this aircraft had been loaded with 12 baggage containers and two cargo pallets in the forward hold located as shown in Figure F-1. Three containers were recorded as being of the glass fibre reinforced plastic type (those at positions 11L, 13L and 21L) with the remaining 9 being of metal construction.

3. Container Description

All the baggage containers installed in the forward cargo hold were of the LD3 type (lower deck container, half width - cargo) and designated with the codes AVE, for those constructed from aluminum alloy, and AVA or AVN for those constructed from fibreglass. Each container was specifically identified with a four digit serial number followed by the letters PA and this nine digit identifier was present at the top of three sides of each container in black letters/numbers approximately 5 inches tall. Detail drawings and photographs of a typical metal container are shown in Figure F-2. Each container was essentially a 5 feet cube with a 17 inch extension over its full length to the left of the access aperture. In order to fit within the section of the lower fuselage this extension had a sloping face at its base joining the edge of the container floor to the left vertical sidewall at a position some 20 inches above the floor. The access aperture on the AVE type container was covered by a blue reinforced plastic curtain, fixed to the container at its top edge, braced by two wires and central and lower edge cross bars which engaged with the aperture structure. The strength of this type of container superstructure was provided by the various extruded section edge members, attached to a robust floor panel, with a thin aluminum skin providing baggage containment and weatherproofing.

4. Container Identification

Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to the town of Lockerbie and was characteristically different from that from the forward hold, in that it was generally severely crushed and covered in mud. The forward hold debris, by comparison, was mostly recovered from the southern wreckage trail some distance from Lockerbie and had mainly been torn into relatively large sections.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this two containers, one metal and one fibreglass, were identified as exhibiting damage likely to have been caused by the IED. From the Pan Am records the metal container of these two had been positioned at position 14L, and the fibreglass at position 21L (adjacent positions, 4th and 5th from the front of the forward cargo hold on the left side). The serial numbers of these containers were respectively AVE 4041 PA and AVN 7511 PA.

5. Container Reconstruction

Those parts which could be positively identified as being from containers AVE 4041 PA and AVN 7511 PA were assembled onto one of three wooden frameworks; one each for the floor and superstructure of container 4041, and one for the superstructure of container 7511. Figures F-3 to F-9 show the reconstruction of container 4041 and Figure F-10 shows the reconstructed forward face of container 7511.
Approximately 85% of container 4041 was identified, the main missing sections being the aft half of the sloping face skin and all of the curtain. Two items were included which could not be fracture or tear matched to container 4041, however, they showed the particular type of blast damage exhibited only by items from this container.

While this work was in progress a buckled section of skin from container 4041 was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device.

Examination of all other component parts of the remaining containers from the front and rear cargo holds did not reveal any evidence of blast damage similar to that found on containers 4041 and 7511.

6. Wreckage Distribution

Those items which were positively identified as parts of container 4041 or 7511, and for which a grid reference was available, were found to have fallen close to the southern edge of the southern wreckage trail. This indicated that one of the very early events in the aircraft break-up sequence was the blast damage to, and ejection of, parts of these two containers.

7. Fuselage Reconstruction

In order to gain a better understanding of the failure sequence, that part of the aircraft's fuselage encompassing the forward cargo hold was reconstructed at AAIB Farnborough. After all available blast damaged pieces of structure had been added, the floor of container 4041 was installed as near to its original position as the deformation of the wreckage would allow and this is shown in Figure F-11. The presence of this floor panel in the fuselage greatly assisted the three-dimensional assessment of the IED location. Witness marks between this floor and the aircraft structure, tie down rail, roller rail and relative areas of blast damage left no doubt that container 4041 had been located at position 14L at the time of detonation.

8. Analysis

The general character of damage that could be seen on the reconstructions of containers 4041 and 7511 was not of a type seen on the wreckage of any of the other containers examined. In particular, the reconstruction of the floor of container 4041 revealed an area of severe distortion, tearing and blackening localised in its aft outboard quarter which, together with the results of the forensic examination of items from this part of the container, left no doubt that the IED had detonated within this container.

Within container 4041 the lack of direct blast damage (of the type seen on the outboard floor edge member and lower portions of the aft face structural members) on most of the floor panel in the heavily distorted area suggested that this had been protected by, presumably, a piece of luggage. The downward heaving of the floor in this area was sufficient to stretch the floor material, far enough to be cut by cargo bay sub structure, and distort the adjacent fuselage frames. This supported the view that the item of baggage containing the IED had been positioned fairly close to the floor but not actually placed upon it. The installation of the floor of container 4041 into the fuselage reconstruction (Figure F-11) showed the blast to have been centered almost directly above frame 700 and that its main effects had not only been directed mostly downwards and outboard but also rearwards. The blast effects on the aircraft skin were onto stringer 39L but centered at station 710 (Figure F-12). Downwards crushing at the top, and rearwards distortion of frame 700 was apparent as well as rearwards distortion of frame 720.

With the two container reconstructions placed together it became apparent that a relatively mild blast had exited container 4041 through the rear lower face to the left of the curtain and impinged at an angle on the forward face of container 7511. This had punched a hole, Figure F-10, approximately 8 inches square some 10 inches up from its base and removed the surface of this face inboard from the hole for some 50 inches. Radiating out from the hole were areas of sooting, and other black deposits, extending to the top of the container. No signs were present of any similar damage on other external or internal faces of container 7511 or the immediately adjacent containers 14R and 21R.

The above assessment of the directions of distortion, comparison of damage to both containers, and the related airframe damage adjacent to the container position, enabled the most probable lateral and vertical location of the IED to be established as shown in Figure F-13, centered longitudinally on station 700.

9. Conclusions

Throughout the general examination of the aircraft wreckage, direct evidence of blast damage was exhibited on the airframe only in the area bounded, approximately, by stations 700 and 720 and stringers 38L and 40L. Blast damage was found only on pieces of containers 4042 and 7511, the relative location and character of which left no doubt that it was directly associated with airframe damage. Thus, these two containers had been loaded in positions 14L and 21L as recorded on the Pan Am cargo loading documents. There was also no doubt that the IED had been located within container 14L, specifically in its aft outboard quarter as indicated in Figure F-13, centered on station 700.

Blast damage to the forward face of container 7511 was as a direct result of hot gases/fragments escaping from the aft face of container 4041. No evidence was seen to suggest that more than one IED had detonated on Flight PA103.

APPENDIX G

MACH STEM SHOCK WAVE EFFECTS

1. Introduction

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity shock wave which will propagate outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant for two reasons. Firstly, it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter. This geometric limitation occurs irrespective of charge size (within the range of charge sizes considered realistic for the Flight PA103 scenario), and thus provides a means of calculating the standoff distance of the explosive charge from the fuselage skin. Secondly, the Mach stem may have been a significant factor in transmitting explosive energy through the fuselage cavities, producing damage at a number of separate sites remote from the source of the explosion.

2. Mach stem shock wave formation

A Mach stem shock is formed by the interaction between the incident and reflected shock waves, resulting in a coalescing of the two waves to produce a new, single, shock wave. If an explosive charge is detonated in a free field at some standoff distance from a reflective surface, then the incident shock wave expands spherically until the wave front contacts the reflective surface, when that element of the wave surface will be reflected back (Figure G-1). The local angle between the spherical wave front and the reflecting surface is zero at the point where the reflecting surface intersects the normal axis, resulting in wave reflection directly back towards the source and maximum reflected overpressure at the reflective surface. The angle between the wave front and the reflecting surface at other locations increases with distance from the normal axis, producing a corresponding increase in the oblique angle of reflection of the wave element, with a corresponding reduction in the reflected overpressure. (To a first order of approximation, explosive shock waves can be considered to follow similar reflection and refraction paths to light waves, ref: "Geometric Shock Initiation of Pyrotechnics and Explosives", R Weinheimer, McDonnel Douglas Aerospace Co.) Beyond some critical (conical) angle about the normal axis, typically around 40 degrees, the reflected and incident waves coalesce to form Mach stem shock waves which, effectively, bisect the angle between the incident and reflected waves, and thus travel approximately at right angles to the normal axis, i.e.parallel with the reflective surface (detail "A", figure G-1).

3. Estimation of charge standoff distance from the fuselage skin

Within the constraint of the likely charge size used on Flight PA103, calculations suggested that the initial Mach stem shock wave pressure close to the region of Mach stem formation (i.e. the shock wave face-on pressure, acting at right angles to the skin), was likely to be more than twice that of the incident shock wave, with a velocity of propagation perhaps 25% greater. However, the Mach stem out-of-plane pressure, i.e.the pressure felt by the reflecting surface where the Mach stem touches it, would have been relatively low and insufficient to shatter the skin material. Therefore, provided that the charge had sufficient energy to produce skin shatter within the conical central region where no Mach stems form, the size of the shattered region would be a function mainly of charge standoff distance, and charge weight would have had little influence. Consequently, it was possible to calculate the charge standoff distance required to produce a given size of shattered skin from geometric considerations alone. On this basis, a charge standoff distance of approximately 25 to 27 inches would have resulted in a shattered region of some 18 to 20 inches in diameter, broadly comparable to the size of the shattered region evident on the three-dimensional wreckage reconstruction.

Whilst the analytical method makes no allowance for the effect of the IED casing, or any other baggage or container structure interposed between the charge and the fuselage skin, the presence of such a barrier would have tended to absorb energy rather than re-direct the transmitted shock wave; therefore its presence would have been more critical in terms of charge size than of position. Certainly, the standoff distance predicted by this method was strikingly similar to the figure of 25 inches derived independently from the container and fuselage reconstructions.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **Reports**

Hi Sundeep! Yes, of course I can and will. I will attach one report to three emails. They are big.

A benefit of reading on the computer is text can be searched and located much faster than in hard copy. Both are important.

They are very important and must be reviewed in detail. The pattern of wiring/cargo door cause can be discerned in each.

There are four actually but one is on a web site. It is over 8 megs of PDF. It is the NTSB AAR 00/03 for TWA 800. http://www.ntsb.gov/publictn/A_Acc1.htm is the URL to go to to download **Title:** Aviation Accident Report: In-flight

Breakup Over the Atlantic Ocean Trans World Airlines (TWA) Flight 800 Boeing 747-141, N93119 near East Moriches, New York July 17, 1996
NTSB Report Number: AAR-00-03, adopted on 08/23/2000 [Abstract | PDF document]
NTIS Report Number: PB2000-910403

The TWA 800 report is 350 pages.

The AI 182 report I shall attach in another email. It is about 250 pages.

The UAL 811 report I shall attach in next email. It is NTSB AAR 92/02 and must almost be memorized, it is the model for the other three.

The PA 103 report I shall insert and attach in another email.

They are very long and if you don't get them from me in the right manner, tell me and we shall try again.

Get lots of printing paper and be patient, it takes a long time to print out, I've done it myself several times.

I must impress upon you, Aniljit, Mr. Malik, and Mr. Smart the importance of becoming very knowledgeable about the details in these four accident reports. Always remember, AI 182 was a plane crash, not a bank robbery. Mr. Malik in prison will find the reading of these documents very enlightening. They will give him hope.

The pattern in all four is wiring/cargo door rupture event and not bomb although for all four, bomb was the initial explanation.

Cheers,
Barry

Hi Barry!

My name is Sundeep Kaur, I am helping Aniljit Singh and Mr. Malik with legal research, etc.

YOu sent three reports to Aniljit Singh and he has asked me to print them up, I was wondering if you could send those reports to me as attachments so that i can do that. It is easier for us to review hard copies of reports than on the computer. This would be much appreciated.

Thanks in advance.

Sundeep Kaur

---

auctions.yahoo.com/

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **Re: UAL 811 report**

Barry,

you do not need to email these documents again. I am going to print them directly from your webpage.

thank you

Sundeep Kaur

Sundeep, good thinking, thanks,

Cheers,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **Facts, data, evidence is/are everything.**

Barry,

I just wanted to let you know I was successfully able to print off the reports. THank you for your

cooperation and help.
Sundeep

Great, Sundeep, I know how much work that was because I've done it myself.

Let me know if there is any more data you need that I can get for you. Facts, data, evidence is/are everything.

Cheers,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: "M. Singh" <babbar187@yahoo.com>
Subject: **Re: Air India Trial**

Dear Mr. Barry, we are currently working to free Mr. Ajaib Singh Bagri and Mr. Ripudaman Singh Malik from the Air India Bombing trial for which they have already been denied bail. We have seen some of your information online and it seems to be very intriguing and amazing. We would like to get into contact with you and possibly even meet you in person and discuss some facts with you. If you could email us at this address and leave a number for us to contact you at that would be very appreciated. I'll also leave a cell phone number of a friend of mine, Perry, and you can get into touch with him if you like. The number is 1-604-833-4550. Thank you very much and we look forward to seeing you in the future.

We would like to get into contact with
you and possibly even meet you in person and discuss
some facts with you.

Dear Perry, we just talked on the phone.

I look forward to discussing with you the details of AI 182 and the wiring/cargo door explanation for the event.

There's three guys on the planet that know for sure the two accused did not plant a bomb on AI 182, the two accused and me.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>

Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net
Subject: **Why all the huge holes on same side?**

Dear Allies,

A question has been raised:

Why is the hole in
the plane from the so called bombs always in the same spot. Is the hole not
better explained by the decompression theory.

This is a very important question. I confronted this anomaly years ago in a similar way with the question to myself, "Why do the 'bombs' always get put in the forward cargo hold when there there are two identical cargo holds, forward and aft, which contain passenger baggage? And yet, for all four of the accident aircraft the 'bomb' was always placed in the forward cargo hold by unwitting, unbiased, ground baggage handlers. There are five possible combinations: 1. All in aft, 2. all in forward, 3. three in aft, one in forward, 4. Three in forward, one in aft. 5. Two in aft, two in forward. So the odds are four to one against that they would all be put in the forward. Possible but unlikely when there exists in the forward cargo hold a door known to have opened inadvertently in the past causing a huge hole and which mimics a bomb in the explosive decompression.

Regarding the present question, the large hole is always on the right side just forward of the wing in the forward cargo door area. The 'bomb' placement for AI 182 is not stated but presumed to be on the starboard side in the forward cargo hold. For PA 103, the 'bomb' is in the forward cargo hold on the left side and makes a small 20 inch hole while at the same time to the instant, a huge hole appears on the right side just forward of the wing. For UAL 811, the 'bomb' was on the right side just forward of the wing, until they landed and discovered it was not a bomb. For TWA 800, the huge hole is on the right side, just forward of the wing in the cargo door area. For all four the port side is relatively smooth compared to the shattered starboard/right side.

So, yes, the question is, if these are bombs randomly placed by baggage handlers in either the aft or forward cargo compartment which may get placed on the left or right side or in the middle, why do the huge holes always appear at precisely the event time at the right side just forward of the wing in the forward cargo door area? My answer is that there are no 'bomb's because that is where the forward cargo door ruptures/opens/blows out and creates the huge hole of missing cargo door and the fuselage skin it takes with it during explosive decompression which leaves all the evidence behind of twisted metal, damaged engine number three and the sudden loud sound...on all four aircraft, AI 182, PA 103, TWA 800, and UAL 811.

The answer to my question above about how the 'bombs' always get put in the forward cargo hold is that there were no bombs. The reason the locus of damage occurs in the forward cargo door area is because that is the locus of damage. Right there, it's where the forward cargo door is located.

The 'decompression theory' as was mentioned may be a better way to state the wiring/cargo door explanation. Shall I use that in future correspondence?

The thing is that once the explanation is accepted that the cause of the accident was an explosive decompression, then the question is, what caused the explosive decompression, and it could have been a bomb, missile, wiring, or center tank explosion. And maybe that is good, go step by step to the wiring/ cargo door explanation with the first step being the 'bomb' did not blow the plane apart but an explosive decompression did, right at the forward cargo door.

The answer to the above question of whether the 'decompression theory' better explains the fact that the huge holes always appears in the same place is 'yes' it does.

The placement of the bomb in AI 182 is never clearly stated but in the forward cargo hold.. For TWA 800 for 17 months while the 'bomb' theory was actively pursued, the exact location was not stated except in the forward cargo hold. For UAL 811, the 'bomb' was on the right side in the forward cargo hold. For PA 103, the 'bomb' is on the left side in the forward cargo hold.

Regarding AI 182.

The Narita circumstantial evidence of the 'bombing' is flimsy when examined, alternate villains have precedent for destruction at the airport, and the complete report has not been available for evaluation. It is not right that two 'bombs' are placed on two Boeing 747s at the same airport by the same group and one goes off after a long flight and landing and the other goes off after three flights after another aircraft gets the bomb. It only makes sense to the conspiracy thinking people. Need report by Japanese on the baggage 'bombing.'

The ticketing of the 'Singhs' is not clearly documented and does not ring true as explained by Shyrone. Need ticketing documents or tapes or interviews.

The Fifth pod is the only accident aircraft of the four with it mounted. It may be relevant as the speed was kept below 300 knots on the fatal flight until descent into London, when the speed crept up and the door blew. All other decompression events also occurred at 300 knots.

The aft door being removed may be relevant as the forward door may have been altered or examined during the removal and replacement of the aft door for comparison. All evidence for AI 182 shows it to be the forward cargo door that blew open, not the aft. Need maintenance logs for AI 182 that shows actual work done.

The above questions for AI 182 need further data before a definitive satisfactory explanation can be made.

I appreciate a real question about AI 182 that shows intelligent consideration is being given to the alternate mechanical explanation and a the thought that maybe it was not a bomb for AI 182.

Yes, what you have been reading and hearing and thinking for 15.5 years that the worst mass murder in aviation history is wrong. It was not a mass murder; it was a terrible mechanically caused plane crash that happened again three years later, then again three months later, then again seven years later.

Over a thousand people dead.

More pix below of what happens when the forward cargo door ruptures/open in flight on an early model Boeing 747, UAL 811.

Below is Report drawing of forward cargo door split in two, just like UAL 811 door.

Below is the split forward cargo door of UAL 811, it matches the sketch from official report of AI 182. The below door from UAL 811 shows rupture at the aft midspan latch by they twisted metal at that location. The vertical tearing of the fuselage skin above the door on AI 182 also matches the vertical tearing in the same location as UAL 811 as shown in photo.

It all matches, the pattern is there. Explosive decompression caused the four accidents and it wasn't bombs that did it, it was the only confirmed cause, wiring/electrical of UAL 811.

I welcome any more questions such as the one above. The thought should be, "If the forward cargo door opened in flight, then...the following should have occurred." Now, did it? For instance, if the door opened in flight, engine number three is nearby and would have ingested material to cause foreign object damage, FOD, now did it? Well, yes, it did, on all four aircraft the evidence shows foreign object damage or the effects of it on engine number three.

It's the 'if-then' logical thinking way of reasoning.

Sincerely,
Barry

(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net
Subject: **Why no burn marks?**

Dear Allies,

More good questions:

At 7:52 AM +0100 2/26/01, Santokh Singh wrote:
Q so far

1.Has it been established that a suit case from CP003 contained a bomb that exploded?

No.
2.Could the bomb's origin lie somewhere else than in Canada?

Yes.
3.What explosive was used?

Unknown, not even established explosive was bomb, could have been gas, propane, fireworks, etc.

4.How much?

Unknown.

5.What sort of residue?

Unknown.

6.What sort of burn marks?

Unknown, need report.

7.And finally, why no residue or burn marks or blackening on any AI182 wreckage?

Ah, ha! This is the very same question that Chairman Jim Hall of the NTSB raised in the public hearing on TWA 800 when there should have been burns on people and metal after an initial event of center tank explosion. Well, no burns on the passengers there for TWA 800 and no burns on the AI 182 passengers. And the reason they were not burned is there there was no bomb or center tank explosion near them to burn them. Explosive decompression does not cause burns, it causes eardrums to burst and that is what happened to the passengers as called in the reports, "baro-trauma'. The forensic evidence on the passengers supports explosive decompression caused by open cargo door and rules out burns by bombs or fuel tank explosion. The passengers in UAL 811 did not have burns but did have 'baro-trauma' as did all the passengers on all four events. More pattern matches.

So, another good question that reveals to me very astute thinking along the lines of "If bomb...then..." and "If cargo door....then..." And the evidence gets to answer the questions.

Sincerely,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **Ms. Amardeep Kaur/defense of nobody 'did' it.**

Below is feedback from Amardeep Kaur, a young lawyer attached to the Kuala Lumpur Stock Exchange, Malaysia. Her views make sense to me.

WKWF JI, have gone through the reports of the Indian court and Canadian aviation safety board and all the mails u forwarded to me from Barry Smith and others over half a dozen times in order to get a good grasp on the material.

Dear Ms. Amardeep Kaur, this is Barry Smith, thank you for your time and effort to read the reports. The answers are there to those willing to do the research with an open mind, which apparently you have.

tackling the more difficult issues in the report and seeking clarification from your goodself about fuselage and so on over the next few days....

Right. Now I concentrate on the physical laws of metal and pressure and aerodynamics and prefer not to get into the interesting but possibly irrelevant conspiracy stuff like ticketing and baggage explosions thousands of miles away. But, the circumstantial evidence must be explained. Narita needs more data and that conclusion of a bomb from Vancouver on CP 003 is very flimsy. The ticketing circumstantial evidence is even funny considering a Sikh named Singh puts his real name on a ticket that allows a mystery bomb in a mystery suitcase to be place on board a 747. But oh, he was smart, he only used his first initial to confuse the authorities, Ha!

This approach should be taken if defence is based solely on NO bomb theory.
No evil Indian conspiracy theory, just stick to facts and evidence gathered from the wreckage.
Not that "Sikhs did not bomb the plane" but there was no bomb at all to speak of in the first place.
In my opinion, this is much safer approach cause no way we are ever going to prove that it was part of conspiracy by GOI to buy ticket in vague name in order to implicate a Sikh.
No Canadian jury cares or is going to fall for that.
All they care is that 320 odd persons died and need someone tangible is to blame.

Exactly correct and my sentiments. I brought that strategy to the

PA 103 Libyan defence team last year but they went with the 'It was a bomb but our guys did not do it." Well, one guy got off and one spends the rest of his life in jail for something I know he did not do.

The best approach is to say the Sikhs did not do it because they nobody 'did' it, but then explain the event they accused of creating. And then let the Crown attack the wiring/cargo door alternate reasonable plausible mechanical explanation with precedent, UAL 811. They can try but the wiring/cargo door explanation always stands true. I've tried to discredit it for 12 years and failed. I don't spend all these years on a fairy tale.

I say we give them Boeing.
I know that brings up another conspiracy by the national safety board and so on for all these years but that is something Canadian jury/judge can probably identify with better rather than vague theory that GOI were out to down their own airline.

No, no, no, please get of this conspiracy crap. There is no conspiracy at Boeing, Scare India, NTSB, AAIB, TSB, FBI, RCMP, and media who 'know' the real reason, and hide it. Each unit above really believes it was a bomb and they are guilt free. When offered the wiring/cargo door explanation, of course they refuse to investigate, why spend time and money on an idea, if true, is perceived to destroy your company, make your country look bad, lose your job, and make yourself extremely disliked? No, they refuse to go down the wiring/cargo door/explosive decompression path because it leads to bad news, so they continue to believe in wishful thinking of bomb.

All that is paramount is what are the guidelines for Canadian travel agents and their practice.
Defence should target that particular travel agent in question - CP Air reservations and as u mentioned in previous mail and pay them a visit.
Subpoena them and their old records and find patterns as to whether they have accepted naming convention like L Singh and M Singh before and whether individuals bearing these type of naming format have boarded plans before.
Show that it is not such an anomaly in CP reservations to handle such a request in ticketing and therefore reliance cannot be placed on it.

Right. A proper investigation of the circumstantial evidence, just like the Narita explosion event which must be in the records somewhere if they convicted Mr. Reyat of the crime.

I say all this because eventhough wiring/cargo theory fits, one is always left with the question of what to do with missing persons - M Singh and their interlined baggage........

Right.
I like Barry's comment that incompetence of Air India does not prove a conspiracy. I agree, I think our stand should be along the lines of fact that world wide AI reputation sucks and always has, what with their X- Ray machine that only work intermediately that night and probably every other night the fact that interlined

baggage are not tagged to passengers shows nothing but the negligence of Air India personnel.
Plus the fact that their staff can be pressured or bullied into interlining a bag eventhough passenger was only on waiting list.
deep

Plus the fact they used duct tape! to cover a fuselage problem. The key here is who, what, why and how did they remove the aft cargo door and how did they replace it. This door is very very difficult to take apart and should only be done in a hangar with supervised personnel in good lighting. Doing this removal and reinstallation in a rush job on the ramp is very very bad maintenance policy and leads to mechanical errors.

Thank you again for your insight, Ms. Amardeep Kaur, and I'll assume it's ok and put you on my email list.

If we accuse others of doing what is being done to the Sikhs, then we become as bad as the false accusers. The authorities are doing the best they can from their perceived best interests. Truth is not the highest priority, especially if the truth harms them. Politics, continued profits and getting along is what they want, and if a few innocents go to jail, then that's the way it is. They are not in a conspiracy to hide the real reason for these plane crashes. They want to and thus really do believe they are not responsible for over a thousand deaths but a few crazy people are, and they looked around and chose some 'crazy' people who of course, did not look, act, or talk like them.

But that's politics and I should stay away from that stuff as it is not science, not real, and can not be verified. I am the wiring/cargo door/decompression expert for four early model Boeing

747s, and that's about it. Aviation safety is my priority and the hazard of bad wiring causing plane crashes exists as I write this and I can never forget that. Full speed ahead.

Cheers,
Barry
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: Research on Comets and bombings and meeting/ decision time

>The catastrophic nature of explosive decompression by an

inadvertently opened window in the structure was shown by the Comet disasters.

This rang a very loud bell.
It should wake up most of the public too.
Lets all do some searching for the Comet 1 crashes, at least two I believe.

santokh

Dear Crew, below is my research on Comet. Note cause of a crash in 1967 is another 'bomb'. After blaming the first few on bombs, they grounded the entire fleet and tried to reproduce the problem on the ground. After months of no luck they started flying them again and again one burst out of the sky. They grounded them again. Then the model on the ground broke and they found out the problem. The windows were squarish and the continued pressurizations had weakened the metal at the corners. The window ruptured/opened and tore away the fuselage skin leading to the explosive decompression that destroyed the structural integrity of the fuselage leading to disintegration of the aircraft. That is why all aircraft windows are not square but rounded. The 747 has the same problem of continued pressurizations weakening the pear shaped forward fuselage. Many cracks were found in that area and a huge retrofit was called on all 747s, it's called 'The Section 41 Retrofit."

Same as it ever was.

Note how many planes are 'bombed.' Note how many real bombings in which the plane then lands safely with hole in side of fuselage. Bombings have been used to explain mystery plane crashes for decades, it is a very old responsibility absolving device. Note the blame for AI 182 on a 'Sikh terrorist." You now know for 15 years that that blanket condemnation of millions of people is based on the most flimsy conspiracy thinking circumstantial evidence while the mechanical plausible explanation has been rejected. You have yet to review the PA 103 report and will find the same rejected reasonable explanation for wiring/cargo door/explosive decompression and the attachment of the flimsy conspiracy thinking bomb explanation. But the person rejecting the obvious are not conspirators, just well meaning people acting in their own perceived best interest, and that interest is not to bring down the house around them. It's the age old problem, how do you police the police?

Note I now refer to the explanation as wiring/cargo door/ explosive decompression, it may be more persuasive to show a sequence.

Can you sense the urgency? These sudden night fiery fatal jet plane crashes happen, it's real, I was in one. I watched as TWA 800 developed and know from the beginning as soon as the sudden loud sound appeared on the CVR and confirmed it was another wiring/cargo door/explosive decompression event because I had been researching the cause for several years up to that time. I do not want to watch more funerals and more crying parents.

I ask to meet with the senior attorneys for the two accused, Mr. Malik and Mr. Bagri, who are, I believe, represented by Mr. Smart, Mr. Mitchell, Mr. Campbell, and Mr. Peck. This wiring/ cargo door/explosive decompression can be presented and decided on in a few hours after the reports have been read. There has been plenty of time to have read the reports. The data is there and it is time for analysis and conclusions. I am here to assist in that decision making process. I invite the attorneys and assistants to come to my home in Carmel Valley California for a detailed review of the research and analysis.

Refute and boot, or agree and see. Fish or cut bait. Time to get off the pot. You pays your nickel and you takes your choice. Push has come to shove.

Make up your mind. Time's a wastin'.

The decision is not to conclusively show that the wiring/cargo door/explosive decompression is the correct answer for AI 182 or even for the others, but to show that wiring/cargo door/explosive decompression for AI 182 has enough truth in it to further investigate it to rule it in or rule it out.

Further investigation to rule it in means bringing me on board as part of the defence team, it means expenses for travel to foreign countries to examine wreckage, it means obtaining depositions, videotapes, and other reports, and it means continued research into AI 182, an event of years past. As time goes on, the job does not get easier; it gets harder.

Cheers,
Barry

De Havilland Comet (CF-CUN)	03/03/1953	Canadian Pacific Airlines
De Havilland Comet (G-ALYV)	05/02/1953	British Overseas Airways
De Havilland Comet	01/10/1954	British Overseas Airways

(G-ALYP)
De Havilland Comet 04/08/1954 South African Airways(G-ALYY)
De Havilland Comet 11/23/1961 Aerolineas Argentinas(LV-AHR)
De Havilland Comet 12/21/1961 British European Airways (G-ARJM)
De Havilland Comet 07/19/1962 United Arab Airlines(SU-AMW)
De Havilland Comet 07/27/1963 United Arab Airlines(SU-ALD)
De Havilland Comet 03/20/1963 Saudi Arabian Royal Flight(SA-R-7)
De Havilland Comet 10/12/1967 British Eurpoean Airways (G-ARCO)
De Havilland Comet 07/03/1970 Dan-Air Services(G-APDN)

05/02/1953 c 16:35
LOCATION: Near Jagalogori West Bengal, India
CARRIER: British Overseas Airlines FLIGHT: 783/057
AIRCRAFT: de Havilland Comet 1 REGISTRY: G-ALYV
ABOARD: 43 FATAL: 43 GROUND:
DETAILS: Broke up in flight during a violent thunderstorm. Metal fatigue due to design flaw.

03/03/1953
LOCATION: Karachi, Pakistan
CARRIER: Canadian Pacific FLIGHT:
AIRCRAFT: Comet REGISTRY:
ABOARD: FATAL: 11 GROUND:
DETAILS: First fatal crash of a commercial jet aircraft.

04/08/1954
LOCATION: Stromboli, Italy
CARRIER: South African Airways   FLIGHT:
AIRCRAFT: de Havilland Comet 1   REGISTRY:
ABOARD: FATAL: 21   GROUND:
DETAILS: Broke up in flight. Metal fatigue due to design flaw. Third crash.

01/10/1954
LOCATION: Elba, Italy
CARRIER: British Overseas Airlines   FLIGHT:
AIRCRAFT: de Havilland Comet 1   REGISTRY:
ABOARD: FATAL: 35   GROUND:
DETAILS: Broke up in flight. Metal fatigue due to design flaw. Second crash.

10/12/1967   c 07:25
LOCATION: Off south-western Turkey
CARRIER: British Eurpoean Airways   FLIGHT: 284
AIRCRAFT: de Havilland Comet 4B   REGISTRY: G-ARCO
ABOARD: 66   FATAL: 66   GROUND:
DETAILS: Broke up at FL290. Detonation of an explosive device in the passenger cabin.

The Comet was a very significant step in commercial air travel, being the first jetliner is service. If not for the misfortunes of this aircraft
and the fact that the American Airline manufacturers were able to take advantage of the lessons the British had learnt. The UK industry might have
enjoyed more dominance in airliner manufacture. When you look at this crafts general shape, not a lot has changed since then.

Some History

The Comet 1 was a very clean low-wing monoplane with four 2,018kg (4,450lb) thrust de Havilland Ghost turbojets buried in the wing root. There was
accommodation for 36 passengers in two cabins and pressurisation enabled it to fly at levels over 12.190m (up to 40,000ft). The first prototype flew on
27th July 1949, and soon made a number of spectacular overseas flights. BOAC took delivery of ten Comet 1s and on 2nd May 1952, operated the
worlds first jet service - over the London-Johannesburg route. With their cruising speed of 788km/h (490mph) Comets covered the 10,821km (6,724
miles) in less than 24hr. On London-Singapore they cut the time from 2 1/2 days to 25hr, and reduced the London-Tokyo time from 86hr to 33 1/4hr.

Air France and UAT introduced Comets, and they were ordered by several other airlines. But exactly one year after their introduction a Comet
broke up in flight near Calcutta, and in January 1954 another disintegrated and fell into the sea near Elba. After modifications the Comet was put
back into service, but less than three weeks later, on 8th April, a third Comet broke up, and the type was withdrawn from service.

Fatigue failure of the pressure cabin was said to have been the cause of the last two failures, and some fuselage redesign resulted. Comet 2's already
under construction, were modified and went to the RAF. Work went ahead on the Rolls-Royce Avon-powered Comet 4 with longer fuselage, seats for

up to 81, and extra wing-mounted, fuel tanks.

BOAC ordered 19 Comet 4's and on 4th October 1958, operated the first ever North Atlantic jet service, the London-New York flight being made in
10 hours 22 minutes with a fuel stop at Gander. The eastbound flight was made non-stop in 6 hours 11 minutes. A shorter-span longer-fuselage
Comet 4B, with seats for up to 101, was introduced by BAe on 1st April 1960, and in the same year the Comet 4C was commissioned - this combined
the Comet 4 wings with the Comet 4B fuselage.

Bombings aboard jet aircraft

#38 23.06.85 Boeing 747-237B
VT-EFO   Air India (India)
329(329)   Atlantic Ocean ()
The aircraft broke up in flight at FL310 and crashed into the Ocean.
CAUSE: A bomb, placed on board by a Sikh terrorist, caused a powerful
explosion.

#43 21.12.88 Boeing 747-121A
N739PA   Pan American World Airways (USA)
259(259) + 11   Lockerbie (UK)
The aircraft disitegrated at FL310 after a bomb exploded in the forward cargo
hold. Larges pieces of debris fell into a residential area of Lockerbie

This listing contains all jet airliners, involved in bombings:
The list contains the following information:

number date Type
registration operator
no. of casulaties (no. of occupants) + cas. on the ground
location of accident

Bombings aboard jet aircraft

#1 22.05.62 Boeing 707-124
N70775 Continental Air Lines (USA)
45(45) Unionville; 6mls NNW (USA)
While on its way from Chicago to Kansas City at FL390, a bomb exploded in the
right rear lavatory. Consequently, the tail section separated, and the
aircraft crashed out of control.
CAUSE: Detonation of dynamite in a towel container.

#2 12.10.67 de Havilland DH-106 Comet 4
G-ARCO British European Airways - BEA (UK)
66(66) Rodhos, 100nm off; 35¡55'N 30¡01'E (Greece)
After a turnover of 1h 20mins at Athens, flight CY284 departed at 02.41h.
Flying at FL290, a bomb exploded under seat 4A or 5A in the rear of the
tourist cabin. At FL150 the Comet broke up and crashed into the sea.

#3 11.12.67 Boeing 727
N..... American Airlines (USA)
0(78) Alamosa, over (USA)
One hour and 42mins after take-off from Chicago, a small explosion occurred
in the rear baggage compartment. The Boeing was able to make a safe landing.

CAUSE: Home made bomb exploded.

#4 19.11.68 Boeing 707-324C
N17325 Continental Air Lines (USA)
0(70) Gunnison; over (USA)
While descending through FL240 towards Denver, an explosion took place in the
lavatory, followed by a fire. A safe emergency landing was made.
The passenger, seen leaving the lavatory just before the explosion, was
arrested by the FBI.

#5 11.03.69 Boeing 707
Ethiopian Airlines
0(0) Frankfurt-Rhein Main APT (Germany)
On the ground, two explosions took place in the tourist class passenger
compartment.

#6 21.02.70 Sud Aviation SE-210 Caravelle VIR
OE-LCU Austrian Airlines (Austria)
0(38) Frankfurt; nr. (Germany)
At FL100, 20mins after take-off from Frankfurt, an explosion in the forward
freight hold blew a hole of 3'x2' through the bottom of the fuselage. The
Caravelle safely returned to Frankfurt.

#7 21.02.70 Convair CV-990-30A-6
HB-ICD Swissair (Switzerland)
47(47) Zƒrich; nr. (Switzerland)
An explosion in the aft of the plane, about 9mins. after take-off. The
Convair crashed, while returning to the airport.

#8 24.08.71 Boeing 707
Alia Jordanian Airlines
0(0) Madrid-Barajas (Spain)
An explosive device in the aft lavatory complex blew a hole in the top
fuselage (3ft long). Lukily the aircraft was parked at the time.

#9 21.11.71 Sud Aviation SE-210 Caravelle III
B- 1852 China Airlines (Taiwan)
25(25) Penghu Island; nr. (Taiwan)
The aircraft crashed into the sea on a flight from Taipei to Hong Kong.
CAUSE: Probably caused by a bomb explosion.

#10 26.01.72 McDonnell Douglas DC- 9-32
YU-AHT   Jugoslovenski Aerotransport - JAT
(Yugoslavia)
27(28)   Krussne Hory Mt (Czech.)
An inflight explosion in the forward cargo hold of a homemade bomb at FL100
caused the DC-9 to break up and crash. The surviving crew member fell 15000ft
in the tailsection!
CAUSE: Bomb placed on the aircraft by the Croatian extremists organisation
'Ustasji'.

#11 08.03.72 Boeing 707-331
N761TW   Trans World Airlines - TWA (USA)
0(0)   Las Vegas-McCarran IAP (USA)
A bomb exploded in the right rear part of the cockpit while the aircraft was
parked.

#12 25.05.72 Boeing 727-116
CC-CAG   LAN Chile (Chile)
0(50)   Cuba, nr ()
One hour and 18mins after take-off from Panama City a homemade pipe bomb
exploded in the ice water fountain service compartment. A rapid decompression
followed. A succesfull emergency landing at Montego Bay was made at 13.10h.

#13 15.06.72 Convair CV-880-22M-21
VR-HFZ   Cathay Pacific Airways (Hong Kong)
81(81)   nr Pleiku (Vietnam)
The Convair (Flight CX 700Z) took off from Bangkok at 04.55h GMT bound for
Homg Kong. While flying at FL290 a bomb exploded, hidden in a suitcase under
a passenger seat on the right side over the wing.
The bomb was put on the aircraft by a police officer whose daughter and
fiancee were aboard.

#14 16.08.72 Boeing 707
4X-A..   El Al (Israel)
0(148)   over Roma (Italy)
A bomb in a portable record player (stored in the aft baggage compartment)
exploded shortly after take-off. The 200grams of explosive just caused a hole
in the baggage compartment. The Boeing landed safely back at Roma.

#15 22.03.74 Sud Aviation SE-210 Caravelle III
F-BRSY   Air Inter (France)
0()   Bastia (France)
On the ground an explosion occurred in the forward landing gear compartment,
causing substantial damage.

#16 26.08.74 Boeing 707
Trans World Airlines - TWA
0()   Roma (Italy)
After landing in Roma, a fire was discovered in the aft baggage compartment.
The fire was caused by an explosive device which malfunctioned.

#17 08.09.74 Boeing 707-331B
N8734   Trans World Airlines - TWA (USA)
88(88)   Cephalonia; 58mls W off (Greece)
En route to Athens, a bomb exploded aboard TWA Flight 841. The Boeing entered
a steep climb, went into a steep nose down spin and crashed into the Ionian
Sea. The bomb was placed in the aft cargo compartment.

#18 03.06.75 BAC One-Eleven 524FF
RP-C1184   Philippine Air Lines (Philippines)
1(64)   nr Manila (Philippines)
During descent into Manila (at FL200) a bomb exploded in the right lavatory
in the rear of the plane. The explosion caused a hole in the fuselage of 1.3m
x 4m. A successfull emergency landing was made.

#19 05.07.75 Boeing 707
Pakistan International Airlines - PIA
0()   Rawalpindi (Pakistan)
On the ground after a flight from Karachi a bomb, placed under a

passenger
seat, exploded. The explosion ripped a 3ft x 4ft hole in the fuselage.

#20 01.01.76 Boeing 720-023B
OD-AFT Middle East Airlines - MEA (Lebanon)
81(81) Al Qaysumah; 20nm NW (Saudi Arabia)
En route at FL370 from Beirut to Dubai, a bomb exploded in the forward
baggage compartment. The aircraft crashed into the desert.

#21 07.09.76 Boeing 707-328
F-BHSH Air France (France)
0(0) Ajaccio (France)
Seven masked men set dynamite explosives aboard the aircraft and caused the
explosion.

#22 06.10.76 McDonnell Douglas DC- 8-43
CU-T1201 Cubana (Cuba)
73(73) Bridgeport; 5mls W off (Barbados)
At 17.15h Flight 455 took off from Bridgetown Runway 09, heading for
Kingston. Nine minutes later, the crew tried to turn back to Barbados due to
an explosion. The DC-8 lost height rapidly and crashed in a nose down, right
wing low attitude into the sea, 5 miles offshore.
CAUSE: An explosive device detonated in the rear of the cabin, which resulted

in an uncontrollable fire, possibly causing crew incapacitation.

#23 17.08.78 BAC One-Eleven 524FF
RP-C1184 Philippine Air Lines (Philippines)
1(84) Sinara Island; over (Philippines)
En explosion in the rear left lavatory blew a hole in the fuselage. The
aircraft was flying at FL240 at the time, on its way from Cebu to Manila.

#24 26.04.79 Boeing 737-2A8
VT-ECR Indian Airlines (India)
0(67) Madras (India)
On its way from Trivandrum to Madras, the aircraft was cleared to descent
from FL270. Shortly afterwards an explosion took place in the forward
lavatory, causing a complete instrument and electrical failure.
The Boeing had to make a flapless landing at Madras. The aircraft touched
down 2500ft past the Runway 25 threshold and overran. The right side of the
plane caught fire.
CAUSE: As a result of the explosion, the flaps, reverse thrust and anti-skid
systems couldn't be used during the emergency landing.

#25 15.11.79 Boeing 727
N..... American Airlines (USA)

0(78) Chicago; nr. (USA)
Thirty minutes after leaving Chicago, a bomb device hidde in a wooden box in
a mail bag detonated. This resulted in pressure fluctuations and smoke in the
cabin. A safe landing was made at Washington-Dulles.
FBI thinks the bomb was placed aboard by the 'Unabomber', who was responsible
for a number of attacks on universities and airlines since 1978.

#26 09.09.80 Boeing 727
N..... United Air Lines (USA)
0(44) Sacramento (USA)
While passengers were deplaning, a small carbord box blew up in the cargo
hold and injured two cargo handlers.

#27 21.12.80 Sud Aviation SE-210 Caravelle VIR
HK-1810 TAC Colombia (Colombia)
70(70) Guajira (Colombia)
At 14.18hrs the Caravelle took off from Rio Hacha for a flight to Medellin.
Five minutes after take-off an explosion occurred and there appeared to be a
fire in the right-hand aft portion of the aircraft. The Caravelle went out of
control and crashed.
The aircraft was on its first scheduled flight after 17 months of maintenance
work.
It's not known for sure whether the explosion was caused by a

bomb or not.

#28 31.08.81 Boeing 720-023B
OD-AFR Middle East Airlines - MEA (Lebanon)
0() Beirut IAP (Lebanon)
Shortly after arriving from a flight from Libya, an explosion of approx. 5kgs
of dynamite destroyed the aircraft.

#29 13.10.81 Boeing 737-2K2C
PH-TVC Air Malta (Malta)
0(0) Cairo IAP (Egypt)
While offloading luggage a porter and 3 security guards were injured when two
parcels exploded about 15mins apart. A third bomb which didn't detonate, was
located later.

#30 12.12.81 Boeing 727-025
YN-BXW Aeronica (Nicaragua)
0() Mexico City (Maxico)
When the passengers were ready to embark the plane, a bomb exploded between
the rearmost cabin seat on the left aisle and the cabin wall. The blast tore
a 3ft hole in the fuselage. The captain, 2 stewardesses and an aiport
mechanic where injured.
The aircraft was preparing for a flight to San Salvador.

#31 11.08.82 Boeing 747-121
N754PA   Pan American World Airways (USA)
1()   Hawaii; 140mls (USA)
On a flight from Tokyo one passenger was killed when a bomb, located under
the seat cushion, exploded. The explosion also resulted in a hole in the
floor and damage to the ceiling and overhead racks. A safe landing was made
at Honolulu.

#32 19.08.83 Boeing 727-294
YK-AGA   Syrian Arab Airlines (Syria)
0(12)   Roma (Italy)
During boarding a glass bottle containing flammable liquid, located under a
seat in the passenger area near the right overwing emergency exit, caused a
fire. The interior of the plane completely burned out.

#33 23.09.83 Boeing 737-2P6
A40-BK   Gulf Air (Oman)
112(112)   Mino Jebel Ali (UAE)
After a brief distress message, the aircraft crashed in the desert.
Evidence indiacted that a bomb had exploded in the baggage compartment.
The aicraft was on a flight from Karachi to Abu Dhabi.

#34 18.01.84 Boeing 747

Air France
0(261) Karachi, 70mls (Pakistan)
An in-flight explosion after leaving Karachi blew a hole in the right rear
cargo hold and caused a loss of cabin pressure. An emergency descent to
5000ft was made and the aircraft returned to Karachi.

#35 10.03.84 McDonnell Douglas DC- 8-63PF
F-BOLL Union de Transportes A⁄riens - UTA (France)
0(23) N'Djamena (Tchad)
Twenty minutes after arriving from Brazzaville, a bomb exploded in the
central baggage compartment.

#36 23.01.85 Boeing 727-2K3
CP-1276 Lloyd A⁄reo Boliviano - LAB (Bolivia)
1(127) Santa Cruz; 30nm (Bolivia)
While descending through FL100 a passenger went into the forward lavatory
carrying a dynamite in a briefcase. The dynamite exploded, killing the
passenger. The aircraft made a safe landing at Santa Cruz.

#37 09.03.85 Lockheed L-1011 TriStar 500
Royal Jordanian Airlines
0() Dubai IAP (UAE)
On ground at Dubai, after a flight from Karachi, a bomb exploded in a baggage

compartment.

#38 23.06.85 Boeing 747-237B
VT-EFO Air India (India)
329(329) Atlantic Ocean ()
The aircraft broke up in flight at FL310 and crashed into the Ocean.
CAUSE: A bomb, placed on board by a Sikh terrorist, caused a powerful
explosion.

#39 30.10.85 Boeing 727
American Airlines
0() Dallas-Fort Worth (USA)
An explosion occurred in the forward baggage compartment while baggage was
being unloaded.
The device was contained in a vinyl tote bag.

#40 02.04.86 Boeing 727-231
N54340 Trans World Airlines - TWA (USA)
4(121) K⁄rkira (Corfu); over (Greece)
While descending through FL100 a bomb exploded, causing a 1,40 x 1,60m hole
in the fuselage. Four passengers fell off the aircraft. The aircraft landed
safely at Athens.

#41 26.10.86 Airbus A.300B4-601
HS-TAE Thai Airways International (Thailand)

0(239)   nr Shimizu (Japan)
An explosion at FL330 caused a rapid decompression and the loss of 2
hydraulic systems.
The Airbus made an emergency descent with a max of 2.6g and landed safely.
CAUSE: A passenger attempted to smuggle handgrenade into Japan but it
exploded in the aft toilet.

#42 29.11.87 Boeing 707-3B5C
HL-7406   Korean Air (South Korea)
115(115)   Andaman Sea; 14¡33' N 97¡23' E ()
At 00.01h UTC Koream flight 858 departed Abu Dhabi for a flight to Seoul via
Bangkok. At 05.01h UTC the last message was received. It appeared that a bomb
explosion aboard caused the crash.
Two passengers who had left the plane at Abu Dhabi, left a radio and liquor
bottle containing hidden explosives in the overhead rack at row 7.

#43 21.12.88 Boeing 747-121A
N739PA   Pan American World Airways (USA)
259(259) + 11   Lockerbie (UK)
The aircraft disitegrated at FL310 after a bomb exploded in the forward cargo
hold. Larges pieces of debris fell into a residential area of Lockerbie.

#44 19.09.89 McDonnell Douglas DC-10-30
N54629   Union de Transportes A⁄riens - UTA (France)
171(171)   T⁄n⁄r⁄ desert; 16¡54'N 11¡59'E (Niger)
Flight UTA 772 (Brazzaville - N'Djamena - Paris CDG) departed N'Djamena at
12.13h. While climbing through FL350, 21mins after take-off, a pentryt bomb
exploded near seat 13R. The DC-10 disintegrated and crashed in the desert.
The bomb was probably placed on board at Brazzaville.
The DC-10 had accumulated 60.267 flying hours and 14.777 cycles.

#45 27.11.89 Boeing 727-21
HK-1803   Avianca (Colombia)
107(107)   nr Bogota (Colombia)
The aircraft exploded shortly after take-off.

#46 18.03.91 Ilyushin 86
SSSR-.....   Aeroflot (Russia)
0(360)   Sverdlovsk (Russia)
A psychiatric patient threw a petrol bomb, which caused an on-board fire. An
mergency landing was made at Sverdlovsk.
The aircraft was on its way from Moscow to Novokuznetsk.

#47 10.12.94 Boeing 747-283B
EI-BWF   Philippine Air Lines (Philippines)
1(293)   Minami Diato Isl.; nr. (Japan)

On a flight from Manila to Tokyo via Cebu, a bomb exploded in the passenger
cabin beneath seat 26K. A succesfull emergency landing at Okinawa was made at
12.45h.
The muslim group Abu Sayyaf claimed responsibility.

Bombings aboard jet aircraft : statistics

Departure airport ranking:

- Karachi (Pakistan) - 4 times
- Athens (Greece) - 3 times
- Roma (Italy) - 3 times
- Chicago (USA) - 3 times
- Brazzaville (Congo) - 2 times
- Cebu (Philippines) - 2 times

Total casualties:
1626
(including 11 casualties on the ground at Lockerbie and 70 casualties of a Colombian Caravelle of which it's not sure whether a bomb caused the
accident or not).

Total aircraft destroyed:
23

Total aircraft destroyed in-flight:
16

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **Money losing AI**

Dear Crew, Pan Am went out of business, TWA is out of business, and AI is about to go out of business unless propped up by another airline. All had mystery crashes of their 747s which were initially thought to be bombs. Only United Airlines, which confirmed it was not a bomb but wiring/cargo door/explosive decompression event and fixed the plane and put it back into service, is still profitable and thriving.

Trying to shift blame may help in the short term for some careers but in the long run, the companies crash just like their planes.

Barry

Lufthansa suddenly pops up in race for Air India
*Updated 9:34 AM ET February 23, 2001*By Aparna Kalra

NEW DELHI, Feb 23 (Reuters) - Lufthansa, the German national airline, suddenly emerged as a possible suitor for a piece of Air India when bidding closed on Friday for a 40 percent stake in the money-losing state-run airline.

Lufthansa surfaced as a technical adviser to the U.K.-based billionaire Hinduja brothers, who lodged bids for both international carrier Air India, and a 26 percent stake in Indian Airlines, a primarily domestic carrier.

Lufthansa's entry in the Air India race surprised analysts as the airline would be competing with Singapore Airlines, its Star Alliance partner, if it eventually joins the Hindujas as a bidding partner for the Indian flag carrier.

As expected, Singapore Airlines tabled a bid jointly with the Tata Group, one of India's largest conglomerates with interests in the vehicle manufacturing, steelmaking and infotech industries.

Lufthansa said earlier it would not compete with Singapore Airlines for Air India. Both airlines are part of the 15-member Star Alliance.

Yet India could be a key market for both airlines.

Due to growing business and tourist traffic between the two countries, Lufthansa is keen to increase its number of flights between Germany and India from 15 a week now.

For cash-rich Singapore Airlines, India, the world's second most populous nation, offers a potentially immense new market and a strategic location from which to branch out to the Middle East.

Singapore Airlines already owns a 49 per cent stake in Britain's Virgin Atlantic Airways.

Lufthansa, Europe's second-largest airline, is in talks to pick up a 10 percent stake in Thai Airways.

With a 24 aircraft fleet, Air India is small by global standards but has unutilised flying rights and vast land assets.

But the route network of the former global carrier has shrunk greatly the past decade as financial and labour problems mounted.

Air India racked up losses totalling 10 billion rupees ($214.6 million) the past five years, is saddled with 38 billion rupees in debt and has a massive workforce - 680 employees per aircraft, twice the industry average.

TECHNICAL ADVISER

Lufthansa Consulting GmbH, a unit of Deutsche Lufthansa AG, the holding company that owns the giant German airline, emerged on Friday, the deadline for finalising partners and submitting business plans, as a technical collaboration partner to the Hinduja brothers.

But a Hinduja spokesman hinted that Lufthansa may step in later to buy an ownership stake in Air India.

"This partnership could be developed further depending on mutual agreement between the two parties," the spokesman told Reuters.

Other bidders in the Air India race include Air France and Atlanta-based Delta Airlines, the third-largest U.S. airline, which have teamed up to bid jointly.

London-based steel magnate L N Mittal has withdrawn from the race, an Indian newspaper reported earlier this week.

The Indian government, which is selling the stakes and management control of the two state-run airlines as part of a privatisation drive, does not disclose any bidding details, even the number of bids received.

INDIAN AIRLINES

The Tata group said on Friday it had dropped out of the race for Indian Airlines IA.UL, a largely domestic airline, leaving just two remaining bidders -- the Hinduja brothers and the Indian consumer electronics firm Videcon International.

Indian Airlines, which has a fleet of 52 aircraft including 30 Airbus A 320s, posted small profits for the three years to last March. But a crash in July, which killed 58 people and raised questions about the state of the airlines' ageing fleet, has since pushed the carrier into the red.

It posted a net loss of 1.37 billion rupees ($29.4 million) for the past April-October half, against a profit of 143.5 million rupees in the same period a year earlier.

Private-sector rival Jet Airways, with a young fleet of 25 Boeing 737s, has been snapping at Indian Airlines heels, eroding its dominant market-share.

(US$1 - 46.595 Indian rupees) ((Aparna Kalra, +91-11-3012024, fax +91-11-3014043, aparna.kalra +reuters.com))

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **Door latches, damage, and cams**

Barry,
Want to push this on forums.

I am stopping for the night and will start tomorrow. I could search for these facts but you probably have them at your finger tips.
The fwd cargo door is 110 x 99 ins.
top 110 length is hinged.

Dear Santokh,

Yes, and that hinge stays mostly intact on all four. Paint smears above hinge on two events and maybe all, need to examine that part of fuselage.

two 99 sides have one latch each. how are they turned?

They are the midspan latches and this is where the ruptures occur. Each is similar to the eight below except these midspan do not have locking sectors. The principle is a locking pin in fuselage, a cam in door goes around the pin and the locking sector keeps the cam from being back driven. For UAL811 the cams bent the locking sectors and allowed door to rupture. The fix AD was to strengthen the locking sectors....but the midspan have no locking sector to strengthen. Stick up your finger and surround it with a "U' of your other hand and then encircle your stuck up finger. The cam encircles the latching pin. Then put another finger across the top of the open U. That is the locking sector.

bottom 110 has 8 locks which can be turned by elec motor.

The are all turned by an electric door unlatch motor which is supposed to not have power after takeoff. The motor turns bellcranks and torque tubes to unlock the locking sectors and then turn the cams to open position and then door can be opened. It is a very complex procedure to open and close this door. Many things can go wrong and have. There are several AD about this door, from the sill, the wiring, to the locking sectors.

AI182:
how many unlocked partially?

Unknown, never stated but look at report of the videotape of the door, probably the most important part of the report. This rules out aft cargo door and keeps forward cargo door as probable. The text description of AI 182 door reads as TWA 800 looks.

'All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed.'

2.11.4.6 Section 42
Portions of section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers.
All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some

fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

how many broke?

Unknown. Need to review videotapes to find out. Very important.

PA, TWA, UA, same questions.

PA 103 also unknown by report but evidence exists in hangar in Farnborough.

UAL 811, all latches let go and rupture occurred at midspan. The midspan latches are missing from wreckage recovery on all four events. That is another important matching clue because it is so rare to have eight specific things missing from all four 747 crashes and of course, it matches UAL 811.

Below is TWA 800 forward cargo door showing rupture at midspan latch and 'outward force' and 'badly frayed, and 'fractured one third up.'

Cheers,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: "aniljit singh uppal" <aniljitsingh@hotmail.com>
Subject: **Re: You guys all right?**

Thank you for asking. We are all fine.
Aniljit Singh

Dear Aniljit, are you an attorney?

And watch out for the aftershocks.......

Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my, dsreyat@hotmail.com
Subject: **Odds against bomb for hole, certain for door**

Dear Aniljit,

Narinder just called me on the phone and we have set up a meeting at my home on Tuesday at 11AM. This should be fruitful. Thank you for you opinion about the persons listed and I shall give Narinder my full trust and confidence.

Crown funding:

Well, at least ask for one legal and one aviation expert to be assigned to staff. The Crown had dozens of both.

Ask for funding to at least visit places the prosecution visited to include India and Great Britain.

Ask for assistance to visit and evaluate the evidence in the hangar in the USA and UK, and videotapes held by the RCMP.

The defense has this right to examine the evidence used against them and has the right of 'discovery' to pursue more evidence that may clear the accused.

That means examining the wreckage, because after all, after all, this is a plane crash, not a bank robbery.

'Bombs" on same side? Just about impossible, almost like being hit by a flying saucer.

It's because of the random placement in the cargo holds by neutral baggage handlers who just put the bags where they do without consideration of maximum bomb damage.

The cargo holds are huge and four bombs designed and put in baggage which go off over a space of 11 years would not put a huge hole in the exact same place on a 747.

The random placement means the possibility of aft cargo hold for one or some or all, left, middle, or right side for one or some or all.

Permutations: Here's just one possible combination:

1 aft left, 3 forward left
1 aft left, 3 forward right
1 aft left, 3 forward center
1 aft left, 2 forward left, 1 forward center
1 aft left, 2 forward left, 1 forward right
1 aft left, 1 forward left, 2 forward right
1 aft left, 1 forward left, 2 forward center
1 aft left, 1 forward left, 1 forward right, 1 forward center
1 aft left, 2 forward right, 1 forward left
1 aft left, 2 forward right, 1 forward center
1 aft left, 2 forward center, 1 forward left
1 aft left, 2 forward center, 1 forward right

1 aft right and all of above for forward
1 aft center and all of the above for forward

That's for one combination if one 'bomb' gets put in aft compartment. Do the math for 2 'bombs' in aft, then 3, then four. (It should be figured out) It goes on and on.
The odds are extremely high against all being 4 forward right if caused by bombs. It's 100 percent certain the holes would be exactly where they are if the forward cargo door ruptured open in flight.

All four 747s had huge hole at event time forward right side of the cargo hold. The shape is generally the same, rectangle, the size is generally the same, large about ten-20 feet by thirty to forty feet high. The time is the same, event time. The consequences are the same, ejected material is ingestest by the nearby engine number three. The cause for one is confirmed, wiring/electrical system and confirmed not a bomb.

My impatience is assuaged by your reassurance the defense team is aware of the wiring/cargo door/explosive decompression explanation and will be calling upon me to present it to them.

Thank you again for keeping me informed, Aniljit. I look forward to meeting Narinder on Tuesday.

Cheers,
Barry

Didar is Mr. Reyat's son and NArinder is Mr. Bagri's son in law's brother. I
know both of them well and they are both fine.

Reyat's defense team has not been organize yet as he is busy contesting his
extradition.

Mr. Bagri's lawyer is busy with the bail appeal and it seems that we are the
only ones thinking trial.

The crown funding is a big if right now and we want it to happen so that the
resources to challenge the crash are quickly put in place. I am sure you can
understand the crown's position.

REst assured, all of the defense teams are aware of your research and will
be calling on you. Rest now as the going in a few weeks / months will be
exhaustive.

My fascination remains with the probability of all four bombs damaging the
same side. This is something that a layperson can easily comprehend. Please
identify all the possible areas - are there six or eight - where a bomb
could be placed.

Aniljit Singh

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl,

KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: Further analysis

Dear Deep,

Am not the one that needs to be convinced anyway.
Have to convince the media and courts......

And the manufacturer and the airlines...to fix the problem so that it does not kill hundreds more....and two more innocents are accused of 'bombing' in addition to the two Libyans and the three Sikhs.

Biggest disadvantage, we only have 3 - 5 % of the wreckage....

but lots and lots of videotapes held by RCMP.

but all we need is reasonable doubt.

Exactly right, a reasonable alternative to 'bomb' so that further investigation is justified. And it is.

Unfortunately though as u are acutely aware, one of the most important pieces of evidence lies at the bottom of the ocean.

It's a movie, the door with the important latches lifted up and just before put on barge......the cable snaps and down it goes never to be found again.

But...but, the videotapes are there as well as any film photo of door in air before loading. The report describes it so the tape does exist.

Only description we have is from 2.11.4.6 as u have reproduced below. some fuselage - vague at best -
no mention of latches and their positions, midspan or otherwise....
no mention of bare wires around cargo door area.....
Manual locking handle - missing ??

Yes.

Condition of door - should be outward and upward force but here cargo floor still attached, is that consistent ??

Well, good question and here's the answer. If bottom latches held and midspan ruptured, as in TWA 800, the bottom sill would be attached to fuselage but rest of door is shattered, as described in report by outward force and explosion decompression occurs. A house door can be blown out and the edge of the door can still be on hinges and even the doorknob can still be locked. But middle is shattered by outward force and big hole exists.

Also,

A beam is solid, the panels are light. If the beam goes down and pulls away from panels, as I contend it did with explosive decompression which bends beams down; it would appear the same to investigators if beam stayed in place and panels blew up, as the 'bombers' contend. The effect is the same but the cause is different. Glass half full or half empty, depends on point of view and bottom line, is the panels moving up is still consistent with explosive decompression sucking everything down.

Again the explosive decompression mimics a bomb.

Also, that means Not the whole door flew open and hit engine 3 but
only some part of it or an object from ??

Right. Probably debris from the baggage compartment.

which then struck crawl of no. 4 engine.

right, cowl, cowling. Which then leads to severe vibration in the engine which jerks free, as pylon is designed to do when stressed, and engine number three falls differently than the other three engines, 1, 2, 4. That is an important match for PA 103, TWA 800, and AI 182, engine number three is always different than the other engines in where it lands, the FDR EPR readings, and the internal descriptions of it. It had to be, that pesky number three.

Also in the whole report, I cannot find any mention of CWT and it's damage which as we know, exploded

We don't know about CWT and exploding. Where did you get that. It can be assumed some tanks caught on fire after the initial event as stated in report, by which tank? TWA 800 has the CWT exploding as initial event.

and is what is being perceived as the "bomb"

The bomb perception is tremendous explosion in forward cargo hold when door ruptures and causes 'explosive decompression' and they don't call it 'explosive' for nuttin'. The bomb mimics the explosive decompression or is it vice versa.

The center tank is aft of the leading edge of the wing right ??

Yes, immediately aft. Are you talking about TWA 800? 800 was stated as initial event as CWT explosion with mystery source. TWA 800 is another wiring/cargo door/explosive decompression event with CWT exploding later on which is why the passengers were not burned or showed signs of explosion. NTSB got TWA 800 wrong too. NTSB blamed a symptom of CWT, not the cause of TWA 800 which is also wiring/cargo door/explosive decompression.

In English, what section would that be ???

I call it the center wing tank section.

What I like to use as my checklist is your list of

nose came off

damaged no 3 engine
sudden loud sound in CVR
sudden power cut to FDR
and so on..

Sequence wrong. All this happens within seconds below

water in hold,
wire chafes to bare wire,
wiring short,
door unlatch motor on
cams turn
midspan latches rupture.
door blows out and up taking fuselage skin with it
Sound on CVR of explosive decompression, nose still on.
Power cut to FDR when adjacent explosion tears into compartment severing wires, nose still on
300 knots hits weakened nose with huge hole in it
foreign objects ingested by engine number three which catches fire
Nose comes off
Fuel tanks may ignite.
Debris from forward cargo door area land on surface first and closest to event time, since first out.

...

I found it most useful to take as broad headings in order to list down the similarity. It is so amazingly true and accurate.
Fantastic list !!!
Using that method, i found all the same patterns so easily.

Yes, the forest is clear to see if one looks and stop only looking at the tree. It's like a successful serial killer, many jurisdictions, many different locations, spread out over time and well respected by the community who would not suspect it and would protect it. Each police force thinks they have a unique crime and will not consider other similar events. They each want the glory of the collar and end up with the wrong arrest. In the Soviet Union they hung an innocent man who was accused of the murder of one of many by a serial killer.

Here the accused innocents just go to jail forever. And a whole group of people are smeared forever.

Also, can easily prove no soot = no fire except two pieces of overhead locker above 2R/4R, one seat cushion - location not known, one suitcase - not identified to come from the crash so distinguishable.
no evidence of fire damage from floating wreckage.

There may have been no large fire for 182. there was for 103 and 800. Engine fires for all which may have given the sooting of the few pieces of floating wreckage. FOD causes fires in engines when ingested.

no chemical trace or nature of explosive identified
no part of explosive device
no explosive type of injury on passengers

if compare with avianca bombing, that is so glaring.

And yet, 'bomb'. The Indian judge stretched so hard to ignore the no bomb evidence, the no bomb sound, the no bomb facts....Bomb was a political answer to a science problem: plane crash.

we have power cut to FDR - abrupt data loss to flight recorder which is located forward of cargo compartment.
stopped recording same time as CVR

Just after sound and very important matching clue to UAl 811 and the other two. All four had this unusual sequence. This is so rare and to happen four times....no coincidence. Cause is either all bombs, all missiles, all center tank explosion or all wiring/ cargo door/explosive decompressions.

no low frequency which is signature of detonation of explosive device.

Right.
All sounds are consistent with each other which is very rare.
To me that is the best proof - sound

I agree, airlines pay all this money for a CVR for the purpose of accident reconstruction and then when it tells them what happens which is contrary to their wishful thinking, they ignore it. Not right, very dangerous, and has resulted in further deaths in PA 103, UAL 811, and TWA 800 and maybe more.

Show that loud sound in CVR is the same and matches precisely the sound in previous aircraft = explosive decompression.

Chart 12 of NTSB document does that, matches UAL 811, AI 182, TWA 800 and PA 103.

It's as plain as the nose on your face.

Presume zone c is nearest to forward cargo compartment ??

Not sure. Need to review.

How come injuries to passengers more severe at zone E ?

Good question.

Would explosion of CWT cause more damage/injury to this zone ?

Not sure.
So few bodies recovered though to prove or disprove the pattern of injury. My only question here is how come vertical force

greater at the rear - zone E and upward from floor to ceiling ??

Good question.

anyway, shall stop here.......my questions are never ending

And good ones.

Keep it up Deep, please, let the information seep into your consciousness,...until an insight beeps to you...it leaps right out at you, makes you weep, and you run to your Jeep...Sorry, Deep, not a peep more out of me...

Cheers,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my,

dsreyat@hotmail.com
Subject: Permutations/law of averages

Dear Crew,

Aniljit has brought up the point that is strange that all the 'bomb's would go off in the same place on four 747s.

I agreed and postulated that since four huge rectangular holes appeared at precisely the event time (CVR sudden loud sound) in four 747 accidents at precisely the same location, (just forward of the wing on the starboard side, while leaving the opposite port side relatively smooth,) that there was a 100 per cent chance the occurrences could be explained as a forward cargo door rupturing/opening in flight since that is precisely where the forward cargo door is located, just forward of the wing on the right side. In addition, the event has occurred before in UAL 811 which sets a precedent supported by hard evidence.

Below are photos and drawings from official AARs which show the damage of the shattered area just forward of the wing on the right side which occurred at the precise time of the sudden loud sound on the CVR, generally agreed to be the start of event time. The port side opposite is relatively smooth or unreported on all four aircraft.

Below is 811 hole unreconstructed

Below is 800 hole area reconstructed

Below is 103 hole area reconstructed

Below is 182 hole area reconstructed.

Then I figured the odds that four bombs on four Boeing 747s spread out of thousands of miles over a period of eleven years were placed by four different terrorist groups at four different airports and still created four huge rectangular holes on the right side of four Boeing 747s. The permutations are below of the different combinations possible assuming that a bomb on the left would cause more damage on left, a bomb on the right would give more damage on right and a bomb in the middle would give equal bilateral damage.

Aft means aft cargo hold which is sealed by a cargo door identical in size and function to the forward cargo door. The holds are generally the same size. The aft is well aft of the wing, while the forward cargo hold is just forward of the wing. Aft cargo doors on all four 747s are reported to be closed and latched after examination of the wreckages while the latch status of the forward cargo door is omitted or ambiguous. Baggage is placed in the cargo hold by unbiased baggage handlers who would place the suitcases in the holds at their discretion based on airport and airline procedures.

There are 75 possible combinations possible for the four bombs in the six different locations possible in the two cargo holds. Only one combination is all four bombs in the forward cargo hold on the right side: 0 aft left, 0 aft center, 0 aft right, ++++ 0 forward left, 0 forward center, 4 forward right,. That's odds of 74 to one against bombs in cargo holds of 747s causing the huge holes at event time. It's 100 percent for the holes to have been caused by a forward cargo door rupturing/opening flight.

Law of averages is on the side of forward cargo door rupture/ opening and against 'bomb's.

Cheers,
Barry

zero bombs aft
0 aft left, 0 aft center, 0 aft right, ++++ 4 forward left, 0 forward center, 0 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 3 forward left, 1 forward center, 0 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 3 forward left, 0 forward center, 1 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 2 forward left, 2 forward center, 0 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 2 forward left, 1 forward center, 1 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 2 forward left, 0 forward center, 2 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 1 forward left, 3 forward center, 0 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 1 forward left, 2 forward

center, 1 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 1 forward left, 1 forward center, 2 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 1 forward left, 0 forward center, 3 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 0 forward left, 0 forward center, 4 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 0 forward left, 4 forward center, 0 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 0 forward left, 3 forward center, 1 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 0 forward left, 2 forward center, 2 forward right,
0 aft left, 0 aft center, 0 aft right, ++++ 0 forward left, 1 forward center, 3 forward right,

one bomb aft left
1 aft left, 0 aft center, 0 aft right, +++ 3 forward left, 0 forward center, 0 forward right,
1 aft left, 0 aft center, 0 aft right, +++ 2 forward left, 1 forward center, 0 forward right,
1 aft left, 0 aft center, 0 aft right, +++ 2 forward left, 0 forward center, 1 forward right,
1 aft left, 0 aft center, 0 aft right, +++ 1 forward left, 2 forward center, 0 forward right,
1 aft left, 0 aft center, 0 aft right, +++ 1 forward left, 1 forward center, 1 forward right,
1 aft left, 0 aft center, 0 aft right, +++ 1 forward left, 0 forward center, 2 forward right,
1 aft left, 0 aft center, 0 aft right, +++ 0 forward left, 3 forward center, 0 forward right,
1 aft left, 0 aft center, 0 aft right, +++ 0 forward left, 2 forward center, 1 forward right,

1 aft left, 0 aft center, 0 aft right, +++ 0 forward left, 1 forward center, 2 forward right,
1 aft left, 0 aft center, 0 aft right, +++ 0 forward left, 0 forward center, 3 forward right,

one bomb aft center
1 aft center, 0 aft center, 0 aft right, +++ 3 forward left, 0 forward center, 0 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 2 forward left, 1 forward center, 0 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 2 forward left, 0 forward center, 1 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 1 forward left, 2 forward center, 0 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 1 forward left, 1 forward center, 1 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 1 forward left, 0 forward center, 2 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 0 forward left, 3 forward center, 0 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 0 forward left, 2 forward center, 1 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 0 forward left, 1 forward center, 2 forward right,
1 aft center, 0 aft center, 0 aft right, +++ 0 forward left, 0 forward center, 3 forward right,

one bomb aft right
1 aft right, 0 aft center, 0 aft right, +++ 3 forward left, 0 forward center, 0 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 2 forward left, 1 forward center, 0 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 2 forward left, 0 forward

center, 1 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 1 forward left, 2 forward center, 0 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 1 forward left, 1 forward center, 1 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 1 forward left, 0 forward center, 2 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 0 forward left, 3 forward center, 0 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 0 forward left, 2 forward center, 1 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 0 forward left, 1 forward center, 2 forward right,
1 aft right, 0 aft center, 0 aft right, +++ 0 forward left, 0 forward center, 3 forward right,

two bombs aft left
2 aft left, 0 aft center, 0 aft right, ++ 2 forward left, 0 forward center, 0 forward right,
2 aft left, 0 aft center, 0 aft right, ++ 1 forward left, 1 forward center, 0 forward right,
2 aft left, 0 aft center, 0 aft right, ++ 1 forward left, 0 forward center, 1 forward right,
2 aft left, 0 aft center, 0 aft right, ++ 0 forward left, 2 forward center, 0 forward right,
2 aft left, 0 aft center, 0 aft right, ++ 0 forward left, 1 forward center, 1 forward right,
2 aft left, 0 aft center, 0 aft right, ++ 0 forward left, 0 forward center, 2 forward right,

two bombs aft center
0 aft left, 2 aft center, 0 aft right, ++ 2 forward left, 0 forward center, 0 forward right,

0 aft left, 2 aft center, 0 aft right, ++ 1 forward left, 1 forward center, 0 forward right,
0 aft left, 2 aft center, 0 aft right, ++ 1 forward left, 0 forward center, 1 forward right,
0 aft left, 2 aft center, 0 aft right, ++ 0 forward left, 2 forward center, 0 forward right,
0 aft left, 2 aft center, 0 aft right, ++ 0 forward left, 1 forward center, 1 forward right,
0 aft left, 2 aft center, 0 aft right, ++ 0 forward left, 0 forward center, 2 forward right,

two bombs aft right

0 aft left, 0 aft center, 2 aft right, ++ 2 forward left, 0 forward center, 0 forward right,
0 aft left, 0 aft center, 2 aft right, ++ 1 forward left, 1 forward center, 0 forward right,
0 aft left, 0 aft center, 2 aft right, ++ 1 forward left, 0 forward center, 1 forward right,
0 aft left, 0 aft center, 2 aft right, ++ 0 forward left, 2 forward center, 0 forward right,
0 aft left, 0 aft center, 2 aft right, ++ 0 forward left, 1 forward center, 1 forward right,
0 aft left, 0 aft center, 2 aft right, ++ 0 forward left, 0 forward center, 2 forward right,

three bombs aft left
3 aft left, 0 aft center, 0 aft right, + 1 forward left, 0 forward center, 0 forward right,
3 aft left, 0 aft center, 0 aft right, + 0 forward left, 1 forward center, 0 forward right,
3 aft left, 0 aft center, 0 aft right, + 0 forward left, 0 forward center, 1 forward right,

three bombs aft center
0 aft left, 3 aft center, 0 aft right, + 1 forward left, 0 forward center, 0 forward right,
0 aft left, 3 aft center, 0 aft right, + 0 forward left, 1 forward center, 0 forward right,
0 aft left, 3 aft center, 0 aft right, + 0 forward left, 0 forward center, 1 forward right,

three bombs aft right
0 aft left, 0 aft center, 3 aft right, + 1 forward left, 0 forward center, 0 forward right,
0 aft left, 0 aft center, 3 aft right, + 0 forward left, 1 forward center, 0 forward right,
0 aft left, 0 aft center, 3 aft right, + 0 forward left, 0 forward center, 1 forward right,

four bombs aft left
4 aft left, 0 aft center, 0 aft right, + 0 forward left, 0 forward center, 0 forward right

four bombs aft center
0 aft left, 4 aft center, 0 aft right, + 0 forward left, 0 forward center, 0 forward right

four bombs aft right.
0 aft left, 0 aft center, 4 aft right, + 0 forward left, 0 forward center, 0 forward right

From: John Barry Smith <barry@corazon.com>

Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **Bombs everywhere but not on AI 182, bombs leave bomb evidence**

The explosion was heard several miles away

Scotland Yard says dissident Irish republicans were behind a bomb explosion at the BBC in London on Saturday night.

Police were carrying out a controlled explosion on the car bomb when it went off at 0030 GMT - just yards from the front door of Television Centre in west London.

Bomb damage: Television Centre

Scotland Yard have warned that the bombing is part of an ongoing terrorist campaign and there are likely to be more attacks in the coming days and weeks.

Deputy Assistant Commissioner Alan Fry, head of Scotland Yard's Anti-Terrorist Branch, said the bomb was linked to three devices in London last year, including the missile attack on the MI6 building.

The Television Centre blast may have been a reprisal for a BBC Panorama documentary which exposed the alleged Real IRA perpetrators of the Omagh bombing, Mr Fry said.

Downing Street has condemned the attack and pledged to hunt down those responsible.

Bomb attacks in west London

21 February Territorial Army barracks, Shepherd's Bush. A 14-year-old cadet is blinded when a bomb explodes
20 Sept 2000 Dissident Irish republicans were the main suspects in the "rocket" attack on the MI6 spy headquarters in central London.
19 July 2000
The Real IRA was understood to have been responsible for a bomb near Ealing Broadway tube station
1 June 2000
A device found on Hammersmith Bridge. No one claimed responsibility
Between 10 and 20 pounds of high explosive exploded in a red taxi (reg D902 GYH) abandoned outside the BBC.

Staff had already been evacuated after police received a coded warning.

One London Underground worker suffered deep cuts to his eye from flying glass and some damage was caused to the front of the building.

The warning was received by a London hospital and an unnamed charitable trust at about 2320GMT on Saturday.

It was the same codeword used when a device was planted on the railway line at Acton, west London, last year. The bomb was also linked to the explosion at Hammersmith bridge last June.

Anti-terrorist chief Alan Fry: "Ruthless terrorists"

It is believed to be the first such attack on the BBC.

Commissioner Fry described those responsible as "ruthless terrorists" prepared to use "ruthless attacks without any care for the consequences of their actions".

Anti-terrorist branch officers are carrying out forensic tests in the Wood Lane area of Shepherd's Bush and the road is expected to remain sealed off to traffic on Sunday.

A BBC spokesman said: "We evacuated the main building and put our emergency plans into action. Broadcasting on channels has remained throughout the incident."

The BBC said it was handing over CCTV tapes from around the building to the police.

The incident was at White City, west London

Richard Sambrook, director of BBC News, said security had been stepped up, and the need for further precautions was being reviewed.

He told the BBC's Breakfast With Frost programme: "The BBC is a very high profile organisation and that may well be the reason for it."

Terrorist attacks on the media were rare and so the bomb marked a significant change, he said.

"What we are all asking ourselves is whether this is simply a general change in tactics in some way, or whether there is something specific behind this particular attack and we simply don't know at the moment."

Underground services were severely disrupted on Sunday morning.

The Central and Metropolitan and City Underground lines were likely to be closed in the area, a police spokesman added.

Police said they were keeping an open mind about possible links between the blast and the explosion at a nearby Territorial Army barracks in February, which blinded a 14-year-old cadet.

Stephen Menary also had his left hand blown off by a bomb packed inside a torch at the TA centre in White City.
Police have appealed for anyone with information to call the Anti-Terrorist Hotline on **0800 789321**.

Bomb Likely Caused Thai Plane Blast
Updated 7:03 AM ET March 4, 2001
full image
Thai Investigators Investigates the Burnt Remains of a Thai...
(AP) more photos *By UAMDAO NOIKORN, Associated Press Writer*

BANGKOK, Thailand (AP) - Thailand's prime minister said Sunday that a bomb likely destroyed a Thai Airways jetliner he was scheduled to board at Bangkok airport, and he suggested that the assassination attempt was an inside job.

"It is relatively clear now it was not the engine, and the only thing that it could definitely be is an explosive device," Prime Minister Thaksin Shinawatra told reporters in the northern city of Chiang Mai.

Thaksin was to fly with 148 other passengers from Bangkok to Chiang Mai on the Boeing 737-400 Saturday when it exploded 35 minutes before scheduled departure at the domestic terminal.

One cabin crew member died, and seven airline staff were injured. No passengers were on board.

Thaksin said he had originally planned to go to Chiang Mai on Sunday but told his secretary on Friday to change the flight to Saturday afternoon.

"If I was a target of the explosion, the one who placed the bomb should have had access to my schedule," he said.

Prasarn Wongwai, a former police general and security adviser to Thaksin, said the source of the explosion "came from where the prime minister was supposed to be seated."

"I already talked to the prime minister and he seems to have a clue who did it. But he wouldn't want to talk too much because it might pressure the investigation officials," he told the Ruam Duay Chuay Kan radio station.

The Nation newspaper quoted a police source as saying that if a bomb was to blame, it could be linked to Thaksin's pledge to crack down on drug smuggling, largely blamed on drug lords in neighboring Myanmar, also known as Burma.

Thaksin said Sunday that his government's top priority over the next four years would be to curb the "rampant" drug trade. He will meet next weekend with agency heads to work on an anti-drug strategy.

Thaksin took power last month after his Thai Rak Thai party won general elections by an unprecedented margin. The campaign was marred by violence and vote fraud.

Thaksin, who had flown to Chiang Mai by a military plane, opened a relative's shopping mall before returning to Bangkok later Sunday.

The Nation quoted an unidentified airline source as saying that the blast occurred under seats 11A and 11B, where Thaksin and his son, Phanthongthae, were supposed to sit.

Police Maj. Gen. Tritos Ronnarithchai, responsible for security of VIPs in Thailand, said he had not received any reports of death threats against Thaksin.

Thaksin said Saturday his movements would be restricted for security reasons.

Thailand has a history of coups and violent overthrows of governments, but no prime minister has faced an assassination attempt. The nation has enjoyed political stability under a succession of democratic governments for the last eight years.

The prime minister had not reached the airport when the explosion occurred. No passengers or pilots had boarded the plane, but the luggage had been loaded. A flight attendant, Kampol Meerlap, was killed while preparing the front section of the aircraft.

Airline officials said it was unlikely the plane could have exploded from an internal malfunction if the engines had not been started. The fully loaded fuel tanks, located in the plane's wings, were intact, they said, indicating that burning fuel was not the cause of the explosion.
The explosion came two days after Thaksin gave Thailand's Constitutional Court 21 boxes of documents as part of his defense against a corruption indictment that could evict him from office. He is accused of deliberately concealing assets in 1997 by transferring large amounts of stock shares to domestic servants.

The BBC's Frank Gardner
"It's been the deadliest explosion to rock Israel this year"
real **56k** Sunday, 4 March, 2001, 10:06 GMT
Blast rocks Israeli city

Police sealed off the area around the market place

A bomb has exploded during the Sunday morning rush hour in the Israeli coastal city of Netanya.

Three people have been killed and about 45 wounded, police said. There are indications that one of those who died may have been the bomber.

The device exploded shortly before 0900 [0700 GMT] in a crowded open-air market in the centre of the city.

Most of the casualties were Israelis. Police Commissioner Shlomo Aharonishki said the bomber was among a group of people standing at a pedestrian crossing opposite the city's central bus station when the explosive detonated.

The bomb was relatively small and was carried in a carrier bag, the commissioner told Israel radio.

But the force of the blast hurled a car into the air, and nearby shops were damaged.

I saw two people lying on the ground. I went to give them first aid but they were dead

Eyewitness Meir Mayos Arabs have been evacuated from the scene to prevent attacks against them by the angry crowd, according to police.

One Arab man was admitted to hospital with serious head injuries which had not been sustained in the blast, Israel Radio reported.

No organisation has admitted responsibility for the attack, although suspicion is falling on the militant Palestinian organisation Hamas following recent threats.

Ground shook

One witness said he saw two police vans rushing toward the scene of the blast just before the bomb went off.

2001 bombs

4 March
Netanya, three dead
1 March
Taxi in northern Israel, one dead
8 February
Two car bombs in ultra-orthodox area of west Jerusalem
1 January
Hamas bomb injures at least 36 in Netanya
"Then I heard a loud explosion and the ground shook under me," Israel TV cameraman Kobi Lahamish said.

Another witness, Meir Mayos, was filling up his car at a nearby petrol station.

"There was smoke everywhere," he said. "I saw two people lying on the ground. I went to give them first aid but they were dead."

Hamas threat

On Saturday, Hamas issued a statement that its members were poised to carry out suicide attacks once Prime Minister-elect Ariel Sharon took office.

"Up to this moment, we don't know which party committed this operation," said Hamas spokesman Mahmoud Zahhar, adding that "resistance will continue until we push the occupiers out of our land".

Hamas was responsible for a previous attack in Netanya on New Year's Day which injured about 20 people.

Israeli police responded to the latest threat by reinforcing patrols in the West Bank and around public buildings.

Sunday morning's attack was the latest in a series of bombings that have occurred since the Israel-Palestinian fighting began more than five months ago.

Last Thursday, one Israeli was killed and nine wounded when a Palestinian militant set off a bomb inside a taxi in northern Israel. Six Palestinians have also been killed by Israeli gunfire in the last three days.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **Re: Odds against bomb for hole, certain for door**

The story of the door gets even more interesting - If someone can confirm this - there is less than 1% chance that all 4 crashes would occur at the same point if the crash was caused by a bomb.

According to my numbers, it's 74 to one.

Now 10 to one would be a 10 percent chance of being a bomb.

50 to one would be a 2% chance.

100 to 1 would be 1% chance.

So, 74 to 1 would be a 1.5% chance of it being a bomb.

There are seventy five possibilities for the for bombs to be placed in the two cargo holds of four airplanes. For all of them to be placed on the right side of the forward cargo hold is so remote that the chances are 1 in seventy five or a 1.5 % chance of it happening.

Another way of putting it, is if you had 75 groups of 4 Boeing 747s, (300 planes) and a bomb was placed in each 747 in each group. Only one group of four 747s of the 75 groups of 300 planes total would have the bombs all on the right side in the forward cargo hold. Possible but very very unlikely. The other 296 planes would have holes all over the place, other than all on the right side forward of the wing.

For the forward cargo door to rupture in flight causing a huge hole on the right side of the forward cargo hold, the chance is 100 %

If 75 groups of 4 Boeing 747s all had the forward cargo door rupture open in flight, all 300 planes would have the huge hole on the right side at the forward cargo hold.

1.5% versus 100%, which is more likely? Ha!

The reason this has not been brought out before is no authority has put the four events into one forest, they continue to look at one tree at a time.

Cheers,
Barry

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Subject: **Bombs aboard planes**

Avianca was a bomb, AI 182 was not a bomb.

What other B747 events were confirmed as bombings?
The Thai bombing events shows massive destruction and fire.
Did either of you see the pix of this B737?

Bombings aboard jet aircraft

#40 02.04.86 Boeing 727-231
N54340 Trans World Airlines - TWA (USA)
4(121) K⁄rkira (Corfu); over (Greece)
While descending through FL100 a bomb exploded, causing a 1,40 x 1,60m hole
in the fuselage. Four passengers fell off the aircraft. The aircraft landed
safely at Athens.

JBS>the one above caused a larger hole in a smaller plane that landed safely than the larger 747 of PA 103 than made a smaller hole. Pa 103 was not a bomb.

By the way, cargo doors open in flight in planes much more often than bombs. Cargo doors open all the time, mostly non fatal.

Barry

This listing contains all jet airliners, involved in bombings:
The list contains the following information:

number   date   Type
registration   operator
no. of casulaties (no. of occupants) + cas. on the ground   location of accident

Bombings aboard jet aircraft

#1 22.05.62 Boeing 707-124
N70775   Continental Air Lines (USA)
45(45)   Unionville; 6mls NNW (USA)
While on its way from Chicago to Kansas City at FL390, a bomb exploded in the
right rear lavatory. Consequently, the tail section separated,

and the
aircraft crashed out of control.
CAUSE: Detonation of dynamite in a towel container.

#2 12.10.67 de Havilland DH-106 Comet 4
G-ARCO British European Airways - BEA (UK)
66(66) Rodhos, 100nm off; 35¡55'N 30¡01'E
(Greece)
After a turnover of 1h 20mins at Athens, flight CY284 departed at 02.41h.
Flying at FL290, a bomb exploded under seat 4A or 5A in the rear of the
tourist cabin. At FL150 the Comet broke up and crashed into the sea.

#3 11.12.67 Boeing 727
N..... American Airlines (USA)
0(78) Alamosa, over (USA)
One hour and 42mins after take-off from Chicago, a small explosion occurred
in the rear baggage compartment. The Boeing was able to make a safe landing.

CAUSE: Home made bomb exploded.

#4 19.11.68 Boeing 707-324C
N17325 Continental Air Lines (USA)
0(70) Gunnison; over (USA)
While descending through FL240 towards Denver, an explosion took place in the
lavatory, followed by a fire. A safe emergency landing was made.
The passenger, seen leaving the lavatory just before the explosion, was
arrested by the FBI.

#5 11.03.69 Boeing 707
Ethiopian Airlines
0(0) Frankfurt-Rhein Main APT (Germany)
On the ground, two explosions took place in the tourist class passenger
compartment.

#6 21.02.70 Sud Aviation SE-210 Caravelle VIR
OE-LCU Austrian Airlines (Austria)
0(38) Frankfurt; nr. (Germany)
At FL100, 20mins after take-off from Frankfurt, an explosion in the forward
freight hold blew a hole of 3'x2' through the bottom of the fuselage. The
Caravelle safely returned to Frankfurt.

#7 21.02.70 Convair CV-990-30A-6
HB-ICD   Swissair (Switzerland)
47(47)   Zƒrich; nr. (Switzerland)
An explosion in the aft of the plane, about 9mins. after take-off. The
Convair crashed, while returning to the airport.

#8 24.08.71 Boeing 707
Alia Jordanian Airlines
0(0)   Madrid-Barajas (Spain)
An explosive device in the aft lavatory complex blew a hole in the top
fuselage (3ft long). Lukily the aircraft was parked at the time.

#9 21.11.71 Sud Aviation SE-210 Caravelle III
B- 1852   China Airlines (Taiwan)
25(25)   Penghu Island; nr. (Taiwan)
The aircraft crashed into the sea on a flight from Taipei to Hong Kong.
CAUSE: Probably caused by a bomb explosion.

#10 26.01.72 McDonnell Douglas DC- 9-32
YU-AHT   Jugoslovenski Aerotransport - JAT (Yugoslavia)
27(28)   Krussne Hory Mt (Czech.)
An inflight explosion in the forward cargo hold of a

homemade bomb at FL100
caused the DC-9 to break up and crash. The surviving crew member fell 15000ft
in the tailsection!
CAUSE: Bomb placed on the aircraft by the Croatian extremists organisation
'Ustasji'.

#11 08.03.72 Boeing 707-331
N761TW Trans World Airlines - TWA (USA)
0(0) Las Vegas-McCarran IAP (USA)
A bomb exploded in the right rear part of the cockpit while the aircraft was
parked.

#12 25.05.72 Boeing 727-116
CC-CAG LAN Chile (Chile)
0(50) Cuba, nr ()
One hour and 18mins after take-off from Panama City a homemade pipe bomb
exploded in the ice water fountain service compartment. A rapid decompression
followed. A succesfull emergency landing at Montego Bay was made at 13.10h.

#13 15.06.72 Convair CV-880-22M-21
VR-HFZ Cathay Pacific Airways (Hong Kong)

81(81)   nr Pleiku (Vietnam)

The Convair (Flight CX 700Z) took off from Bangkok at 04.55h GMT bound for
Homg Kong. While flying at FL290 a bomb exploded, hidden in a suitcase under
a passenger seat on the right side over the wing.
The bomb was put on the aircraft by a police officer whose daughter and
fiancee were aboard.

#14 16.08.72 Boeing 707

4X-A..   El Al (Israel)

0(148)   over Roma (Italy)

A bomb in a portable record player (stored in the aft baggage compartment)
exploded shortly after take-off. The 200grams of explosive just caused a hole
in the baggage compartment. The Boeing landed safely back at Roma.

#15 22.03.74 Sud Aviation SE-210 Caravelle III

F-BRSY   Air Inter (France)

0()   Bastia (France)

On the ground an explosion occurred in the forward landing gear compartment,
causing substantial damage.

#16 26.08.74 Boeing 707
Trans World Airlines - TWA
0() Roma (Italy)
After landing in Roma, a fire was discovered in the aft baggage compartment.
The fire was caused by an explosive device which malfunctioned.

#17 08.09.74 Boeing 707-331B
N8734 Trans World Airlines - TWA (USA)
88(88) Cephalonia; 58mls W off (Greece)
En route to Athens, a bomb exploded aboard TWA Flight 841. The Boeing entered
a steep climb, went into a steep nose down spin and crashed into the Ionian
Sea. The bomb was placed in the aft cargo compartment.

#18 03.06.75 BAC One-Eleven 524FF
RP-C1184 Philippine Air Lines (Philippines)
1(64) nr Manila (Philippines)
During descent into Manila (at FL200) a bomb exploded in the right lavatory
in the rear of the plane. The explosion caused a hole in the fuselage of 1.3m
x 4m. A successfull emergency landing was made.

#19 05.07.75 Boeing 707

Pakistan International Airlines - PIA
0() Rawalpindi (Pakistan)
On the ground after a flight from Karachi a bomb, placed under a passenger
seat, exploded. The explosion ripped a 3ft x 4ft hole in the fuselage.

#20 01.01.76 Boeing 720-023B
OD-AFT Middle East Airlines - MEA (Lebanon)
81(81) Al Qaysumah; 20nm NW (Saudi Arabia)
En route at FL370 from Beirut to Dubai, a bomb exploded in the forward
baggage compartment. The aircraft crashed into the desert.

#21 07.09.76 Boeing 707-328
F-BHSH Air France (France)
0(0) Ajaccio (France)
Seven masked men set dynamite explosives aboard the aircraft and caused the
explosion.

#22 06.10.76 McDonnell Douglas DC- 8-43
CU-T1201 Cubana (Cuba)
73(73) Bridgeport; 5mls W off (Barbados)
At 17.15h Flight 455 took off from Bridgetown Runway 09, heading for
Kingston. Nine minutes later, the crew tried to turn back to

Barbados due to
an explosion. The DC-8 lost height rapidly and crashed in a nose down, right
wing low attitude into the sea, 5 miles offshore.
CAUSE: An explosive device detonated in the rear of the cabin, which resulted
in an uncontrollable fire, possibly causing crew incapacitation.

#23 17.08.78 BAC One-Eleven 524FF
RP-C1184 Philippine Air Lines (Philippines)
1(84) Sinara Island; over (Philippines)
En explosion in the rear left lavatory blew a hole in the fuselage. The
aircraft was flying at FL240 at the time, on its way from Cebu to Manila.

#24 26.04.79 Boeing 737-2A8
VT-ECR Indian Airlines (India)
0(67) Madras (India)
On its way from Trivandrum to Madras, the aircraft was cleared to descent
from FL270. Shortly afterwards an explosion took place in the forward
lavatory, causing a complete instrument and electrical failure.
The Boeing had to make a flapless landing at Madras. The aircraft touched

down 2500ft past the Runway 25 threshold and overran. The right side of the
plane caught fire.
CAUSE: As a result of the explosion, the flaps, reverse thrust and anti-skid
systems couldn't be used during the emergency landing.

#25 15.11.79 Boeing 727
N..... American Airlines (USA)
0(78) Chicago; nr. (USA)

Thirty minutes after leaving Chicago, a bomb device hidde in a wooden box in
a mail bag detonated. This resulted in pressure fluctuations and smoke in the
cabin. A safe landing was made at Washington-Dulles.
FBI thinks the bomb was placed aboard by the 'Unabomber', who was responsible
for a number of attacks on universities and airlines since 1978.

#26 09.09.80 Boeing 727
N..... United Air Lines (USA)
0(44) Sacramento (USA)

While passengers were deplaning, a small carbord box blew up in the cargo
hold and injured two cargo handlers.

#27 21.12.80 Sud Aviation SE-210 Caravelle VIR
HK-1810 TAC Colombia (Colombia)
70(70) Guajira (Colombia)
At 14.18hrs the Caravelle took off from Rio Hacha for a flight to Medellin.
Five minutes after take-off an explosion occurred and there appeared to be a
fire in the right-hand aft portion of the aircraft. The Caravelle went out of
control and crashed.
The aircraft was on its first scheduled flight after 17 months of maintenance
work.
It's not known for sure whether the explosion was caused by a bomb or not.

#28 31.08.81 Boeing 720-023B
OD-AFR Middle East Airlines - MEA (Lebanon)
0() Beirut IAP (Lebanon)
Shortly after arriving from a flight from Libya, an explosion of approx. 5kgs
of dynamite destroyed the aircraft.

#29 13.10.81 Boeing 737-2K2C
PH-TVC Air Malta (Malta)
0(0) Cairo IAP (Egypt)
While offloading luggage a porter and 3 security guards

were injured when two
parcels exploded about 15mins apart. A third bomb which didn't detonate, was
located later.

#30 12.12.81 Boeing 727-025
YN-BXW Aeronica (Nicaragua)
0() Mexico City (Maxico)
When the passengers were ready to embark the plane, a bomb exploded between
the rearmost cabin seat on the left aisle and the cabin wall. The blast tore
a 3ft hole in the fuselage. The captain, 2 stewardesses and an aiport
mechanic where injured.
The aircraft was preparing for a flight to San Salvador.

#31 11.08.82 Boeing 747-121
N754PA Pan American World Airways (USA)
1() Hawaii; 140mls (USA)
On a flight from Tokyo one passenger was killed when a bomb, located under
the seat cushion, exploded. The explosion also resulted in a hole in the
floor and damage to the ceiling and overhead racks. A safe landing was made
at Honolulu.

#32 19.08.83 Boeing 727-294
YK-AGA Syrian Arab Airlines (Syria)
0(12) Roma (Italy)
During boarding a glass bottle containing flammable liquid, located under a
seat in the passenger area near the right overwing emergency exit, caused a
fire. The interior of the plane completely burned out.

#33 23.09.83 Boeing 737-2P6
A40-BK Gulf Air (Oman)
112(112) Mino Jebel Ali (UAE)
After a brief distress message, the aircraft crashed in the desert.
Evidence indiacted that a bomb had exploded in the baggage compartment.
The aicraft was on a flight from Karachi to Abu Dhabi.

#34 18.01.84 Boeing 747
Air France
0(261) Karachi, 70mls (Pakistan)
An in-flight explosion after leaving Karachi blew a hole in the right rear
cargo hold and caused a loss of cabin pressure. An emergency descent to
5000ft was made and the aircraft returned to Karachi.

#35 10.03.84 McDonnell Douglas DC- 8-63PF
F-BOLL   Union de Transportes A⁄riens - UTA
(France)
0(23)   N'Djamena (Tchad)
Twenty minutes after arriving from Brazzaville, a bomb
exploded in the
central baggage compartment.

#36 23.01.85 Boeing 727-2K3
CP-1276   Lloyd A⁄reo Boliviano - LAB (Bolivia)
1(127)   Santa Cruz; 30nm (Bolivia)
While descending through FL100 a passenger went into the
forward lavatory
carrying a dynamite in a briefcase. The dynamite
exploded, killing the
passenger. The aircraft made a safe landing at Santa Cruz.

#37 09.03.85 Lockheed L-1011 TriStar 500
Royal Jordanian Airlines
0()   Dubai IAP (UAE)
On ground at Dubai, after a flight from Karachi, a bomb
exploded in a baggage
compartment.

#38 23.06.85 Boeing 747-237B
VT-EFO   Air India (India)

329(329) Atlantic Ocean ()
The aircraft broke up in flight at FL310 and crashed into the Ocean.
CAUSE: A bomb, placed on board by a Sikh terrorist, caused a powerful
explosion.

#39 30.10.85 Boeing 727
American Airlines
0() Dallas-Fort Worth (USA)
An explosion occurred in the forward baggage compartment while baggage was
being unloaded.
The device was contained in a vinyl tote bag.
#40 02.04.86 Boeing 727-231
N54340 Trans World Airlines - TWA (USA)
4(121) K⁄rkira (Corfu); over (Greece)
While descending through FL100 a bomb exploded, causing a 1,40 x 1,60m hole
in the fuselage. Four passengers fell off the aircraft. The aircraft landed
safely at Athens.

#41 26.10.86 Airbus A.300B4-601
HS-TAE Thai Airways International (Thailand)
0(239) nr Shimizu (Japan)
An explosion at FL330 caused a rapid decompression and the loss of 2

hydraulic systems.
The Airbus made an emergency descent with a max of 2.6g and landed safely.
CAUSE: A passenger attempted to smuggle handgrenade into Japan but it
exploded in the aft toilet.

#42 29.11.87 Boeing 707-3B5C
HL-7406 Korean Air (South Korea)
115(115) Andaman Sea; 14¡33' N 97¡23' E ()
At 00.01h UTC Koream flight 858 departed Abu Dhabi for a flight to Seoul via
Bangkok. At 05.01h UTC the last message was received. It appeared that a bomb
explosion aboard caused the crash.
Two passengers who had left the plane at Abu Dhabi, left a radio and liquor
bottle containing hidden explosives in the overhead rack at row 7.

#43 21.12.88 Boeing 747-121A
N739PA Pan American World Airways (USA)
259(259) + 11 Lockerbie (UK)
The aircraft disitegrated at FL310 after a bomb exploded in the forward cargo
hold. Larges pieces of debris fell into a residential area of Lockerbie.

#44 19.09.89 McDonnell Douglas DC-10-30
N54629   Union de Transportes A⁄riens - UTA (France)
171(171)   T⁄n⁄r⁄ desert; 16¡54'N 11¡59'E (Niger)
Flight UTA 772 (Brazzaville - N'Djamena - Paris CDG) departed N'Djamena at
12.13h. While climbing through FL350, 21mins after take-off, a pentryt bomb
exploded near seat 13R. The DC-10 disintegrated and crashed in the desert.
The bomb was probably placed on board at Brazzaville.
The DC-10 had accumulated 60.267 flying hours and 14.777 cycles.

#45 27.11.89 Boeing 727-21
HK-1803   Avianca (Colombia)
107(107)   nr Bogota (Colombia)
The aircraft exploded shortly after take-off.

#46 18.03.91 Ilyushin 86
SSSR-.....   Aeroflot (Russia)
0(360)   Sverdlovsk (Russia)
A psychiatric patient threw a petrol bomb, which caused an on-board fire. An
mergency landing was made at Sverdlovsk.
The aircraft was on its way from Moscow to

Novokuznetsk.

#47 10.12.94 Boeing 747-283B
EI-BWF   Philippine Air Lines (Philippines)
1(293)   Minami Diato Isl.; nr. (Japan)
On a flight from Manila to Tokyo via Cebu, a bomb exploded in the passenger
cabin beneath seat 26K. A succesfull emergency landing at Okinawa was made at
12.45h.
The muslim group Abu Sayyaf claimed responsibility.

Bombings aboard jet aircraft : statistics

Departure airport ranking:

- Karachi (Pakistan) - 4 times
- Athens (Greece) - 3 times
- Roma (Italy) - 3 times
- Chicago (USA) - 3 times
- Brazzaville (Congo) - 2 times
- Cebu (Philippines) - 2 times

Total casualties:

1626
(including 11 casualties on the ground at Lockerbie and 70 casualties of a Colombian Caravelle of which it's not sure whether a bomb caused the
accident or not).

Total aircraft destroyed:
23

Total aircraft destroyed in-flight:
16

Back to TWA Flight 800 accident

Harro Ranter
hranter@inter.NL.net

Most recent revision Thursday 18 July 1996

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
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The Convair (Flight CX 700Z) took off from Bangkok at 04.55h GMT bound for
Homg Kong. While flying at FL290 a bomb exploded, hidden in a suitcase under
a passenger seat on the right side over the wing.
The bomb was put on the aircraft by a police officer whose daughter and
fiancee were aboard.

#14 16.08.72 Boeing 707
4X-A..   El Al (Israel)
0(148)   over Roma (Italy)
A bomb in a portable record player (stored in the aft

baggage compartment)
exploded shortly after take-off. The 200grams of explosive just caused a hole
in the baggage compartment. The Boeing landed safely back at Roma.

#15 22.03.74 Sud Aviation SE-210 Caravelle III
F-BRSY Air Inter (France)
0() Bastia (France)
On the ground an explosion occurred in the forward landing gear compartment,
causing substantial damage.

#16 26.08.74 Boeing 707
Trans World Airlines - TWA
0() Roma (Italy)
After landing in Roma, a fire was discovered in the aft baggage compartment.
The fire was caused by an explosive device which malfunctioned.

#17 08.09.74 Boeing 707-331B
N8734 Trans World Airlines - TWA (USA)
88(88) Cephalonia; 58mls W off (Greece)
En route to Athens, a bomb exploded aboard TWA Flight 841. The Boeing entered
a steep climb, went into a steep nose down spin and

crashed into the Ionian
Sea. The bomb was placed in the aft cargo compartment.

#18 03.06.75 BAC One-Eleven 524FF
RP-C1184 Philippine Air Lines (Philippines)
1(64) nr Manila (Philippines)
During descent into Manila (at FL200) a bomb exploded in the right lavatory
in the rear of the plane. The explosion caused a hole in the fuselage of 1.3m
x 4m. A successfull emergency landing was made.

#19 05.07.75 Boeing 707
Pakistan International Airlines - PIA
0() Rawalpindi (Pakistan)
On the ground after a flight from Karachi a bomb, placed under a passenger
seat, exploded. The explosion ripped a 3ft x 4ft hole in the fuselage.

#20 01.01.76 Boeing 720-023B
OD-AFT Middle East Airlines - MEA (Lebanon)
81(81) Al Qaysumah; 20nm NW (Saudi Arabia)
En route at FL370 from Beirut to Dubai, a bomb exploded in the forward
baggage compartment. The aircraft crashed into the desert.

#21 07.09.76 Boeing 707-328
F-BHSH Air France (France)
0(0) Ajaccio (France)
Seven masked men set dynamite explosives aboard the aircraft and caused the
explosion.

#22 06.10.76 McDonnell Douglas DC- 8-43
CU-T1201 Cubana (Cuba)
73(73) Bridgeport; 5mls W off (Barbados)
At 17.15h Flight 455 took off from Bridgetown Runway 09, heading for
Kingston. Nine minutes later, the crew tried to turn back to Barbados due to
an explosion. The DC-8 lost height rapidly and crashed in a nose down, right
wing low attitude into the sea, 5 miles offshore.
CAUSE: An explosive device detonated in the rear of the cabin, which resulted
in an uncontrollable fire, possibly causing crew incapacitation.

#23 17.08.78 BAC One-Eleven 524FF
RP-C1184 Philippine Air Lines (Philippines)
1(84) Sinara Island; over (Philippines)
En explosion in the rear left lavatory blew a hole in the fuselage. The

aircraft was flying at FL240 at the time, on its way from Cebu to Manila.

#24 26.04.79 Boeing 737-2A8
VT-ECR Indian Airlines (India)
0(67) Madras (India)

On its way from Trivandrum to Madras, the aircraft was cleared to descent
from FL270. Shortly afterwards an explosion took place in the forward
lavatory, causing a complete instrument and electrical failure.
The Boeing had to make a flapless landing at Madras. The aircraft touched
down 2500ft past the Runway 25 threshold and overran. The right side of the
plane caught fire.
CAUSE: As a result of the explosion, the flaps, reverse thrust and anti-skid
systems couldn't be used during the emergency landing.

#25 15.11.79 Boeing 727
N..... American Airlines (USA)
0(78) Chicago; nr. (USA)

Thirty minutes after leaving Chicago, a bomb device hidde in a wooden box in
a mail bag detonated. This resulted in pressure fluctuations

and smoke in the
cabin. A safe landing was made at Washington-Dulles.
FBI thinks the bomb was placed aboard by the
'Unabomber', who was responsible
for a number of attacks on universities and airlines since
1978.

#26 09.09.80 Boeing 727
N..... United Air Lines (USA)
0(44) Sacramento (USA)
While passengers were deplaning, a small carbord box
blew up in the cargo
hold and injured two cargo handlers.

#27 21.12.80 Sud Aviation SE-210 Caravelle VIR
HK-1810 TAC Colombia (Colombia)
70(70) Guajira (Colombia)
At 14.18hrs the Caravelle took off from Rio Hacha for a
flight to Medellin.
Five minutes after take-off an explosion occurred and there
appeared to be a
fire in the right-hand aft portion of the aircraft. The
Caravelle went out of
control and crashed.
The aircraft was on its first scheduled flight after 17
months of maintenance
work.
It's not known for sure whether the explosion was caused

by a bomb or not.

#28 31.08.81 Boeing 720-023B
OD-AFR Middle East Airlines - MEA (Lebanon)
0() Beirut IAP (Lebanon)
Shortly after arriving from a flight from Libya, an explosion of approx. 5kgs
of dynamite destroyed the aircraft.

#29 13.10.81 Boeing 737-2K2C
PH-TVC Air Malta (Malta)
0(0) Cairo IAP (Egypt)
While offloading luggage a porter and 3 security guards were injured when two
parcels exploded about 15mins apart. A third bomb which didn't detonate, was
located later.

#30 12.12.81 Boeing 727-025
YN-BXW Aeronica (Nicaragua)
0() Mexico City (Maxico)
When the passengers were ready to embark the plane, a bomb exploded between
the rearmost cabin seat on the left aisle and the cabin wall. The blast tore
a 3ft hole in the fuselage. The captain, 2 stewardesses and an aiport

mechanic where injured.
The aircraft was preparing for a flight to San Salvador.

#31 11.08.82 Boeing 747-121
N754PA Pan American World Airways (USA)
1() Hawaii; 140mls (USA)
On a flight from Tokyo one passenger was killed when a bomb, located under
the seat cushion, exploded. The explosion also resulted in a hole in the
floor and damage to the ceiling and overhead racks. A safe landing was made
at Honolulu.

#32 19.08.83 Boeing 727-294
YK-AGA Syrian Arab Airlines (Syria)
0(12) Roma (Italy)
During boarding a glass bottle containing flammable liquid, located under a
seat in the passenger area near the right overwing emergency exit, caused a
fire. The interior of the plane completely burned out.

#33 23.09.83 Boeing 737-2P6
A40-BK Gulf Air (Oman)
112(112) Mino Jebel Ali (UAE)
After a brief distress message, the aircraft crashed in the

desert.
Evidence indiacted that a bomb had exploded in the baggage compartment.
The aircraft was on a flight from Karachi to Abu Dhabi.

#34 18.01.84 Boeing 747
Air France
0(261) Karachi, 70mls (Pakistan)
An in-flight explosion after leaving Karachi blew a hole in the right rear
cargo hold and caused a loss of cabin pressure. An emergency descent to
5000ft was made and the aircraft returned to Karachi.

#35 10.03.84 McDonnell Douglas DC- 8-63PF
F-BOLL Union de Transportes A⁄riens - UTA (France)
0(23) N'Djamena (Tchad)
Twenty minutes after arriving from Brazzaville, a bomb exploded in the
central baggage compartment.

#36 23.01.85 Boeing 727-2K3
CP-1276 Lloyd A⁄reo Boliviano - LAB (Bolivia)
1(127) Santa Cruz; 30nm (Bolivia)
While descending through FL100 a passenger went into the forward lavatory

carrying a dynamite in a briefcase. The dynamite exploded, killing the
passenger. The aircraft made a safe landing at Santa Cruz.

#37 09.03.85 Lockheed L-1011 TriStar 500
Royal Jordanian Airlines
0() Dubai IAP (UAE)
On ground at Dubai, after a flight from Karachi, a bomb exploded in a baggage
compartment.

#38 23.06.85 Boeing 747-237B
VT-EFO Air India (India)
329(329) Atlantic Ocean ()
The aircraft broke up in flight at FL310 and crashed into the Ocean.
CAUSE: A bomb, placed on board by a Sikh terrorist, caused a powerful
explosion.

#39 30.10.85 Boeing 727
American Airlines
0() Dallas-Fort Worth (USA)
An explosion occurred in the forward baggage compartment while baggage was
being unloaded.
The device was contained in a vinyl tote bag.

#40 02.04.86 Boeing 727-231
N54340 Trans World Airlines - TWA (USA)
4(121) K⁄rkira (Corfu); over (Greece)
While descending through FL100 a bomb exploded, causing a 1,40 x 1,60m hole
in the fuselage. Four passengers fell off the aircraft. The aircraft landed
safely at Athens.

#41 26.10.86 Airbus A.300B4-601
HS-TAE Thai Airways International (Thailand)
0(239) nr Shimizu (Japan)
An explosion at FL330 caused a rapid decompression and the loss of 2
hydraulic systems.
The Airbus made an emergency descent with a max of 2.6g and landed safely.
CAUSE: A passenger attempted to smuggle handgrenade into Japan but it
exploded in the aft toilet.

#42 29.11.87 Boeing 707-3B5C
HL-7406 Korean Air (South Korea)
115(115) Andaman Sea; 14¡33' N 97¡23' E ()
At 00.01h UTC Koream flight 858 departed Abu Dhabi for a flight to Seoul via
Bangkok. At 05.01h UTC the last message was received. It appeared that a bomb

explosion aboard caused the crash.
Two passengers who had left the plane at Abu Dhabi, left a radio and liquor
bottle containing hidden explosives in the overhead rack at row 7.

#43 21.12.88 Boeing 747-121A
N739PA Pan American World Airways (USA)
259(259) + 11 Lockerbie (UK)
The aircraft disitegrated at FL310 after a bomb exploded in the forward cargo
hold. Larges pieces of debris fell into a residential area of Lockerbie.

#44 19.09.89 McDonnell Douglas DC-10-30
N54629 Union de Transportes A⁄riens - UTA (France)
171(171) T⁄n⁄r⁄ desert; 16¡54'N 11¡59'E (Niger)
Flight UTA 772 (Brazzaville - N'Djamena - Paris CDG) departed N'Djamena at
12.13h. While climbing through FL350, 21mins after take-off, a pentryt bomb
exploded near seat 13R. The DC-10 disintegrated and crashed in the desert.
The bomb was probably placed on board at Brazzaville.
The DC-10 had accumulated 60.267 flying hours and 14.777 cycles.

#45 27.11.89 Boeing 727-21
HK-1803   Avianca (Colombia)
107(107)   nr Bogota (Colombia)
The aircraft exploded shortly after take-off.

#46 18.03.91 Ilyushin 86
SSSR-.....   Aeroflot (Russia)
0(360)   Sverdlovsk (Russia)
A psychiatric patient threw a petrol bomb, which caused an on-board fire. An
mergency landing was made at Sverdlovsk.
The aircraft was on its way from Moscow to Novokuznetsk.

#47 10.12.94 Boeing 747-283B
EI-BWF   Philippine Air Lines (Philippines)
1(293)   Minami Diato Isl.; nr. (Japan)
On a flight from Manila to Tokyo via Cebu, a bomb exploded in the passenger
cabin beneath seat 26K. A succesfull emergency landing at Okinawa was made at
12.45h.
The muslim group Abu Sayyaf claimed responsibility.

Bombings aboard jet aircraft : statistics

Departure airport ranking:

- Karachi (Pakistan) - 4 times
- Athens (Greece) - 3 times
- Roma (Italy) - 3 times
- Chicago (USA) - 3 times
- Brazzaville (Congo) - 2 times
- Cebu (Philippines) - 2 times

Total casualties:
1626
(including 11 casualties on the ground at Lockerbie and 70 casualties of a Colombian Caravelle of which it's not sure whether a bomb caused the accident or not).

Total aircraft destroyed:
23

Total aircraft destroyed in-flight:
16

Back to TWA Flight 800 accident

Harro Ranter

hranter@inter.NL.net

Most recent revision Thursday 18 July 1996

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **Cargo door openings much more often than bombings part 2**

Open cargo door forces plane to return to airport

SYRACUSE, N.Y. (AP) -- A Delta Airlines flight headed to Cincinnati had to turn around Thursday and return to Hancock International Airport after a cargo door opened.

``We actually had our people count the luggage and everything was there. It's amazing nothing fell out,'' Airport Commissioner Charles Everett said.

The pilot saw a signal light indicating the door was open minutes after taking off and immediately returned to the airport, where it landed safely, Everett said.

The plane was ordered grounded while mechanics investigated how the door came open even though the latch was in a locked position, he said.

The plane was carrying 53 passengers. Delta arranged for the passengers to continue their trips on other flights, he said.NTSB Identification: **MIA83FA242** For details, refer to NTSB microfiche number **24127A**
Accident occurred SEP-30-83 at MATACUMBE KEY, FL
Aircraft: ROCKWELL COMMANDER 560E, registration: N70C
Injuries: 1 Fatal, 1 Serious.
THE ACFT CRASHED IN THE WATER IN AN ISOLATED AREA OF THE FLORIDA BAY WHILE IN A NEAR INVERTED, LEFT WING LOW, NOSE DOWN ATTITUDE & AT A HIGH RATE OF DESCENT WITH SLOW FORWARD SPEED. THE LANDING GEAR WERE DOWN & LOCKED, & THE

FLAPS WERE EXTENDED ABOUT 10 DEGS. EXAMINATION OF THE CARGO DOOR REVEALED EVIDENCE TO SUGGEST THAT IT WAS NOT HINGED TO THE ACFT DURING IMPACT. THE PURPOSE OF THE FLT IS STILL UNDER INVESTIGATION BY OTHER GOV'T AGENCIES.

NTSB Identification: **NYC96FA027**. The docket is stored in the (offline) NTSB Imaging System.
Accident occurred NOV-23-95 at ATLANTIC CITY, NJ
Aircraft: Beech A36, registration: N550RR
Injuries: 1 Fatal.
Shortly after departure on runway 22, the pilot radioed the tower controller that he wanted to return due to an "open door." The controller cleared the pilot to land on any runway. According to the controller, the airplane climbed to an altitude of approximately 200 feet above the ground before leveling off. Witnesses watched the airplane turn left, commence a descent, and roll almost inverted before it impacted the ground. The first rescue personnel to arrive at the crash site said the right side cargo door was open. Examination of the exterior door handle "D" ring on the forward door of the two aft cargo doors revealed that it was not latched completely, and the door was "open" at the time of the accident. Examination of the door rods and latches revealed that all the rods were in place, and moved without restrictions when activated by hand. No discrepancies were observed with the door's latches or rods.
Probable Cause
the pilot's failure to maintain control of the airplane. A factor was the pilot's diverted attention due to an open aft cargo door.

NTSB Identification: **MIA83FA242** For details, refer to NTSB microfiche number **24127A**
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FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19990816024809C
Local Date: 08/16/1999
Local Time: 13:00
City: NEWARK
State: NJ
Airport Name: NEWARK INTL
Airport Id: EWR
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: TO INITIAL CLIMB (1ST POWER REDUCTION)
Aircraft Make/Model: BOEING B-737-2L9
Airframe Hours:
Operator Code: ZZDA
Operator: AIRTRAN AIRWAYS INC - ZZDA
Owner Name: AIRTRAN AIRWAYS INC

Narrative

AIRCRAFT DEPARTED LGA ENROUTE TO ATL. UPON ROTATION THE AFT **CARGO DOOR**
LIGHT ILLUMINATED. AIRCRAFT DIVERTED TO EWR AND LANDED

WITHOUT
INCIDENT. NO LUGGAGE WAS LOST. DOOR WAS INSPECTED AND FOUND THAT THE
AFT **CARGO DOOR** COULD BE CLOSED BUT NOT PROPERLY LOCKED AND THE COCKPIT
LIGHT AFT **CARGO DOOR** LIGHT WAS NOT ILLUMINATED.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 737Q
Total Aboard: 0
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):

Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT PILOT FLIGHT INSTRUCTOR
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 8820
Total in Make/Model:
Total Last 90 Days:
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19990523014399C
Local Date: 05/23/1999
Local Time: 13:08
City: DU BOIS
State: PA

Airport Name: DU BOIS-JEFFERSON COUNTY
Airport Id: DUJ
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FCD/PREC LDG FROM CRUISE
Aircraft Make/Model: BEECH BE-1900-D
Airframe Hours: 3223
Operator Code: MASA
Operator: MESA AIRLINES INC - MASA
Owner Name: MESA AIRLINES INC

Narrative

CARGO DOOR ILLUMINATED IN FLIGHT AND CREW INITIATED EMERGENCY DECENT
INTO DUBOISE PA. (DUJ) AIRPORT. THERE WERE NO INJURIES TO PASSANGERS OR
CREW. SUBMISSION OF THIS REPORT CLOSES THIS INCIDENT.

Detail

Primary Flight Type: SUPPLEMENTAL OR COMMERCIAL OPERATOR
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL

Registration Number: 65YV
Total Aboard: 2
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: UNKNOWN
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates:
Pilot Rating:
Pilot Qualification:

Flight Time (Hours)

Total Hours:
Total in Make/Model:
Total Last 90 Days:

Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19981004035009C
Local Date: 10/04/1998
Local Time: 20:35
City: BUFFALO
State: NY
Airport Name: BUFFALO NIAGARA INTL
Airport Id: BUF
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: NORMAL CRUISE
Aircraft Make/Model: BOEING B-737-322
Airframe Hours:
Operator Code: UALA
Operator: UNITED AIR LINES INC - UALA
Owner Name: UNITED AIR LINES INC

Narrative

ON SUNDAY, OCTOBER 4, 1998, A BOEING 737, N32IUA, FLIGHT 1070, OPERATED
BY UNITED AIRLINES, DEPARTED FROM HARTFORD, CT FOR CHICAGO, IL AND
EXPERIENCED PROBLEMS WITH THE PRESSURIZATION SYSTEM DURING CRUISE
FLIGHT. THE AIRCRAFT DIVERTED TO BUFFALO NIAGARA AIRPORT. A LANDING
WAS ACCOMPLISHED WITHOUT INCIDENT. FIRE AND RESCUE RESPONDED. THERE
WERE NO INJURIES. THE AIRCRAFT TAXIED TO THE GATE WHERE MECHANICS
FOUND THE FORWARD **CARGO DOOR** SEAL PARTIALLY OUT OF TRACK AT THE LOWER
FORWARD END. THE MECHANIC SECURED THE SEAL. THE AIRCRAFT WAS
PRESSURIZED WITH ENGINES AND APU PNEUMATICS. AN OPERATIONAL CHECK WAS
SATISFACTORY AND THE AIRCRAFT WAS RELEASED FOR SERVICE. THE INCIDENT
IS CONSIDERED CLOSED.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 321UA

Total Aboard: 4
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: UNKNOWN
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DUSK
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates:
Pilot Rating:
Pilot Qualification:

Flight Time (Hours)

Total Hours:
Total in Make/Model:
Total Last 90 Days:
Total Last 90 Days Make/Model:

<<>>

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FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source:	FAA INCIDENT DATA SYSTEM
Report Number:	19990415020099C
Local Date:	04/15/1999
Local Time:	13:30
City:	LINCOLN
State:	NE
Airport Name:	LINCOLN MUNI
Airport Id:	LNK
Event Type:	INCIDENT - AIR CARRIER
Mid Air Collision:	NOT A MIDAIR

Aircraft Information

Aircraft Damage:	NONE
Phase of Flight:	FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model:	DOUG DC-9-32
Airframe Hours:	
Operator Code:	TWAA
Operator:	TRANS WORLD AIRLINES INC - TWAA

Owner Name: TRANS WORLD AIRLINES INC

Narrative

TWA, FLIGHT 580 DEPARTED RUNWAY 32 AT LINCOLN, NE. DURING CLIMB CABIN
FAILED TO PRESSURIZE. AIRCRAFT RETURNED TO LINCOLN, NE LANDING ON
RUNWAY 32. THE CREW DISCOVERED THE AFT **CARGO DOOR** WASN'T SECURE (LEFT
OPEN).

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 932L
Total Aboard: 2
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: UNKNOWN
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 13770
Total in Make/Model: 9174
Total Last 90 Days:
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19990506015529C
Local Date: 05/06/1999
Local Time: 16:27
City: DALLAS-FORT WORTH
State: TX
Airport Name: DALLAS/FORT WORTH INTERNATIONAL
Airport Id: DFW
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: SUBSTANTIAL
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: BOEING B-727-247
Airframe Hours: 71976
Operator Code: DALA
Operator: DELTA AIR LINES INC - DALA
Owner Name: DELTA AIR LINES INC

Narrative

ON 5/6/99 AT APPROXIMATELY 1608C, DELTA 789 DEPARTED RUNWAY 36 BOUND

FOR SAN FRANCISCO, CA. SHORTLY AFTER TAKEOFF THE CREW OF DELTA 789
DECLARED AN EMERGENCY DUE TO AN ENGINE FAILURE. INITIAL INVESTIGATION
HAS REVEALED THAT THE TOWER ADVISED THE CREW OF DELTA 789 THAT THEY MAY
HAVE AN OPEN **CARGO DOOR**. PIC JAMES BURG ADVISED THAT THIS INITIAL
NOTIFICATION CAME JUST AS THE TAKEOFF ROLL WAS AT VR SPEED. SHORTLY
THEREAFTER, THE FLIGHT ENGINEER OF DELTA 789 ADVISED THE REST OF THE
CREW THAT A LIGHT WAS INDICATING AN OPEN AFT **CARGO DOOR**. PIC BURG
ADVISED THAT THIS WAS FOLLOWED BY COMPRESSOR STALLS AND A LARGE
FLUCTUATION IN ENGINE #3'S INSTRUMENTS. PIC BURG FURTHER ADVISED THAT
HE SHUT DOWN ENGINE #3 AND STARTED DUMPING FUEL IN PREPARATION FOR AN
EMERGENCY LANDING. DELTA 789 LANDED WITHOUT FURTHER INCIDENT AT 1626C.
INVESTIGATION IS CURRENTLY ON-GOING BY THE DFW FSDO. NTSB WAS NOTIFIED.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 2819W
Total Aboard: 6
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model:
Total Last 90 Days:
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19971007033469G
Local Date: 10/07/1997
Local Time: 10:30
City: NOGALES
State: AZ
Airport Name: NOGALES INTL
Airport Id: OLS
Event Type: INCIDENT - GENERAL AVIATION
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: FCD/PREC LDG FROM CRUISE
Aircraft Make/Model: PIPER PA-28R-201T
Airframe Hours: 1850
Operator Code:
Operator:
Owner Name:

Narrative

NARRATIVE: DEPARTED TUCSON, AZ TO OBREGON, MEXICO. AIRCRAFT ENCOUNTERED TURBULENCE, THE AIRCRAFT BATTERY WAS NOT SECURE AND STRUCK THE AIRFRAME AND CONTROL CABLES CAUSING ARCHING. A FIRE STARTED AND THE PILOT LANDED AT NOGALES, AZ AIRPORT. THE FIRE WAS PUT OUT BY GROUND CREW. THE FIRE DEPT. ARRIVED AND INSPECTED THE AIRCRAFT AND REMOVED THE BATTERY. THE DAMAGE IS MINOR WITH BURNED WIRING AND A **CARGO DOOR** PANEL. NO STRUCTURAL DAMAGE WAS SEEN.

Detail

Primary Flight Type: BUSINESS
Secondary Flight Type: NONE OR OTHER
Type of Operation: GENERAL OPERATING RULES
Registration Number: XBEGL
Total Aboard: 1
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: UNDER 12501 LBS
Engine Make:
Engine Model:
Engine Group:

Number of Engines: 1
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: TURBULENCE
Wind Direction (deg): 19
Wind Speed (mph): 14
Visibility (mi): GREATER THAN 10 MILES
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: NONE
Approach Type:

Pilot-in-Command

Pilot Certificates: PRIVATE PILOT
Pilot Rating: AIRPLANE SINGLE ENGINE LAND
Pilot Qualification:

Flight Time (Hours)

Total Hours: 2000
Total in Make/Model: 400
Total Last 90 Days: 200
Total Last 90 Days Make/Model: 200

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19971225044639C
Local Date: 12/25/1997
Local Time: 07:02
City: PEORIA
State: IL
Airport Name: GREATER PEORIA REGIONAL
Airport Id: PIA
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FCD/PREC LDG FROM CRUISE
Aircraft Make/Model: AEROSP ATR-42-300
Airframe Hours: 21483
Operator Code: SIMA
Operator: SIMMONS AIRLINES INC - SIMA
Owner Name: AMERICAN EAGLE AIRLINES INC

Narrative

NARRATIVE: N144DD, AN ATR-42, DEPARTED PEORIA, IL FOR CHICAGO, IL.
SHORTLY AFTER DEPARTURE, THE FLIGHT CREW NOTED THE MAIN **CARGO DOOR**
WARNING INDICATOR ILLUMINATE AND ELECTED TO RETURN TO PEORIA FOR

FURTHER INSPECTION. DURING THE APPROACH SEGMENT OF FLIGHT INTO PEORIA,
THE FLIGHT CREW PLACED THE LANDING GEAR HANDLE TO THE DOWN POSITION. IT
WAS THEN OBSERVED THAT THE NOSE GEAR LIGHT DID NOT ILLUMINATE TO
INDICATE THAT THE NOSE GEAR HAD EXTENDED. THE FLIGHT CREW DECLARED AN
EMERGENCY AND EXECUTED A FLY-BY OF THE PEORIA ATCT FOR THE PURPOSE OF
OBTAINING A VISUAL CONFIRMATION FROM THE TOWER OPERATORS THAT THE NOSE
GEAR WAS EXTENDED. N144DD THEN COMPLETED THE CONFIRMATION FROM THE
TOWER OPERATORS THAT THE NOSE GEAR WAS EXTENDED. N144DD THEN COMPLETED
THE LANDING WITHOUT FURTHER INCIDENT. SUBSEQUENT INSPECTION OF THE
AIRCRAFT REVEALED CHAFED WIRING TO BE THE CAUSE OF THE NOSE GEAR
INDICATOR LIGHT MALFUNCTION AND NO DEFECTS WERE NOTED UPON INSPECTION
OF THE **CARGO DOOR** WARNING SYSTEM. THIS INCIDENT IS CLOSED WITH THIS
REPORT.

Detail

Primary Flight Type:	SUPPLEMENTAL OR COMMERCIAL OPERATOR
Secondary Flight Type:	PASSENGERS
Type of Operation:	AIR CARRIER/COMMERCIAL
Registration Number:	144DD
Total Aboard:	2
Fatalities:	0
Injuries:	0

Landing Gear:	RETRACT TRICYCLE

Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: UNKNOWN
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 10825
Total in Make/Model: 2781
Total Last 90 Days: 161
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19980613036149C
Local Date: 06/13/1998
Local Time: 06:00
City: DAYTON
State: OH
Airport Name: JAMES M COX DAYTON INTL
Airport Id: DAY
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: SUBSTANTIAL
Phase of Flight: TO INITIAL CLIMB (1ST POWER REDUCTION)
Aircraft Make/Model: DOUG DC-8-62F
Airframe Hours: 62293
Operator Code: RRXA
Operator: EMERY WORLDWIDE AIRLINES INC - RRXA
Owner Name: EMERY WORLDWIDE AIRLINES INC

Narrative

(-5) ON THE ABOVE DATE AND TIME EMERY 024 (HEAVY) WAS DEPARTING DAY

WHEN THE MAIN **CARGO DOOR** OPENED FOR UNKNOWN REASONS. ACCORDING TO
STATEMENTS BY THE FLIGHT CREW THEY PERFORMED ALL PREFLIGHT CHECKS TO
INCLUDE PROCEEDURES FOR PROPER CLOSING OF THE MAIN **CARGO DOOR**. THE
OPERATOR CAUSED THE AIRCRAFT TO BE REMOVED FROM DAY BEFORE FAA
INVESTIGATORS WERE ABLE TO CONDUCT AN INSPECTION OF THE MAIN **CARGO DOOR**
AND RELATED SYSTEMS. STATEMENTS BY THE COMPANY AND CREWMEMBERS ARE IN
CONFLICT AS TO THE CAUSE OF THE DOOR OPENING. ACCORDING TO ALL
CREWMEMBERS THE TAKEOFF FROM DAY WAS NORMAL UNTIL JUST PRIOR TO V1. AT
THAT POINT CAPTAIN RACHFORD STATED THAT THE AIRCRAFT DID NOT WANT TO
ROTATE. THIS WAS ALSO ACCOMPANIED WITH A LOUD ROARING NOISE WHICH THE
CREW INITIALLY SUSPECTED TO BE A MALFUNCTION OF THE NUMBER TWO ENGINE.
AS THE AIRCRAFT WAS GOING THROUGH 400 FEET AGL THE DAY ATCT ADVISED THE
FLIGHT THAT THE MAIN **CARGO DOOR** WAS COMING OPEN, AND CLEARED THE
AIRCRAFT FOR RETURN TO LAND ON RUNWAY 6R. ON THE DOWNWIND LEG A LOUD
BANG WAS HEARD. IT IS ASSUMED THAT THIS WAS THE MAIN **CARGO DOOR**
SLAMMING BACK AGAINST THE FUSELAGE OF THE AIRCRAFT. CAPTAIN RACHFORD
STATES THAT OTHER THAN DIFFICULTY WITH ROLL CONTROL THE AIRCRAFT WAS
FOR THE MOST PART NORMAL. THE CREW STATED THAT IT WAS NECESSARY TO
LOWER THE MAIN LANDING GEAR (TO REGAIN THE USE OF THE SPOILERS) FOR
ADDED ROLL CONTROL. MAXIMUM BANK UTILIZED WAS 20 DEGREES. THE AIRCRAFT
WAS ABLE TO RETURN TO THE AIRPORT WITHOUT FURTHER INCIDENT. ON TOUCH
DOWN THE MAIN **CARGO DOOR** WARNING LIGHT ILLUMINATED. THE AIRCRAFT THEN

RETURNED TO THE RAMP UNDER IT'S OWN POWER. THE AIRCRAFT WAS MET BY EWA OFFICIALS WHO IMMEDIATELY BOARDED THE AIRCRAFT. MR. MALSON STATES THAT NOTHING WAS DISTURBED. THE FLIGHT CREW STATES THAT MAINTENANCE PERSONNEL BOARDING THE AIRCRAFT IMMEDIATELY BEGAN PULLING CIRCUIT BREAKERS. THESE STATEMENTS ARE IN CONFLICT.. CREWMEMBERS ARE UNWAVERING IN THEIR ASSERTION THAT THE MAIN **CARGO DOOR** WAS CLOSED IN ACCORDANCE WITH EMERY WORLDWIDE AIRLINE PROCEDURES. THE COMPANY REPRESENTATIVE, DAVID MALSON, DIRECTOR OF AIRLINE SAFETY, IS JUST AS UNWAVERING IN HIS ASSERTION THAT THE SECOND OFFICER, MATTHEW J. COMLISH, DID NOT CLOSE THE MAIN **CARGO DOOR** IN ACCORDANCE WITH EMERY WORLDWIDE AIRLINE PROCEDURES. DURING THE COURSE OF THE INVESTIGATION SEVERAL INCONSISTENCIES WERE UNCOVERED. ALL CREWMEMBERS, INCLUDING A JUMP SEAT RIDER, (SEE PAGE #2 OF CONTINUATION) STATE THAT THE MAIN **CARGO DOOR** LIGHT WAS EXTINGUISHED DURING THE TAXI OUT AT DAY. THE CREW, INCLUDING THE JUMP SEAT RIDER, ALL INSIST THE MAIN **CARGO DOOR** WARNING LIGHT DID NOT COME ON UNTIL THE AIRCRAFT TOUCHED DOWN ON RUNWAY 6R AT DAY.

Detail

Primary Flight Type: ALL CARGO CARRIERS
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 995CF
Total Aboard: 4
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make: PWA
Engine Model: JT3D7
Engine Group: JT3D
Number of Engines: 4
Engine Type: TURBOFAN/TURBOJET BYPASS

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 10000
Total in Make/Model: 2000
Total Last 90 Days: 39
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19980716021779C
Local Date: 07/16/1998
Local Time: 08:39
City: GREAT FALLS
State: MT
Airport Name: GREAT FALLS INTL
Airport Id: GTF
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: SWRNGN SA-227-AC
Airframe Hours: 19733
Operator Code: BSAA
Operator: BIG SKY TRANSPORTATION CO - BSAA
Owner Name: BIG SKY TRANSPORTATION CO

Narrative

AIRCRAFT FAILED PRESSURIZE ON CLIMB OUT. RETURNED. **CARGO DOOR** NOT
PROPERLY CLOSED.

Detail

Primary Flight Type: SUPPLEMENTAL OR COMMERCIAL OPERATOR
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL

Registration Number: 160MC
Total Aboard: 2
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates:
Pilot Rating:
Pilot Qualification:

Flight Time (Hours)

Total Hours:
Total in Make/Model:
Total Last 90 Days:

Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19970213004729C
Local Date: 02/13/1997
Local Time: 13:00
City: ATLANTA
State: GA
Airport Name: THE WILLIAM B HARTSFIELD ATLANTA INTL
Airport Id: ATL
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-727-232
Airframe Hours:
Operator Code: DALA
Operator: DELTA AIR LINES INC - DALA
Owner Name: DELTA AIR LINES INC

Narrative

AFT CARGO LIGHTO ON CLIMBOUT. LOST PRESSURIZATION. NR3 ENGINE FAILED.
RETURNED. **CARGO DOOR** OPEN. DOOR HIT ENGINE.

Detail

Primary Flight Type:	SCHEDULED AIR CARRIER
Secondary Flight Type:	PASSENGERS
Type of Operation:	AIR CARRIER/COMMERCIAL
Registration Number:	416DA
Total Aboard:	84
Fatalities:	0
Injuries:	0

Landing Gear:	
Aircraft Weight Class:	OVER 12500 LBS
Engine Make:	
Engine Model:	
Engine Group:	
Number of Engines:	3

Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: UNKNOWN
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 13750
Total in Make/Model: 4640
Total Last 90 Days: 238
Total Last 90 Days Make/Model: 238

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19970515015589C
Local Date: 05/15/1997
Local Time: 12:30
City: CLEVELAND
State: OH
Airport Name: CLEVELAND-HOPKINS INTL
Airport Id: CLE
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: EMB EMB-120-ER
Airframe Hours: 16486
Operator Code: C2XA
Operator: CONTINENTAL EXPRESS INC - C2XA
Owner Name: CONTINENTAL EXPRESS INC

Narrative

NARRATIVE: FLIGHT CREW RETURNED AIRCRAFT TO CLEVELAND. TO LOW HYDRAULIC
SYSTEM PRESSURE INDICATION AND **CARGO DOOR** LIGHT ILLUMINATION.
MAINTENANCE SERVICED THE AIRCRAFT THE PAX DOOR/LANDING GEAR HYDRAULIC
ACCUMULATOR, DRAINED RESERVOIR AND THE SYSTEM OPS

CHECKED GOOD. THE
CARGO DOOR LIGHT INDICATION DISCREPANCY WAS DEFERRED AND THE AIRCRAFT
WAS RELEASED IN ACCORDANCE WITH MEL 52-70-1. THE AIRCRAFT MAINTENANCE
REPAIRED THE **CARGO DOOR** SEQAL AND **CARGO DOOR** WARNING SYSTEM THAT HAD
BEEN DEFERRED. A MECHANICAL INTERRUPTION SUMMARY WAS SUBMITTED.

Detail

Primary Flight Type: SUPPLEMENTAL OR COMMERCIAL OPERATOR
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 27716
Total Aboard: 2
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: UNKNOWN
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates:
Pilot Rating:
Pilot Qualification:

Flight Time (Hours)

Total Hours:
Total in Make/Model:
Total Last 90 Days:
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19970702024639C
Local Date: 07/02/1997
Local Time: 04:25
City: TOLEDO
State: OH
Airport Name:
Airport Id:
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: TO INITIAL CLIMB (1ST POWER REDUCTION)
Aircraft Make/Model: DOUG DC-8-63
Airframe Hours: 56919
Operator Code: IXXA
Operator: AIR TRANSPORT INTERNATIONAL LIMIT - IXXA
Owner Name: AIR TRANSPORT INTERNATIONAL LI

Narrative

CARGO DOOR CAME OPEN ON ROTATION. CIRCLED AND RETURNED. UNABLE FIND
CAUSE. ONE LATCH BENT.

Detail

Primary Flight Type: ALL CARGO CARRIERS
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 869BX
Total Aboard: 2
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: NIGHT

Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 6800
Total in Make/Model: 4200
Total Last 90 Days: 200
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19960825033429C
Local Date: 08/25/1996
Local Time: 17:33
City: RICHMOND
State: VA
Airport Name: RICHMOND INTERNATIONAL
Airport Id: RIC
Event Type: INCIDENT - AIR CARRIER

Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: GROUND TAXI, OTHER AIRPLANE
Aircraft Make/Model: BOEING B-737-217
Airframe Hours: 76111
Operator Code: CALA
Operator: CONTINENTAL AIRLINES INC - CALA
Owner Name: CONTINENTAL AIRLINES INC

Narrative

NARRATIVE: ON 08-25-96, AT 17:33 LOCAL, THE RICHMOND TOWER RECEIVED A CALL FROM CONTINENTAL OPERATIONS ON THE FIELD. CONTINENTAL OPERATIONS REPORTED THAT THE FORWARD **CARGO DOOR** WAS FOUND TO BE OPEN WHEN FLIGHT 1135 ARRIVED AT THE GATE. CONTRACT MAINTENANCE INSPECTED THE FORWARD **CARGO DOOR** AND ADJUSTED THE ROLLERS AND STOPS IN ACCORDANCE WITH MAINTENANCE MANUAL PROCEDURES. THE AIRCRAFT SUBSEQUENTLY DEPARTED AND A FOLLOW-UP INSPECTION WAS PERFORMED IN EWR WITH NO FURTHER PROBLEMS. THE PMI WAS NOTIFIED ^PRIVACY DATA OMITTED^

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 16232
Total Aboard: 54
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model:
Total Last 90 Days:
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19961024041959C
Local Date: 10/24/1996
Local Time: 12:08
City: SALT LAKE CITY
State: UT
Airport Name: SALT LAKE CITY INTL
Airport Id: SLC
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-727-232
Airframe Hours:
Operator Code: DALA
Operator: DELTA AIR LINES INC - DALA
Owner Name: DELTA AIR LINES INC

Narrative

CARGO DOOR LIGHT PUT ON MEL. RETURNED DUE ENGINE OUT. BAGGAGE FELL OUT
LANDING. CREW FAILED TO VISUAL CHECK DOOR.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 418DA
Total Aboard: 3
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:

Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: LIGHT RAIN
Wind Direction (deg): 16
Wind Speed (mph): 07
Visibility (mi): 10
Visibility Restrictions: RAIN
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 20000
Total in Make/Model: 7000
Total Last 90 Days: 226
Total Last 90 Days Make/Model:

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my

Subject: Cargo door openings much more often than bombings part 3

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19961101038849C
Local Date: 11/01/1996
Local Time: 21:18
City: PHOENIX
State: AZ
Airport Name: PHOENIX SKY HARBOR INTL
Airport Id: PHX
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BEECH BE-1900-D
Airframe Hours: 10185
Operator Code: MASA
Operator: MESA AIRLINES INC - MASA
Owner Name: MESA AIRLINES INC

Narrative

NARRATIVE: FLIGHT 5275 DEPARTED PHX ENROUTE TO FLG. VMC PREVAILED.
AFTER DEPARTURE AND CLIMBING, THE BLEED AIR WAS SELECTED BY THE F/O.
THE CREW HEARD RUSHING AIR AND CHECKED THE CABIN DOOR. NO LIGHTS
ILLUMINATED ON THE ANNUNCIATOR PANEL. THE CREW DETERMINED THE AFT **CARGO**
DOOR HAD OPENED. AN EMERGENCY WAS DECLARED AND THE AIRCRAFT RETURNED TO
PHX WITHOUT FURTHER INCIDENT. THE PIC REPORTED THAT DURING DESCENT AT
APPROXIMATELY 500' AGL HE PUSHED THE "PRESS TO TEST" BUTTON ON THE
ANNUNCIATOR PANEL AND ALL THE LIGHTS ILLUMINATED. WHEN HE RELEASED THE
BUTTON "THEN" THE AFT **CARGO DOOR** WARNING LIGHT REMAINED ILLUMINATED.
THE LIGHT REMAINED ON DURING TAXI TO THE GATE. AFTER PASSENGER
DEPLANING THE PIC TURNED POWER BACK ON AND THE AFT **CARGO DOOR** (OPEN)
LIGHT WOULD NOT ILLUMINATE UNTIL IT WAS TAPPED WITH A FINGER.

Detail

Primary Flight Type: AIR TAXI (NON-SCHEDULED)

Secondary Flight Type: PASSENGERS AND CARGO
Type of Operation: AIR TAXI/COMMUTER
Registration Number: 35YV
Total Aboard: 9
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg): 33
Wind Speed (mph): 33
Visibility (mi): 10
Visibility Restrictions:
Light Condition: NIGHT
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 4671

Total in Make/Model: 2072
Total Last 90 Days: 239
Total Last 90 Days Make/Model: 239

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19950814029019C
Local Date: 08/14/1995
Local Time: 10:30
City: LOUISVILLE
State: KY
Airport Name: LOUISVILLE INTL-STANDIFORD FIELD
Airport Id: SDF
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: TAKEOFF GROUND ROLL
Aircraft Make/Model: DOUG DC-9-31
Airframe Hours:
Operator Code: TWAA
Operator: TRANS WORLD AIRLINES INC - TWAA
Owner Name: TRANS WORLD AIRLINES INC

Narrative

PASSENGER FELL OUT OF DC9 ONTO RUNWAY DURING TAKEOFF. RETURNED UNAWARE
EXCEPT **CARGO DOOR** LIGHT AND NO AIR PRESSURE.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 987Z
Total Aboard: 90
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:

Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model:
Total Last 90 Days:
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19960303017599C
Local Date: 03/03/1996
Local Time: :
City: MANILA, PHILIPINES
State: OF
Airport Name:
Airport Id:
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: NORMAL CRUISE
Aircraft Make/Model: BOEING B-747-251B
Airframe Hours:
Operator Code: NWAA
Operator: NORTHWEST AIRLINES INC - NWAA
Owner Name: NORTHWEST AIRLINES INC

Narrative

NARRATIVE: FLT. 007 DEPARTED NRT EN-ROUTE TO SIN ON MARCH 3, 1996. AT
FL 390 AGL. THE "AUTO FAIL LIGHT" ILLUMINATED AT THE SECOND OFFICER'S
PANEL. THE CREW COULD NOT STABILIZE CABIN ALTITUDE. WITH THE

CABIN ALT
CLIMBING, THE CREW INITIATED A DESCENT. PASSENGER OXYGEN MASKS DEPLOYED
AUTOMATICALLY. CREW DESCENDED TO 10,000 FL AGL AND DIVERTED TO MANILA.
THE AIRCRAFT LANDED WITHOUT INCIDENT. NO INJURIES REPORTED. MAINTENANCE
IN MNL REPLACED THE AIR GROUND RELAY, RIGHT OUTFLOW VALVE ACTUATOR, AND
PRESS CONTROLLER. A SMALL DENT WAS REPAIRED AT FWD **CARGO DOOR** DEPRESSOR
SEAL. THE AIRCRAFT WAS RETURNED TO SERVICE.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 631US
Total Aboard: 2
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition:
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 18700
Total in Make/Model: 10438
Total Last 90 Days: 213
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19920422024099C
Local Date: 04/22/1992
Local Time: 07:30
City: LITTLE ROCK
State: AR
Airport Name: ADAMS FIELD
Airport Id: LIT
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: BOEING B-727-222
Airframe Hours:
Operator Code: UALA
Operator: UNITED AIR LINES INC - UALA
Owner Name: UNITED AIR LINES INC

Narrative

CREW LEARNED AFT **CARGO DOOR** OPEN AFTER DEPARTURE. RETURNED. CREW FAILED TO NOTICE WARNING LIGHT.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 7443U
Total Aboard: 37
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph): 00
Visibility (mi): 7

Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type: VISUAL

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: UNKNOWN, FOREIGN PILOT

Flight Time (Hours)

Total Hours: 16600
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19910813041289C
Local Date: 08/13/1991
Local Time: 08:17
City: LOS ANGELES
State: CA

Airport Name: LOS ANGELES INTL
Airport Id: LAX
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: DOUG DC-8-63
Airframe Hours:
Operator Code: RAXA
Operator: FLAGSHIP EXPRESS SERVICES INC - RAXA
Owner Name: FLAGSHIP EXPRESS SERVICES INC

Narrative

MAIN **CARGO DOOR** OPENED AFTER TAKEOFF. DUMPED FUEL AND RETURNED. LANDED SAFELY.

Detail

Primary Flight Type: ALL CARGO CARRIERS
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 783AL
Total Aboard: 3
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg): 11
Wind Speed (mph): 06
Visibility (mi): GREATER THAN 10 MILES
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type: VISUAL

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating:
Pilot Qualification: UNKNOWN, FOREIGN PILOT

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19910919049469C
Local Date: 09/19/1991
Local Time: 12:20
City: LANSING
State: MI
Airport Name: CAPITAL CITY
Airport Id: LAN
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: TO ABORTED (FIXED WING)
Aircraft Make/Model: DOUG DC-9-31
Airframe Hours:
Operator Code: USAA
Operator: US AIRWAYS INC - USAA
Owner Name: USAIR INC

Narrative

ABORTED TAKEOFF ROLL WHEN TOWER CONTROLLER STATED LUGGAGE FALLING FROM PLANE. **CARGO DOORS** LOCKED IN OPEN POSITION.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS AND CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 975VJ

Total Aboard: 33
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 20416
Total in Make/Model: 12039
Total Last 90 Days: 104
Total Last 90 Days Make/Model: 104

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19911102056629C
Local Date: 11/02/1991
Local Time: :
City: TOLEDO
State: OH
Airport Name: TOLEDO EXPRESS
Airport Id: TOL
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: DOUG DC-8-63
Airframe Hours: 70081
Operator Code: RAXA
Operator: FLAGSHIP EXPRESS SERVICES INC - RAXA
Owner Name: FLAGSHIP EXPRESS SERVICES INC

Narrative

CARGO DOOR LIGHT ILLUMINATED ON CLIMB. RETURNED. FOUND **CARGO DOOR** DAMAGED.

Detail

Primary Flight Type: ALL CARGO CARRIERS
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 794AL
Total Aboard: 3
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: UNKNOWN
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating:
Pilot Qualification: UNKNOWN, FOREIGN PILOT

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19911204060469C
Local Date: 12/04/1991
Local Time: 07:35
City: SALT LAKE CITY
State: UT
Airport Name: SALT LAKE CITY INTL
Airport Id: SLC
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: EMB EMB-120-XXX
Airframe Hours: 6747
Operator Code: SWIA
Operator: SKYWEST AIRLINES INC - SWIA
Owner Name: SKYWEST AIRLINES INC

Narrative

LOST ALL PRESSURIZATION ON CLIMB. EMERGENCY DESCENT. RETURNED. FOUND INCORRECT **CARGO DOOR** STOPS INSTALLED.

Detail

Primary Flight Type: AIR TAXI COMMUTER (SCHEDULED 5 OR MORE ROUNDTRIPS PER WEEK)
Secondary Flight Type: PASSENGERS
Type of Operation: AIR TAXI/COMMUTER
Registration Number: 195SW
Total Aboard: 23
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):

Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 18185
Total in Make/Model: 2257
Total Last 90 Days: 246
Total Last 90 Days Make/Model: 246

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19901203064709C
Local Date: 12/03/1990
Local Time: 12:13

City: DAYTONA BEACH
State: FL
Airport Name: DAYTONA BEACH INTL
Airport Id: DAB
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: DOUG DC-9-51
Airframe Hours:
Operator Code: EALA
Operator: EASTERN AIR LINES INC - EALA
Owner Name: EASTERN AIR LINES INC

Narrative

CARGO DOOR LIGHT ON AFTER TAKEOFF. UNABLE TO PRESSURIZE. RETURNED.
FOUND **CARGO DOOR** OPENED UPON TAKEOFF.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 413EA
Total Aboard: 76
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type: VISUAL

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 14249
Total in Make/Model: 8253
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19900427019639C
Local Date: 04/27/1990
Local Time: 10:08
City: LOS ANGELES
State: CA
Airport Name: LOS ANGELES INTL
Airport Id: LAX
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: LKHEED L-1011-3851
Airframe Hours:
Operator Code: DALA
Operator: DELTA AIR LINES INC - DALA
Owner Name: DELTA AIR LINES INC

Narrative

RAPID DECOMPRESSION INFLIGHT. MASKS DEPLOYED. RETURNED. C2
CARGO DOOR
FRAME SEALS WERE DAMAGED.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS

Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 727DA
Total Aboard: 246
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates:
Pilot Rating:
Pilot Qualification:

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0

Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19900524034429C
Local Date: 05/24/1990
Local Time: :
City: AMARILLO
State: TX
Airport Name: AMARILLO INTL
Airport Id: AMA
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-737-3H4
Airframe Hours: 6734
Operator Code: SWAA
Operator: SOUTHWEST AIRLINES CO - SWAA
Owner Name: SOUTHWEST AIRLINES CO

Narrative

UNABLE TO PRESSURIZE ON CLIMB. CONTINUED TO DESTINATION AT 10000 FT.
CARGO DOOR WAS OPEN AND SENSOR SWITCH FAULTY.

Detail

Primary Flight Type:	SCHEDULED AIR CARRIER
Secondary Flight Type:	PASSENGERS
Type of Operation:	AIR CARRIER/COMMERCIAL
Registration Number:	334SW
Total Aboard:	2
Fatalities:	0
Injuries:	0
Landing Gear:	RETRACT TRICYCLE
Aircraft Weight Class:	OVER 12500 LBS
Engine Make:	
Engine Model:	

Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition:
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating:
Pilot Qualification: UNKNOWN, FOREIGN PILOT

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 232

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19900524034429C
Local Date: 05/24/1990
Local Time: :
City: AMARILLO
State: TX
Airport Name: AMARILLO INTL
Airport Id: AMA
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-737-3H4
Airframe Hours: 6734
Operator Code: SWAA
Operator: SOUTHWEST AIRLINES CO - SWAA
Owner Name: SOUTHWEST AIRLINES CO

Narrative

UNABLE TO PRESSURIZE ON CLIMB. CONTINUED TO DESTINATION AT 10000 FT.
CARGO DOOR WAS OPEN AND SENSOR SWITCH

FAULTY.

Detail

Primary Flight Type:	SCHEDULED AIR CARRIER
Secondary Flight Type:	PASSENGERS
Type of Operation:	AIR CARRIER/COMMERCIAL
Registration Number:	334SW
Total Aboard:	2
Fatalities:	0
Injuries:	0

Landing Gear:	RETRACT TRICYCLE
Aircraft Weight Class:	OVER 12500 LBS
Engine Make:	
Engine Model:	
Engine Group:	
Number of Engines:	2
Engine Type:	

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition:
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating:
Pilot Qualification: UNKNOWN, FOREIGN PILOT

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 232

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19890319016379C
Local Date: 03/19/1989
Local Time: 09:48
City: ANCHORAGE
State: AK
Airport Name: ANCHORAGE INTL
Airport Id: ANC
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-747-251F
Airframe Hours:
Operator Code: NWAA
Operator: NORTHWEST AIRLINES INC - NWAA
Owner Name: NORTHWEST AIRLINES INC

Narrative

POPPING NOISE IN CABIN ON CLIMBOUT. DUMPED FUEL AND RETURNED. **CARGO DOOR** RETAINER BAR UNLOCKED DUE SHEARED DOOR PIN

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 629US
Total Aboard: 3
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: UNKNOWN
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES

Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 18000
Total in Make/Model: 1600
Total Last 90 Days: 210
Total Last 90 Days Make/Model: 210

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19890319016379C
Local Date: 03/19/1989
Local Time: 09:48
City: ANCHORAGE
State: AK
Airport Name: ANCHORAGE INTL
Airport Id: ANC
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-747-251F
Airframe Hours:
Operator Code: NWAA
Operator: NORTHWEST AIRLINES INC - NWAA
Owner Name: NORTHWEST AIRLINES INC

Narrative

POPPING NOISE IN CABIN ON CLIMBOUT. DUMPED FUEL AND RETURNED. **CARGO DOOR** RETAINER BAR UNLOCKED DUE SHEARED DOOR PIN

From: John Barry Smith <barry@corazon.com>

Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: Cargo door openings much more often than bombings part 4

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 629US
Total Aboard: 3
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: UNKNOWN
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY

Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 18000
Total in Make/Model: 1600
Total Last 90 Days: 210
Total Last 90 Days Make/Model: 210

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19890402028359C
Local Date: 04/02/1989
Local Time: 13:14
City: MIDDLETOWN
State: PA
Airport Name: HARRISBURG INTERNATIONAL
Airport Id: MDT
Event Type: INCIDENT - AIR CARRIER

Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: GROUND TAXI, OTHER AIRPLANE
Aircraft Make/Model: BOEING B-727-35
Airframe Hours:
Operator Code: AALA
Operator: AMERICAN AIRLINES INC - AALA
Owner Name: AMERICAN AIRLINES INC

Narrative

FORWARD **CARGO DOOR** OPENED AFTER LANDING. WARNING SYSTEM INOPERATIVE.
VERIFIED CLOSED. REPLACED HANDLE SPRING

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 1957
Total Aboard: 3
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi): GREATER THAN 10 MILES
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type: VISUAL

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND

Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19890714050329G
Local Date: 07/14/1989
Local Time: 14:06
City: MIAMI
State: FL
Airport Name: MIAMI INTL
Airport Id: MIA
Event Type: INCIDENT - GENERAL AVIATION
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: DOUG DC-8

Airframe Hours:
Operator Code: FMRA
Operator:
Owner Name: TAMPA AIRWAYS INC

Narrative

MAIN **CARGO DOOR** OPENED DURING ROTATION. RETURNED. CAUSE HAS NOT BEEN DETERMINED.

Detail

Primary Flight Type: INSTRUCTION
Secondary Flight Type: TRAINING
Type of Operation: GENERAL OPERATING RULES
Registration Number: 3490X
Total Aboard: 4
Fatalities: 0
Injuries: 0

Landing Gear: F (No Decode Available)
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: VISUAL FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19890714057219C
Local Date: 07/14/1989
Local Time: 10:20
City: PORTLAND
State: OR
Airport Name: PORTLAND INTL
Airport Id: PDX
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: NORMAL CRUISE
Aircraft Make/Model: BOEING B-737-293
Airframe Hours:
Operator Code: AALA
Operator: AMERICAN AIRLINES INC - AALA
Owner Name: AMERICAN AIRLINES INC

Narrative

LOSS OF PRESSURIZATION EN ROUTE. FORWARD **CARGO DOOR** SEAL HAD BLOWN OUT.
SOME MASKS FAILED TO DEPLOY.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 469AC
Total Aboard: 79
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: VISUAL FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 13000
Total in Make/Model: 1043
Total Last 90 Days:
Total Last 90 Days Make/Model:

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19890804050719C
Local Date: 08/04/1989
Local Time: 23:31
City: NASHVILLE
State: TN
Airport Name: NASHVILLE INTERNATIONAL
Airport Id: BNA
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: CVAC CV-600-240DSTC
Airframe Hours: 65024
Operator Code: SMBA
Operator: SMB STAGE LINE INC - SMBA
Owner Name: SMB STAGE LINE INC

Narrative

CARGO DOOR CAME OFF ON LIFTOFF. DOOR HAD BEEN CHECKED BEFORE DEPARTURE.
RETURNED. CAUSE HAS NOT BEEN DETERMINED.

Detail

Primary Flight Type: ALL CARGO CARRIERS
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 94205
Total Aboard: 2
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg): 20
Wind Speed (mph): 04
Visibility (mi): GREATER THAN 10 MILES
Visibility Restrictions:
Light Condition: NIGHT

Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 4500
Total in Make/Model: 2800
Total Last 90 Days: 150
Total Last 90 Days Make/Model: 150

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19870925071529C
Local Date: 09/25/1987
Local Time: 14:30
City: CLEVELAND
State: OH
Airport Name: CLEVELAND-HOPKINS INTL
Airport Id: CLE
Event Type: INCIDENT - AIR CARRIER

Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-727-123
Airframe Hours:
Operator Code: AALA
Operator: AMERICAN AIRLINES INC - AALA
Owner Name: AMERICAN AIRLINES INC

Narrative

UNABLE TO PRESSURIZE AFTER TAKEOFF. AIRLINER SAFELY RETURNED TO AIRPORT. CARGO NET POLE JAMMED AFT **CARGO DOOR** OPEN.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 1980
Total Aboard: 56
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT

Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 21000
Total in Make/Model: 5000
Total Last 90 Days: 100
Total Last 90 Days Make/Model: 60

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19880413028689C
Local Date: 04/13/1988
Local Time: 10:49
City: SHREVEPORT
State: LA
Airport Name:
Airport Id:
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: NORMAL CRUISE

Aircraft Make/Model: BOEING B-727-123
Airframe Hours:
Operator Code: AALA
Operator: AMERICAN AIRLINES INC - AALA
Owner Name: AMERICAN AIRLINES INC

Narrative

PRESSURIZATION LOST AT ALTITUDE. EMERGENCY DESCENT. DIVERT TO DFW.
FUSELAGE SKIN AROUND **CARGO DOOR** MISSING.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 1974
Total Aboard: 7
Fatalities: 0

Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19881125063329C
Local Date: 11/25/1988
Local Time: 14:10
City: BUFFALO
State: NY
Airport Name: BUFFALO NIAGARA INTL
Airport Id: BUF
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FCD/PREC LDG FROM CRUISE
Aircraft Make/Model: BOEING B-737-130
Airframe Hours:
Operator Code: CALA
Operator: CONTINENTAL AIRLINES INC - CALA
Owner Name: CONTINENTAL AIRLINES INC AND O

Narrative

LOST CABIN PRESSURE. DIVERTED TO BUFFALO DUE TO PASSENGER MEDICAL
PROBLEM. FORWARD **CARGO DOOR** SEAL LOOSE.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 416PE
Total Aboard: 90
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 14000
Total in Make/Model: 2500
Total Last 90 Days: 105
Total Last 90 Days Make/Model: 105

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19890130023189C
Local Date: 01/30/1989
Local Time: 19:35
City: SAN JOSE
State: CA
Airport Name: SAN JOSE INTERNATIONAL
Airport Id: SJC
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: FORCED/PRECAUTIONARY LANDING
Aircraft Make/Model: BOEING B-737-301
Airframe Hours:
Operator Code: USAA
Operator: US AIRWAYS INC - USAA
Owner Name: USAIR INC

Narrative

PRESSURIZATION PROBLEMS ON TAKEOFF. RETURNED. FOUND AFT
CARGO DOOR
OPEN. WARNING LIGHT SWITCH IN CLOSED POSITION

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS AND CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 592US
Total Aboard: 40
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg): 21
Wind Speed (mph): 03
Visibility (mi): 5
Visibility Restrictions: HAZE/SMOKE

Light Condition: NIGHT
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 8950
Total in Make/Model: 300
Total Last 90 Days: 100
Total Last 90 Days Make/Model: 100

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19860308009739C
Local Date: 03/08/1986
Local Time: 13:48
City: KANSAS CITY
State: MO
Airport Name:
Airport Id:

Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-727-225
Airframe Hours:
Operator Code: EALA
Operator: EASTERN AIR LINES INC - EALA
Owner Name: EASTERN AIR LINES INC

Narrative

RAPID DECOMPRESSION DURING CLIMB. RETURNED AND FOUND AFT **CARGO DOOR** SEAL BLOWN OUT.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 8120N
Total Aboard: 40
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type: VISUAL

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT

Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19860613031719C
Local Date: 06/13/1986
Local Time: 12:20
City: ST LOUIS
State: MO
Airport Name:
Airport Id:
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE

Aircraft Make/Model: BOEING B-727-31
Airframe Hours: 51647
Operator Code: TWAA
Operator: TRANS WORLD AIRLINES INC - TWAA
Owner Name: TRANS WORLD AIRLINES INC

Narrative

AFT **CARGO DOOR** WARNING LIGHT CAME ON. MANUALLY CONTROLLED
PRESSURIZATION. AFT EDGE OF REAR **CARGO DOOR** NOT LATCHED.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: jeffreytcampbell@home.com, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my
Subject: **Cargo door openings much more often than bombings part 5**

Detail

Primary Flight Type: SCHEDULED AIR CARRIER

Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 854TW
Total Aboard: 98
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:

Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19861208079879C
Local Date: 12/08/1986
Local Time: 08:45
City: MEMPHIS
State: TN
Airport Name:
Airport Id:
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-727-223
Airframe Hours: 33354
Operator Code: AALA
Operator: AMERICAN AIRLINES INC - AALA
Owner Name: AMERICAN AIRLINES INC

Narrative

UNABLE TO CONTROLCABIN PRESSURIZATION IN AUTO OR MANUAL MODE. FOUND
CARGO DOOR SEAL OUT OF THE TRACK.

Detail

Primary Flight Type:	SCHEDULED AIR CARRIER
Secondary Flight Type:	PASSENGERS
Type of Operation:	AIR CARRIER/COMMERCIAL
Registration Number:	847AA
Total Aboard:	74
Fatalities:	0
Injuries:	0

Landing Gear:	
Aircraft Weight Class:	OVER 12500 LBS
Engine Make:	
Engine Model:	
Engine Group:	

Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: UNKNOWN
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19861227081709C
Local Date: 12/27/1986
Local Time: 09:11
City: CHICAGO
State: IL
Airport Name: CHICAGO O'HARE INTL
Airport Id: ORD
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: DOUG DC-8-73F
Airframe Hours:
Operator Code: TAGA
Operator: ORION LIFT SERVICE INC - TAGA
Owner Name: ORION AIR INC

Narrative

CARGO DOOR OPENED ON TAKEOFF. RETURNED WITH DOOR LIGHTS ON.

Detail

Primary Flight Type: ALL CARGO CARRIERS
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 808UP
Total Aboard: 0
Fatalities: 0
Injuries: 0

Landing Gear: RETRACT TRICYCLE
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR

Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19870408025949C
Local Date: 04/08/1987
Local Time: 07:08
City: GREAT FALLS

State: MT
Airport Name: GREAT FALLS INTL
Airport Id: GTF
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-737-222
Airframe Hours:
Operator Code: UALA
Operator: UNITED AIR LINES INC - UALA
Owner Name: UNITED AIRLINES INC

Narrative

A **CARGO DOOR** WARNING LIGHT CAME ON DURING CLIMB. THE AIRCRAFT RETURNED TO THE AIRPORT. DOOR IMPROPERLY LATCHED.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS AND CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 9051U
Total Aboard: 39
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19870430022259C
Local Date: 04/30/1987
Local Time: 07:45
City: COLUMBUS
State: OH
Airport Name: PORT COLUMBUS INTL
Airport Id: CMH
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: TO INITIAL CLIMB (1ST POWER REDUCTION)
Aircraft Make/Model: BOEING B-737-204
Airframe Hours:
Operator Code: PDLA
Operator: PRESIDENTIAL AIRWAYS INC - PDLA
Owner Name: PRESIDENTIAL AIRWAYS INC

Narrative

THE AIRCRAFT WOULD NOT PRESSURIZE AND THE AIRCRAFT RETURNED TO AIRPORT.
CARGO DOOR UNLATCHED. WARNING LIGHT INOP.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL

Registration Number: 313XV
Total Aboard: 31
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 8400
Total in Make/Model: 830
Total Last 90 Days: 160

Total Last 90 Days Make/Model: 160

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19870310025169C
Local Date: 03/10/1987
Local Time: 10:25
City: LONDON, UNITED KINGDOM
State: OF
Airport Name:
Airport Id:
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-747-121
Airframe Hours: 68950
Operator Code: PAAA
Operator: PAN AMERICAN WORLD AIRWAYS INC - PAAA
Owner Name: PAN AMERICAN WORLD AIRWAYS INC

Narrative

THE AIRCRAFT RETURNED TO AIRPORT WHEN UNABLE TO PRESSURIZE THE CABIN.
CARGO DOOR LATCH TORQUE TUBE WORN.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 740PA
Total Aboard: 245
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:

Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19841101064029C
Local Date: 11/01/1984
Local Time: 20:43
City: DETROIT
State: MI
Airport Name:
Airport Id: SVM
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: NORMAL CRUISE
Aircraft Make/Model: LKHEED L-188-A
Airframe Hours: 40607
Operator Code: ZIAA
Operator: ZANTOP INTERNATIONAL AIRLINES INC - ZIAA
Owner Name: ZANTOP INTERNATIONAL AIRLINES

Narrative

CREW DOOR PORTION OF FORWARD **CARGO DOOR** SEPARATED DROM AIRCRAFT OVER
LAKE ERIE. RETURNED FOR LANDING.

Detail

Primary Flight Type: ALL CARGO CARRIERS
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 346HA
Total Aboard: 0
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR

Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: NIGHT
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19860128014289C
Local Date: 01/28/1986
Local Time: 10:13

City: ST LOUIS
State: MO
Airport Name: LAMBERT-ST LOUIS INTL
Airport Id: STL
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: TO INITIAL CLIMB (1ST POWER REDUCTION)
Aircraft Make/Model: CVAC CV-340-XXX
Airframe Hours:
Operator Code: GAIA
Operator: KITTY HAWK AIRCARGO INC - GAIA
Owner Name: GENERAL AVIATION INC

Narrative

FORWARD **CARGO DOOR** OPENED AS AIRCRAFT TOOK OFF. OBJECTS DROPPED OUT.
RETURNED. FAILED TO SEE WARNING LIGHT.

Detail

Primary Flight Type: ALL CARGO CARRIERS
Secondary Flight Type: CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 453GA
Total Aboard: 0
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 2
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours: 6000
Total in Make/Model: 500
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

<<>>

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FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19831229069289C
Local Date: 12/29/1983
Local Time: 22:15
City: CHICAGO
State: IL
Airport Name: CHICAGO O'HARE INTL
Airport Id: ORD
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: NONE
Phase of Flight: CLIMB TO CRUISE
Aircraft Make/Model: BOEING B-747-131
Airframe Hours:
Operator Code: TWAA
Operator: TRANS WORLD AIRLINES INC - TWAA
Owner Name: TRANS WORLD AIRLINES INC

Narrative

AFT **CARGO DOOR** LIGHT ILLUMINATED ON CLIMBOUT. DOOR DIFFERENTIAL FLAPPER
DOOR OPEN DUE TO ICED UP MASTER LOCK PIN.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS AND CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 93108
Total Aboard: 0
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: FREEZING TEMPERATURE
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: NIGHT
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19840214010999C
Local Date: 02/14/1984
Local Time: 06:45
City: JAMAICA
State: NY
Airport Name: JOHN F KENNEDY INTL
Airport Id: JFK
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: FINAL APPROACH- INSTRUMENT FLIGHT RULES
Aircraft Make/Model: DOUG DC-8-63F
Airframe Hours:

Operator Code:
Operator:
Owner Name: VIASA VENEZUELA

Narrative

FORWARD **CARGO DOOR** OPENED ON FINAL APPROACH. CAUSE OF THE DOOR OPENING
COULD NOT BE DETERMINED.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: CARGO
Type of Operation: FOREIGN AIR CARRIER
Registration Number: 801WA
Total Aboard: 0
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 4
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: UNKNOWN
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg):
Wind Speed (mph):
Visibility (mi):
Visibility Restrictions:
Light Condition: DAWN
Flight Plan Filed: NONE
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

--
FAA INCIDENT DATA SYSTEM REPORT

[Return to Search Screen]

General Information

Data Source: FAA INCIDENT DATA SYSTEM
Report Number: 19840310022409C
Local Date: 03/10/1984
Local Time: 13:41
City: DALLAS
State: TX
Airport Name: DALLAS/FORT WORTH INTERNATIONAL
Airport Id: DFW
Event Type: INCIDENT - AIR CARRIER
Mid Air Collision: NOT A MIDAIR

Aircraft Information

Aircraft Damage: MINOR
Phase of Flight: NORMAL CRUISE
Aircraft Make/Model: BOEING B-727-123
Airframe Hours: 50208
Operator Code: AALA
Operator: AMERICAN AIRLINES INC - AALA
Owner Name: AMERICAN AIRLINES INC

Narrative

RAPID DECOMPRESSION AT CRUISE ALTITUDE. FOUND FATIGUE

FAILURE OF THE
FUSELAGE SKIN FORWARD OF THE AFT **CARGO DOOR**.

Detail

Primary Flight Type: SCHEDULED AIR CARRIER
Secondary Flight Type: PASSENGERS AND CARGO
Type of Operation: AIR CARRIER/COMMERCIAL
Registration Number: 1993
Total Aboard: 38
Fatalities: 0
Injuries: 0

Landing Gear:
Aircraft Weight Class: OVER 12500 LBS
Engine Make:
Engine Model:
Engine Group:
Number of Engines: 3
Engine Type:

Environmental/Operations Information

Primary Flight Conditions: VISUAL FLIGHT RULES
Secondary Flight Conditions: WEATHER NOT A FACTOR
Wind Direction (deg): 03
Wind Speed (mph): 06
Visibility (mi): GREATER THAN 10 MILES
Visibility Restrictions:
Light Condition: DAY
Flight Plan Filed: INSTRUMENT FLIGHT RULES
Approach Type:

Pilot-in-Command

Pilot Certificates: AIRLINE TRANSPORT
Pilot Rating: AIRPLANE SINGLE, MULTI-ENGINE LAND
Pilot Qualification: QUALIFIED

Flight Time (Hours)

Total Hours:
Total in Make/Model: 0
Total Last 90 Days: 0
Total Last 90 Days Make/Model: 0

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Subject: **Introduction.**

Dear Jaspreet,

Thank you for your email. I am now reviewing it and will reply soon.

Very nice to correspond with you.

Sincerely,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

*** This e-mail is private*** Please do not forward without permission.

Dear Mr. Smith,

My name is Jaspreet Singh Malik. I am the eldest son of Mr. Ripudaman Singh
Malik who stands accused of plotting to blow up Air India flight 182 and
plotting to put a bomb on another Air India plane that killed two baggage
handlers at Narita Airport in Japan.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Subject: **Answers, answers....**

*** This e-mail is private*** Please do not forward without permission.

Righto, I've spend all day preparing an email to the defence crew, it should arrive the same time as this.

My name is Jaspreet Singh Malik.

Nice to meet you Jaspreet, call me Barry.

I am the eldest son of Mr. Ripudaman Singh
Malik who stands accused of plotting to blow up Air India flight 182 and
plotting to put a bomb on another Air India plane that killed two baggage
handlers at Narita Airport in Japan.

Complete conspiracy nonsense of course. Both counts.

I am also a recent graduate of the UBC Law School and am currently Articling
at a Criminal Defence law firm. I know you have been in contact with
Sundeep and Paramjit, two friends of mine who are currently in Law School.

Very good. Very very good.

First, I would like to thank you for the time and effort you are putting in
to help us with this case. As far as I can tell you have nothing but pure
motives and only wish to have the truth revealed.

Well, my wife needs persuading too that I have pure motives as she and my folks think I'm nuts to pursue this. Especially now with the controversy about Sikhs.

I trace my drive back to my ejection in 1967 when my life was saved by a pilot who did not have to but did anyway. The truth revealed is faulty wiring and badly designed cargo doors on early model Boeing 747s that need fixing before they crash again. I am not defending Sikhs against a crime they did not commit because they are Sikhs. I am defending all those falsely accused of destroying airliners with bombs or missiles such as Libyans or the US Navy. As it turns out, only the Sikhs are 'man' enough to fight the false accusations at the root, willing to consider all reasonable explanations for the event other than conspiracy nonsense and refuse to believe the propaganda of 15 years put out by the media who love a good terror story but are bored by science explanations of an event that happened before and was supposed to be fixed.

The Crown has sought and the Attorney General has granted a Direct
Indictment. In common practice an accused would have an Preliminary Hearing
in which his lawyers would get to test the Crown's evidence.

Makes sense.

All the
Crown's witnesses would be forced to testify unless specifically excused by
the accused's lawyer. This is of a great benifit to an accused as he gets
to test the evidence without being required to testify.

Right. And filters out the nonsense early on.

It is not an error
in law for the Crown to get a Driect Indictment. In complex cases the Crown
may seek a Direct Indictment so as to be able to speed up the process and
avoid having to offer the Crown's evidence twice.

Yeah, yeah, yeah, so the Crown can steamroller past any questions or doubts that need to be brought up and digested by the public, such as being wrong about the cause of a plane crash 15 years ago. Speed up the process...when did a government ever speed up the process except for its own good. The speeding up request is a clue to their not being so sure about the prosecution.

> > What's next on April 4th?
> >
The next court appearance but nothing of any significance.

Maybe it can be turned into something of significance. Better to bring up the wiring/cargo door/explosive decompression sooner than later.

> > What are the discovery rules in Canada?
The Law in Canada is the the Crown must disclose everything that it has in
its possesion. Even if that evidence leads to the conclusion that the
accused are innocent.

Fair enough.

The challenge in this case will be to get the Crown
to disclose everything they have.

Well, we can be very specific. List below.
Unfortunately you don't know what your
missing unless you stumble upon it.

Well, that's true, I also know exactly what I am looking for, where it is and how to find it: Hangars with wreckage in them and 25 videotapes of 3 hours each.

We have requested that but we have to deal with Corrections officials who do not have such exceptions in their manuals.

It is a writing instrument and diary. That is the category he is entitled to.

Obviously we have tried to work
this out with the Crown and with the Judge so we can meet the constitutional
right to make full answer in defence.

Yes, something to bring up at the 'procedural' hearing April 4. Every opportunity before a judge is rare and must be fully exploited.

> > Can he have internet access via phone lines?
> >
I do not believe that will be possible but we can look into it.

Do not accused, not even convicted, get phone time? Just three minutes a day is OK. Your father needs to be able to address his supporters and give them moral support. It works both ways. He is not alone and when the Sikhs realize that he is not a bad guy that may have his sentence reduced with their support but an unjustly accused victim because of his religion, the support will grow immensely, in my humble opinion.

> > Can he receive and send out removable disks for
> > laptop computer?
> >

Once he gets access to a computer we can request to send in disks or CDs

And get his out. A burnable CD writer in a laptop will be perfect. It's all doable. One of the terrible things of locking an unconvicted person up is that it isolates him from his moral and factual supporters. What's the phrase? Right to make full answer in defence. That's it and requires 2001 technology of computer and phone line.

> > Is he eligible for assistance from the Crown for a
> > legal expert and
> > technical expert?
> >

Such requests require Crown consent or Judge approval. I understand that
currently there are preliminary negotiations underway so that each party has
adequate funding.

Big one, Jaspreet, the Crown is flying people all over the world, from Scotland to Vancouver, they have experts of their own from all over the world, they will call in people from India, they have multi million dollar agencies saying bomb and the defence can not possibly fairly and adequately provide the required standard of fairness without financial assistance as well as expert advice. I would ask for cash and a Boeing structural expert and a TSB accident investigator assigned to the case on our side.

Something to ask the judge April 4.

>From here a Trial calendar will be set up. hopefully sooner
rather than
later we can start with all the pretrial motions. Our best hope is
that in
January 2002 a trial will start and will finish some 4-6 months
later.

Hmmm.....Jan 02. Pretrial motions......

If
an Appeal of the case was to be filed it would be heard about 1
year after
the end of the case.

> > Is he a joint defendant with Mr. Bagri or
> > independent?
> >
They are charged jointly and will be tried jointly unless an
application for
severance is made and granted. Usually such applications are not
successful. The Courts like it better when people charged with
the same
crime are tried together.

Hmmmm.....

> > Can an American (California) aviation trial attorney
> > practice in

> > Canada or what capacity can he assist?
> >
I'm not sure I'll have to look into that.

I ask because Mr. Jerry Sterns of Oakland California is aware of this case and he is the legal and technical expert in explosive decompressions in airliners. At least he can be consulted later on.

I was wondering if you had any contact with the Defence team for the men
charged with blowing up a plane over Lockerbie, Scotland.

Good question, and I sent many many emails to them before the trial imploring them to not accept the bomb existed but to fight it on those grounds. They did not reply and instead when with the "It was a bomb but our guys did not put it there.....maybe the Palistinians did." Of course they lost halfway, one guy off and one guy in jail for life, which is what will happen here. A political verdict of the rich guy going to jail for life and the poor guy freed, just like PA 103. Below are emails and names. I suggest you contact them to touch base. The same tactics used against them will be used against your father.

adlaw@planet.nl, rskeenqc@compuserve.com,
adlaw@callnetuk.com

Gentlemen Kamal Maghur,
Mr. Alistair Duff,
Mr. Stephen Mitchell,
Mr. Richard Keen,
Murdo Macleod,

Eddie MacKechnie,
McGRIGOR DONALD,
Alex Prentice,
William Taylor,
John Beckett

Well, Jaspreet, I am heartened to know that a young, articulate, motivated, and educated man is on the defence team. The fact you know about the law is incredibly valuable.

If the wiring/cargo door/explosive decompression explanation is brought up at 4 April hearing, then the heat will be transferred to me to justify it. I can do that. All our ducks are not in a row but the media attention on the mechanical explanation will help persuade the Crown to give us all our discovery requests. It gives legitimate hope to the accused and his supporters. It gives time for the prosecutors to prepare against the mechanical explanation but if you have faith, as I do, in the evidence, then the explanation can not be refuted no matter how much time they have. In addition, the revelation of the mechanical explanation for AI 182 on 4 April will justify to the Court to grant our request for technical assistance in the form of an assigned Canadian government official from the Transportation Safety Board. I will persuade the TSB the wiring/cargo door/explosive decompression is worthy of further investigation for AI 182, all I need is a face to face with them and my documents.

In addition, if the idea is confirmed that AI 182 may not have been a bomb, then bail proceedings may be fruitful.

Do you have the necessary four Aircraft Accident Reports? AAR for AI 182, PA 103, TWA 800, and UAL 811. I can send three and direct you the web address for the other. To understand AI

182 is to understand UAL 811.

Many Sikhs may believe your father did the heinous crimes he is accused of because they feel he was justified in revenge. Many Sikhs may believe he did not do the crimes because they know the man and feel he is not capable of doing the crimes but can't prove it. I know he did not do it because I know nobody did it and I can prove it. I can provide reasonable doubt a bomb exploded on AI 182, I can prove the forward cargo door ruptured/opened in flight for AI 182, and I can provide the probable cause of that door rupture as faulty wiring turning on the door unlatch motor.

Now to persuade the authorities. 'Right to make full answer in defence,' says it all.

Sincerely,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Aircraft:
AI 182:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the RCMP and TSB.
2. Access to all hard evidence of the wreckage which was

retrieved from ocean.
3. Interviews with TSB, AAIB, and NTSB investigators who contributed to the AI 182 report through deposition or voluntary meeting.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

PA 103: The same officials who worked on the AI 182 report also worked on the PA 103 AAIB report.
1. Interviews with NTSB metallurgists and Boeing explosive expert and British law enforcement involved with the investigation.
2. Copies of all videotapes, photographs, interview notes, and sketches now held by the AAIB and Scotland Yard.
3. Access inside the hangar at Farnborough of the Pan Am 103 wreckage for at least 40 hours (five days at 8 hours a day) by at least five of your team.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

TWA 800: The same officials who worked on AI 182 and PA 103 worked on TWA 800.
1. Access to the hangar where the wreckage of TWA 800 is stored for at least 40 hours (five days at 8 hours a day) by at least five of your team.
2. Copies of all photographs, videotapes, interviews about TWA 800 now held by FBI and NTSB.
3. Interviews with NTSB metallurgists, explosive expert and American law enforcement involved with the investigation.

4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

UAL 811:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the NTSB.
2. Access to any existing wreckage.
3. Interviews with NTSB metallurgists, explosive expert and American law enforcement involved with the investigation.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

Airport:
Narita:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the RCMP and TSB and Japanese airport and police authorities
2. Transcripts of the trial

Manufacturer:
Boeing:
1. Copies of all memos, data, and information about cargo doors and cargo holds on Boeing 747s.
2. Copies of all memos, data, and information about cargo doors and cargo holds on DC-10, MD-11, and MD-12.

Airlines:
Pan Am, TWA, Air India, United Airlines:
1. Copies of all videotapes, photographs, interview notes, and

sketches regarding PA 103, AI 182, TWA 800, and UAL 811
2. Access to any existing wreckage held by them.
3. Interviews with airline staff involved with the accidents.
4. Maintenance logs for the accident aircraft long before and just before the fatal flights.

Miscellaneous:
1. Copies of all data about Canadian Pacific Air Flight 003, another Boeing 747 supposed to have a bomb on board and by inference, abetted by you, sir, or your fellow Sikh, Mr. Reyat.
2. Copies of all Data about Airworthiness Directives about cargo door on commercial airliners held by FAA and NTSB databanks.
3. Bruntingthorpe 747 evidence.
4. DC 10 CVR data, explosive decompression accidents, Windsor and Paris.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Subject: **UAL 811 AAR**

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(SUPERSEDES NTSB/AAR-90/01)
NATIONAL
TRANSPORTATION
SAFETY
BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION--

LOSS OF CARGO DOOR IN FLIGHT
UNITED AIRLINES FLIGHT 811
BOEING 747-122, N4713U
HONOLULU, HAWAII
FEBRUARY 24, 1989

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NATIONAL TRANSPORTATION
SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989

Adopted: March 18, 1992 Notation 5059C

Abstract: This report explains the explosive decompression resulting from the loss of a cargo door in flight on United Airlines flight 811, a Boeing 747-122, near Honolulu, Hawaii, on February 24, 1989. The safety issues discussed in the report are the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, and emergency response. Recommendations concerning these issues were made to the Federal Aviation Administration, the State of Hawaii, and the U.S. Department of Defense.

CONTENTS

EXECUTIVE SUMMARY

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.

The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.

A year after the accident, the Safety Board was uncertain that the cargo door would be located and recovered from the Pacific Ocean. The Safety Board decided to proceed with a final report based on the available evidence without the benefit of an actual examination of the door mechanism. The original report was adopted by the Safety Board on April 16, 1990, as NTSB/AAR-90/01.

Subsequently, on July 22, 1990, a search and recovery operation was begun by the U.S. Navy with the cost shared by the Safety Board, the Federal Aviation Administration, Boeing Aircraft Company, and United Airlines. The search and recovery effort was supported by Navy radar data on the separated cargo door, underwater sonar equipment, and a manned submersible vehicle. The effort was successful, and the cargo door was recovered in two pieces from the ocean floor at a depth of 14,200 feet on September 26 and October 1, 1990.

Before the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.

Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.

The issues in this investigation centered around the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

As a result of this investigation, the Safety Board issued safety recommendations concerning cargo doors and other nonplug doors on pressurized transport category airplanes, cabin safety, and emergency response.

NATIONAL TRANSPORTATION SAFETY BOAR

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122,

N4713U HONOLULU, HAWAII FEBRUARY 24, 1989

1. FACTUAL INFORMATION

1.1 History of the Flight

On February 24, 1989, United Airlines (UAL) flight 811, a Boeing 747-122 (B-747), N4713U, was being operated as a regularly scheduled flight from Los Angeles, California (LAX) to Sydney, Australia (SYD), with intermediate stops in Honolulu, Hawaii (HNL) and Auckland, New Zealand (AKL).

The flightcrew assigned to the LAX/HNL route segment reported no difficulty during their flight.

A flightcrew change occurred when flight 811 arrived at HNL. The oncoming captain stated that he and his crew reported to UAL operations 1 hour and 15 minutes prior to the flight's scheduled departure time from HNL. The crew had completed a 34-hour layover (rest period) in HNL.

The captain reviewed the flight plan, the weather, pertinent NOTAMs, and maintenance records, and signed the Instrument Flight Rules (IFR) clearance before boarding the airplane.

Flight 811 departed HNL gate 10 at 0133 Honolulu Standard Time (HST), 3 minutes after the scheduled departure time, with 3 flight crewmembers, 15 cabin crewmembers, and 337 passengers. The flightcrew attributed the short delay to cabin crew problems with arming the 5L cabin door emergency exit slide and the normal securing of the 2L door after a somewhat extended passenger boarding process. The second officer stated that all cabin and cargo door warning lights were out prior to the airplane's departure from the gate. He said that he dimmed the annunciator panel lights at his station while the airplane was departing the gate area.

The captain was at the controls when the flight was cleared for takeoff on HNL runway 8R at 0152:49 HST. The auxiliary power unit (APU), which was used during the takeoff, was shutdown shortly after making the initial power reduction to climb thrust.

The flightcrew reported the airplane's operation to be normal during the takeoff and during the initial and intermediate segments of the climb. The flightcrew observed en route thunderstorms both visually and on the airplane's weather radar, so they requested and received clearance for a deviation to the left of course from the HNL Combined Center Radar Approach Control (CERAP). The captain elected to leave the passenger seat belt sign "on."

The flightcrew stated that the first indication of a problem occurred while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed (IAS) of 300 knots. They heard a sound, described as a "thump," which shook the airplane. They said that this sound was followed immediately by a "tremendous explosion." The airplane had experienced an explosive decompression. They said that they donned their respective oxygen masks but found no oxygen available. The airplane cabin altitude horn sounded and the flightcrew believed the passenger oxygen masks had deployed automatically.

The captain immediately initiated an emergency descent, turned 180(to the left to avoid a thunderstorm, and proceeded toward HNL. The first officer informed CERAP that the airplane was in an emergency descent and appeared to have lost power in the No. 3 engine. The appropriate 7700 emergency code was placed in the airplane's radar beacon transponder and an emergency was declared with CERAP at approximately 0220 HST. The No. 3 engine was shut down shortly after commencing the descent because of heavy vibration, no N1 compressor indication, low exhaust gas temperature (EGT), and low engine pressure ratio (EPR).

The second officer then left the cockpit to inspect the cabin area and returned to inform the captain that a large portion of the forward right side of the cabin fuselage was missing. The captain subsequently shut down the No. 4 engine because of high EGT and no N1 compressor indication, accompanied by visible flashes of fire. The flightcrew initiated fuel dumping during the descent to reduce the airplane landing weight.

The airplane was cleared for an approach to HNL runway 8L. The final approach was flown at 190 to 200 knots with the No. 1 and No. 2 engines only. During flap extension, the flightcrew observed an indication of asymmetrical flaps as the flap position approached 5(. The flightcrew decided to extend inboard trailing edge flaps to 10(for the landing. The right outboard leading edge flaps did not extend during the flap lowering sequence. The airplane touched down on the runway, approximately 1,000 feet from the approach end, and came to a stop about 7,000 feet later. The captain applied idle reverse on the Nos. 1 and No. 2 engines and employed moderate to heavy braking to stop the airplane. At 0234 (HST), HNL tower was notified by the flightcrew that the airplane was stopped and an emergency evacuation had commenced on the runway.

After the accident, UAL ramp service personnel, who had been involved with the cargo loading and unloading of flight 811 before takeoff from HNL, stated that they had opened and closed the forward cargo door electrically. They said that they had observed no damage to the cargo door. The ramp service personnel said that they had verified that the forward cargo door was flush with the fuselage of the airplane, that the master door latch handle was stowed, and that the pressure relief doors were flush with the exterior skin of the cargo door.

The dispatch mechanic stated that, in accordance with UAL procedures, he had performed a "circle check" prior to the airplane's departure from the HNL gate. This check included verification that the cargo doors were flush with the fuselage of the airplane, that the master latch lock handles were stowed, and that the pressure relief doors were flush or within 1/2 inch of the cargo door's exterior skin. He said a flashlight was used during

this inspection.
The second officer stated that, in accordance with UAL Standard Operating Procedures (SOP) he had performed an operational check of the door warning annunciator lights as part of his portion of the cockpit preparation. The second officer also stated that he used a flashlight while performing an exterior inspection, again in accordance with UAL procedures. The exterior inspection was conducted while ramp service personnel were performing cargo loading operations and the cargo doors were open. He stated that he had observed no abnormalities or damage.

1.2 Injuries to Persons

Injuries Flightcrew Cabincrew Passengers Others Serious *Lost in flight. An extensive air and sea search for the passengers was unsuccessful.

1.3 Damage to the Airplane

The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward.
Examination of all structure around the area of primary damage disclosed no evidence of preexisting cracks or corrosion. All fractures were typical of fresh overstress breaks.
Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos. 3 and 4. No damage was noted on the left side of the airplane, including

engines Nos. 1 and 2.
The right wing had sustained impact damage along the leading edge between the No. 3 engine pylon and the No. 17 variable camber leading edge flap. Slight impact damage to the No. 18 leading edge flap was noted.

There was a break and scuff in the wing leading edge aft of engine No. 4 and a scuff in the wing leading edge outboard of engine No. 4. There was a large indentation (to a depth of nearly 8 inches) in the area just above the outboard landing light, and the landing light covers were broken. There was a small puncture in the upper surface of the No. 14 krueger flap and impact damage to the wing leading edge just aft of the No. 14 krueger flap. There was a gash on the upper wing surface aft of the No. 14 krueger flap and leading edge, as well as punctures to the wing leading edge aft of the number 16 krueger flap. The under wing surface aft of the krueger flaps also sustained impact damage.

The right wing also had sustained damage at the wing-to-body fairing and two flap track canoe fairings.1 Wing-to-body fairing damage was limited to surface scraping forward of and below the wing. The outboard surface of the No. 6 flap track canoe fairing revealed a slightly more significant gouge mark. The most severe damage was evident on the inboard surface of the No. 8 flap track canoe fairing, where three separate punctured areas were observed. The trailing edge flaps were not damaged.

The leading edge of the right horizontal stabilizer had several dents. The most severe dents, located 8 to 10 feet from the stabilizer root, were approximately 3 inches wide and 1 inch deep. No punctures were found. The vertical stabilizer had multiple small and elongated indentations with a maximum depth of 1/2 inch near the right base of the leading edge. A small gouge and two small scrapes were noted at midspan of the upper rudder.

A piece of cargo container was found lodged between the No. 3

engine pylon (inboard) and the wing underside. The piece of metal had severed the pneumatic duct for the leading edge flaps. Various nicks and punctures were evident on the inboard side of the No. 3 engine pylon. The No. 4 engine pylon had a small puncture near the leading edge of the wing.

The external surfaces of the No. 3 engine inlet cowl assembly exhibited foreign object damage including small tears, scuffs and a large outwardly directed hole. The entire circumference of all the acoustic (sound attenuator) panels installed on the inlet section of the cowl had been punctured, torn, or dented. None of the No. 3 engine cases were penetrated by objects, nor was there evidence of fire damage to any visible engine components and accessories. The

leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage.

External damage to the No. 4 engine inlet and core cowls was confined to the inboard side of the inlet cowl assembly. The damage consisted of one major scuff mark, four lesser scuff marks and one crescent- shaped cut. The sound attenuator panels that were installed in the inlet area of the inlet cowl assembly had not been penetrated. The No. 4 engine fan blade airfoils had sustained both soft and hard object damage from foreign objects.

The cargo door separation resulted in the loss of fuselage shell structure above the cargo door, along with main cabin floor structure below seats 8GH through 12GH (see figure 3). The missing floor area extended inboard from the interior of the right side fuselage wall to the inboard seat track of seats 8GH through 12GH.

The supply and fill lines from the flightcrew oxygen bottle, and the supply line for the passenger oxygen system had been broken below the cabin floor inboard of the missing cargo door.

The two cabin pressurization out-flow valves, located on the underside of the fuselage, aft of the rear cargo compartment, were found fully open. The two over-pressure relief valves located on the forward left side of the airplane were found in the normal closed position. These valves were removed and bench tested. (See section 1.16.3, Pressurization System.) The majority of the cabin floor-to-cargo compartment blowout panels were found activated. The blowout panels are designed to relieve excess pressure differential following an explosive decompression to prevent catastrophic damage to the cabin floor structures.

The estimated damage to the airplane was $14,000,000, based on UAL's costs to repair it.

1.4 Other Damage

No other property damage resulted from this accident.

1.5 Personnel Information

The crew consisted of 3 flight crewmembers (the captain, the first officer, and the second officer) and 15 cabin crewmembers. (See appendix B.)

1.6 Aircraft Information

1.6.1 General

On February 24, 1989, the United Airlines B-747 fleet consisted of 31 airplanes, including: 2 B-747-222B, 11 B-747-SP, 5 B-747-123, and 13 B-747-122 series airplanes. N4713U was equipped with four Pratt & Whitney model JT9D engines.

The accident airplane, serial No. 19875, registered in the United States as N4713U, was manufactured as a Boeing 747-122 transport category airplane by the Boeing Commercial Airplane Company (Boeing), Seattle, Washington, a Division of the Boeing Company. N4713U, the 89th B-747 built by Boeing, was manufactured in accordance with Federal Aviation Administration (FAA) type certificate No. A20WE, as approved on December 30, 1969. The airplane was certificated in accordance with the provisions of 14 CFR Part 25, effective February 1, 1965.

The maximum calculated takeoff weight for flight 811 was 706,000 pounds. The flight plan data showed an actual takeoff weight of 697,900 pounds. The center of gravity (CG) for takeoff was computed at 20.4 percent mean aerodynamic chord (MAC). The forward and aft CG limits were 12 and 29.7 percent MAC, respectively.

At the time of the accident, N4713U had accumulated 58,815 total flight hours and 15,028 flight cycles. N4713U had not been involved in any previous accident. Records indicated that the airplane had been inspected and maintained in accordance with the General Maintenance Program as defined in UAL Operations Specifications and in accordance with the FAA approved Aircraft and Powerplants Reliability Program. The records indicated that all required inspection and maintenance actions had been completed within specified time limits and all applicable airworthiness directives (AD) had been accomplished or were in the process of being accomplished, with the exception of AD 88-12-04, which was applicable to the B-747 lower lobe cargo door, and which had only been complied with partially. (See section 1.6.8 for explanation).

1.6.2 Cargo Door Description and Operation

Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Electrical power for operation of the cargo door switches and actuators is supplied from the ground handling bus, which is powered by either external power or the APU. See figure 17 for a diagram of the cargo door electrical circuitry. The engine generators cannot provide power to the ground handling bus. APU generator electrical power to the ground handling bus is interrupted when an engine generator is brought on line after engine start. The APU generator "field" switch can be reengaged by the flightcrew, if necessary on the ground, to power the ground handling bus. The air/ground safety relay automatically disconnects the APU generator from the ground handling bus, if it is energized, when the airplane becomes airborne and the air/ground relay senses that the airplane is off the ground.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with pull-in hook pins on the sides of the door frame. (See figure 4 for cargo door components).

The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. Figure 5 depicts a lock sector and latch cam in an unlocked and locked condition.

Figure 4.--Boeing 747 lower lobe forward cargo door.

Figure 5.--Cargo door latch cam and lock sector in unlocked and locked ositions.

The door has three electrical actuators for opening/closing and latching of the door. One actuator (main actuator) moves the door from the fully open position to the near closed position, and vice versa. A second actuator (pull-in hook actuator) moves the pull-in hooks closed or open, and the third actuator (latch actuator) rotates the latch cams from the unlatched position to the latched position, and vice versa. The latch actuator has an internal clutch, which slips to limit the torque output of the actuator.

Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull- in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator. The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The B-747 cargo door has eight (8) view ports located beneath the latch cams for direct viewing of the position of the cams by means of alignment stripes. Procedures for using these view ports for verifying the position of the cams were not in place or required by Boeing, the FAA, or UAL (see 1.17.5 for additional information).

Closing the door manually is accomplished through the same sequence of actions without electrical power. The door actuator mechanisms are manually driven to a closed and latched position by the use of a one-half inch socket driver. The door can also be opened manually with the use of the socket driver. There are separate socket drives for the door raising/lowering mechanism, the pull-in hooks, and the latches.

Operating procedures for the normal electrical operation of the forward and aft cargo doors are outlined in the UAL Maintenance Manual (MM). Authorization for deferral of maintenance on the door power system is contained in the UAL B-747 Minimum Equipment List (MEL). In addition, operating procedures for dispatching aircraft with an inoperative door electrical power system (manual operation) are specified in the operator's MEL.

The UAL MM differs from Boeing's recommended MM. UAL had modified Boeing printed material or replaced pages with their own methods and procedures for conducting maintenance functions. The modifications to the manufacturer's MM were accepted by the FAA through "approval" by the FAA Principal Maintenance Inspector (PMI). Electrical cargo door open/close operations in the UAL and Boeing MM's are approximately the same, except the final "Caution" statement differs in methods to ensure that the latch cams are closed:

United Airlines Maintenance Manual

CAUTION DO NOT FORCE HANDLE. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

Boeing Airplane Company Maintenance Manual

CAUTION DO NOT FORCE HANDLE. IF RESISTANCE IS FELT, CHECK LATCH ALIGNMENT STRIPES THROUGH VIEWING PORTS IN DOOR. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

The following step in Boeing's MM does not appear in the UAL MM: "Check that the Cargo Door Warning Light on flight engineer panel goes out." The UAL flightcrew checklist includes a check of the warning light as part of the cockpit procedures for dispatch.

Prior to the issuance of AD-88-12-04 (see 1.6.8), UAL ramp service personnel only operated the cargo doors electrically. Manual operation was accomplished only by maintenance personnel. AD-88-12-04 required the additional procedure of recycling the master latch lock handle following manual operation of the latch actuator.

1.6.3 UAL Boeing 747 Special Procedures--Doors

The Safety Board's investigation revealed that UAL had published a "special maintenance procedure" in the UAL MEL for manual operation of the cargo door. The Maintenance Manual Special Procedures, 5-8-2-52, dated January 1988, were incorporated into UAL's MEL for use by maintenance controllers and work foremen in issuing instructions or procedures to mechanics. The procedure allowed the use of a special 1/2-inch socket drive wrench as the primary tool for use in manually opening or closing the cargo door. The document further authorized, as an alternate tool, an air-driven torque-limiting screwdriver. UAL procedures required approval by San Francisco Line Maintenance and the station maintenance coordinator before an air-driven screwdriver could be used to operate the doors of a B-747 airplane with an inoperative cargo door power system.

At the Safety Board's public hearing, the FAA PMI and the FAA B-747 maintenance inspector for UAL testified that prior to the accident they were unaware of an FAA authorization for UAL's use of an air-driven torque-limiting screwdriver on B-747 cargo doors. However, the FAA's approval for the use of the tool was noted in the MEL section of the airline's maintenance manual. The original approval had occurred before the current inspectors assumed their respective positions. Both testified that they had not reviewed UAL's B-747 MEL because they assumed that the previous inspectors had reviewed it.

According to UAL, the calibration/adjustment for the torque-limited air-driven screwdrivers was tested every six months. Safety Board investigators found no records for the calibration/adjustment of the power tools used to manually open and close UAL B-747 cargo doors.

The Safety Board received statements from UAL supervisory maintenance personnel at all UAL stations and contract facilities for B-747 operations indicating that air-driven screwdrivers had not been used by maintenance personnel to open or close the forward cargo door on N4713U in the months prior to the accident.

1.6.4 UAL Maintenance Program

Airplanes operated by UAL are maintained under an FAA-approved continuous airworthiness maintenance program, as required by 14 CFR Part 121, Subpart L. The requirements of the UAL maintenance program are detailed in their Operations Specifications, dated November 21, 1988. Generally, UAL has an overall in-house capability to perform virtually all of the maintenance required on its own airframes and powerplants. All of the required major airframe and powerplant maintenance for N4713U had been performed at the UAL maintenance facility in San Francisco, California.

UAL's maintenance and inspection program is scheduled either at specific flight hour or calendar intervals. These maintenance and inspection programs are designated as: Service No. 1, Service No. 2, or A, B, C, MPV, and D Checks.

The work scope of Service Checks consists of a general inspection of the airplane and engines, including servicing of consumable fluids, oxygen, and tire pressures. The Service No. 1 check involves an inspection at each maintenance facility where the airplane lands. The Service No. 2 check is performed at a maintenance facility where the airplane is scheduled for at least 12 hours of ground time. The maximum time interval between Service No. 2 Checks is not to exceed 65 flight hours.

The "A" Check is performed at intervals not to exceed 350 flight hours. This check includes an extended inspection of the cockpit, cabin, cargo compartments, landing gear, tires, and brakes. It does not include a detailed inspection of the cargo doors.

The Phase Check ("B" Check) is scheduled on a calendar basis, not to exceed 131 days. The scope of the "B" Check contains items of inspection such as interior safety equipment and functional verification of various aircraft systems and components. It does not include a detailed inspection of the cargo doors.

The "C" Check is heavy maintenance oriented and is scheduled on a calendar basis, every 13 months. The "C" Check work scope is substantial and includes:

structural inspection items;

corrosion repair;

prevention and inspection of critical flight control systems; and,

a detailed inspection of the cargo doors.

The Mid-Period Visit (MPV) Check is a heavy maintenance inspection that is scheduled at intervals not to exceed 5 years. Items requiring scheduled overhaul are contained in the check as well as inspections of the airplane structure and interior.

The D Check, completes the routine scheduled B-747 maintenance plan and is scheduled at intervals not to exceed 9 years. The work scope is very similar to the MPV Check and consists of heavy maintenance to the airplane structure, landing gear, interior, and airplane systems, including the cargo doors.

1.6.5 Maintenance Records Review

A review of the airplane's history indicated that the forward and aft cargo doors were the original doors and neither had been removed for repair or replaced for cause. There was no record of major repair to either door or adjacent airplane structure.

The forward cargo door's forward mid-span latch pin had been removed because of gouging of the pin surface, during the last "C" check on

November 28, 1988. According to the available maintenance documents, including the most recent "D" check, a full cargo door rigging check had not been accomplished. UAL maintenance personnel indicated that no rigging of the forward or aft cargo doors was required during the following checks:

1. "D" check accomplished April 1984;
2. "C" checks accomplished November 11, 1987, and November 28, 1988; and,
3. "B" checks accomplished March 21, 1988 and July 27, 1988;

The records prior to the "D" check in 1984 and the "C" check accomplished in November 1987 were not required to be retained. This procedure complies with FAR 121.380.

The logbook of N4713U was reviewed and all numbered pages were in sequential order with none missing. The airplane had been released for flight by UAL, HNL Maintenance, in accordance with UAL procedures. The Los Angeles to HNL segment of flight 811, on February 23, 1989, generated four logbook discrepancy entries. All items were cleared by HNL maintenance and none were related to the cargo door. No new deferred items were generated and no current deferred items were corrected. The Maintenance Release document for flight 811 indicated that all deferred items were in accordance with the UAL Minimum Equipment List (MEL) and none referenced the forward cargo door.

UAL stores its maintenance information in an "electronic logbook," entitled Aircraft Maintenance Information System (AMIS). This system tracks on a daily and worldwide basis the flightcrew defect reports, all nonroutine maintenance defects, and maintenance corrective actions for the UAL airplane fleet. The system follows an Airline Transport Association (ATA) chapter format. According to UAL, the AMIS information is used as part of UAL's FAA approved maintenance reliability program affording the capability to assess trends at any given time.

A complete history of N4713U was reviewed for the following ATA Chapters:

Chapter-00-Miscellaneous

No significant items associated with the cargo door systems.

Chapter-21-Air Conditioning and Pressurization

An entry, dated August 19, 1988, indicated "Auto and Standby pressure controllers were erratic." UAL maintenance cleared this item as "Checked per Maintenance Manual Chapter (MM) 21-31-00.

Chapter-31-Instruments (Not related to any specific system)
No significant items associated with the cargo door systems.
Chapter-52-Doors (Cargo door section only)
During the period September 7, 1988, through November 1, 1988, a series of five discrepancies on the forward cargo door's electrical opening and closing system were noted. Ground handling personnel were required to operate the door by the manual system. On November 1, 1988, UAL maintenance corrective action for this discrepancy was signed off as, "replaced power unit [lift mechanism] per Maintenance Manual Chapter 52-34-02.
An expanded AMIS history of the N4713U forward cargo door system was prepared beginning December 1, 1988, and continuing until the date of the accident. The history tracked the airplane by each flight and station transited.
During the period December 5, 1988, through December 23, 1988, eight defect reports regarding the opening and closing of the forward cargo door were entered into the system. The reported defects involved problems with the cargo door not always operating with the normal electrical system. Appendix E contains the details of the writeups and corrective actions.
During the period December 23, 1988, through February 23, 1989, two forward cargo door discrepancies were noted on N4713U. On January 3, 1989, the discrepancy was, "Manual lock seals broken." The corrective action was signed off as, "recycled [door] per placard on door and documented. No door problems." On January 15, 1989, the discrepancy was, "cargo door seal, lower aft corner is torn and loose from retainer." The corrective action was "repaired seal." There were no further recorded discrepancies.
On February 23, 1989, a written discrepancy noted "Aft cargo door damaged aft lower corner." The corrective action listed, "Interim repair per (EVA) LM-8-433. Accomplish permanent

repair within 60 flight hours."

Chapter-53-Structures (Fuselage)

During the period March 1988, through February 24, 1989, one defect was noted for each of the forward and aft cargo doors on N4713U.

Forward Cargo Door.--On September 6, 1988, the discrepancy was, "Approximately six inches of forward cargo door jamb damaged center of lower side sealing surface." The corrective action was, "Installed doubler and sealed area."

Aft Cargo Door.--On April 22, 1988, the discrepancy was, "Aft cargo door rear sill latch does not spring up to lock." The corrective action was, "Replaced latch."

1.6.6 Service Difficulty Report Information

A review was made of the Service Difficulty Reports (SDRs) for ATA Chapter 52 for all UAL Boeing 747 airplanes. Thirty-nine SDRs were recorded over the period January 31, 1983, through March 21, 1989. The following summarizes data concerning the forward and aft cargo doors:

cases of corrosion;

cases of cracking;

cases of door open (false) indications;

cases where cabin did not pressurize;

cases of cabin pressure loss; and

case of dent caused by ground equipment.

None of the noted SDR cases were recorded for N4713U.

1.6.7 Service Letters and Service Bulletins

Boeing issues information to its customers via Service Letters (SL's) and Service Bulletins (SB's) to inform operators of reported and anticipated difficulties with various airplane models. Twelve SL's provided guidance for maintenance or information applicable to the B-747 cargo doors. Twenty-nine SB's provided guidance for maintenance or information applicable to the B-747 cargo door.

SB-747-52-2097, "Pressure Relief Door Shroud Installation--Lower Lobe and Side Cargo Doors," was issued on June 27, 1975. Revision 1 to SB-747-52-2097 was issued November 14, 1975. In general, the SB recommended the installation of shrouds on the inboard sides of the cargo door pressure relief door openings. The purpose of the shrouds was to prevent the possibility of the pressure relief doors being rotated (blown) to the closed position during the pressurization cycle. This condition could only occur if the master latch lock handle had been left open and the flightcrew failed to note the cargo door open warning before takeoff.

UAL records for N4713U indicated that SB-747-52-2097 had been complied with and the shrouds had been installed on the forward and aft cargo doors. However, examination of the aft cargo door on N4713U revealed that the shrouds were not in place. UAL could not find records to verify if the shrouds had been installed or if they had been removed from either door.

1.6.8 Airworthiness Directives

There had been 141 Airworthiness Directives (ADs) issued that were applicable to the accident airplane. Two ADs were pertinent to the cargo door. AD 79-17-02-R2 ("Inspection of Fore and Aft Lower Cargo Door Sill Latch Support Fittings,") required an inspection every 1,700 flight hours. The second, AD 88-12-04 ("To Insure That Inadvertent Opening Of The Lower Cargo Door Will Not Occur In Flight,") issued on May 13, 1988, required an initial one time inspection of the cargo door latch locking mechanisms within 30 days of issuance of the AD, and certain repetitive inspections until terminating action for the AD was taken.

The circumstances of a Pan American World Airways (Pan Am), Boeing 747-122 cargo door opening in flight (see 1.17.1 for details) led to the issuance of Boeing Alert Service Bulletins (ASB) 52A2206 on April 8, 1987, and 52A2209 on August 27, 1987, entitled, "Doors - Cargo Doors Lower Lobe Forward and Aft Cargo Doors, Latch Locking System Tests, Operation and Modification." Tests and investigation revealed that latch lock sectors would, in some instances, not restrain the latch cams from being driven open manually or electrically. Movement of the latch cams without first moving the lock sectors to the stowed [unlocked] position would cause bending, gouging, and breaking of the sectors. The FAA issued AD-88-12-04 to make the provisions of SB's 52A2206 and 52A2209 mandatory.

The terminating action for AD 88-12-04 called for installing steel doublers to add strength to the lock sectors to prevent the latch cams from being able to be driven to the open position manually or electrically with the sectors in the locked position. AD 88-12-04 also required that, if the door could not be operated normally (electrically), a trained and qualified mechanic was to open and close the door manually, rather than ramp service personnel. Further, the AD required an inspection of the lock sectors for damage once a cargo door was restored to electrical operation after any malfunction had required manual operation of the door. The amount of time allowed for completing the terminating action portion of AD 88-12-04 was either 18 months or 24 months, from the issue date of the AD, depending on the Boeing 747 model series. Terminating action for the AD had not been accomplished on N4713U prior to the accident, nor was it required since, for this airplane, the deadline for compliance with the terminating action was January 1990. According to UAL, N4713U was scheduled for completion of the terminating action in April 1989, when the airplane was scheduled for other heavy maintenance.

During the Safety Board's investigation it was determined that a clerical error was made by UAL personnel, while attempting to expedite the processing of an advanced copy of a Notice of Proposed Rulemaking (NPRM 87-NM-148-AD), preceding AD 88-12-04. The error involved the omission of one line of text during the typing of the document. Because of that error, the portion of the text of the NPRM (and the final text of the AD) was left out of UAL's maintenance procedures. The omitted text required an inspection of the B-747 cargo door lock sectors every time a cargo door was restored to normal (electrical) operation after manual operation was required.

The UAL maintenance internal auditing system, including quality assurance personnel, did not detect the omission until after the accident. UAL personnel stated that, for unknown reasons, no one within the maintenance or quality assurance programs had reviewed the final AD language for comparison with the UAL maintenance procedure.

A review by Safety Board investigators of forms used by UAL to verify compliance with applicable FAA AD's issued indicated that all of the applicable mandatory ADs were satisfied within their specified time limits. The list provided by UAL to the FAA as part of the FAA's oversight responsibilities showed compliance with AD-88-12-04, with the exception of the terminating action.

Section 1.17.3 contains information relevant to the B-747 cargo door corrective actions taken since the accident.

1.7 Meteorological Information

The accident occurred in night visual meteorological conditions. No adverse weather was experienced, although the flight did have to deviate around thunderstorms during the descent.

1.8 Aids to Navigation

There were no navigational problems.

1.9 Communications

There were no radio communication difficulties between flight 811 and air traffic control (ATC). Members of the flightcrew did not have any difficulty in verbally communicating with each other; however, attempts to communicate with the cabin crewmembers by interphone were unsuccessful following the explosive decompression.

1.10 Aerodrome Information

After the explosive decompression, the airplane returned to HNL, a 14 CFR Part 139 certificated airport on the island of Oahu, Hawaii. The airport is located about 4 miles west of Honolulu, Hawaii.

HNL is a "joint use" airport that is used by the State of Hawaii, the U.S. Air Force, general aviation, commercial, air carrier, air taxi, and military aircraft. Aircraft Rescue and Fire Fighting (ARFF) services are provided by State and Hickam Air Force Base ARFF units. Prior to the emergency landing at Honolulu, flight 811 requested that all available rescue and medical equipment to be on hand when they landed. When the crash alarm was broadcast, all civilian and military fire units responded and were in position in 1-minute at pre-designated stations at runway 8 left.

The Safety Board's investigation revealed that there was no direct radio communications between the State Airport vehicles and Hickam ARFF vehicles. Because there were no direct radio communications, the Chief of the airport's units had to drive his vehicle to the vehicle of the Chief of the Hickam units to coordinate the positioning of ARFF units prior to the landing of United 811.

The Hickam vehicles are painted olive drab camouflage. During the response, the Chief of the State ARFF vehicles observed a near collision between a State and a Hickam vehicle. He attributed this to the camouflaged Hickam vehicle not being visually conspicuous in spite of the fact that each of the vehicles had a red rotating beacon operating. The response took place on a moonless night and in light rain.

1.11 Flight Recorders

The airplane was equipped with a Sundstrand model 573 digital type Flight Data Recorder (DFDR) and a Sundstrand model AV557-B Cockpit Voice Recorder (CVR).

Examination of the data plotted from the DFDR indicated that the flight was normal from liftoff to the accident. The recorder operated normally during the period. However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent.

The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.

1.12 Wreckage and Impact Information

An extensive air and surface search of the ocean conducted immediately following the accident failed to locate the portions of the airplane lost during the explosive decompression. However, the Safety Board, as well as other parties to the investigation, pursued several avenues to search for and recover the cargo door. Navy radar near Honolulu tracked debris that fell from the airplane when the cargo door was lost. Refinement of the radar data led to a probable "splashdown" point in the ocean. Further assistance from the Navy regarding the ocean currents and drift information led to a probable location of the cargo door and associated debris on the ocean floor.

The undersea search operation was begun on July 22, 1990, using the Orion, a state-of-the-art Navy side-scanning sonar "fish." Searching in the area selected by analysis of radar data and undersea currents, the Orion located a debris field on its first pass over the 14,200-foot-deep ocean floor. The second pass located a significant sonar target, which later analysis indicated was probably the cargo door. Since the Orion is only capable of searching, the debris field was marked with transponders for use during the subsequent recovery phase.

On September 14, 1990, the recovery ship Laney Chouest sailed from Pearl Harbor with the manned, deep-sea submersible Sea Cliff. Safety Board, FAA, Boeing, and UAL engineering staff assisted the recovery team aboard the Laney Chouest. After four dives in the area previously identified as the debris field, only pieces of cargo container and other small debris from the airplane had been recovered. (It appears that the significant target identified by the Orion was a piece of cargo container rather than the cargo door.) On the following dive, however, the lower portion of the cargo door was located and recovered. The fuselage structure above the cargo door was located and raised to the surface on the sixth dive, but heavy seas prevented its recovery. The upper portion of the door was recovered during the Sea Cliff's seventh dive on October 1, 1990. Afterward, it was decided that no further effort could be justified to recover the fuselage structure above the cargo door, and the recovery mission was terminated.

Following recovery of the cargo door, each piece was sprayed with a corrosion inhibitor. The ship promptly returned to Pearl Harbor, and the retrieved door portions were removed and examined before being shipped to Seattle, Washington, for detailed examinations under the supervision of Safety Board staff. Visual examinations on the recovery ship and in Pearl Harbor confirmed that the cargo door lock sectors were in the locked position and that the latch cams were in the nearly open position. Figure 6 depicts the position of the lock sectors and cams as recovered from the ocean. There was no evidence of progressive fractures in the door structure.

The cost for the search mission was $193,000, and the cost for the recovery mission was $250,000. These costs were shared by the Safety Board, the FAA, UAL, and Boeing. Section 1.16 contains information on the examination of the recovered wreckage.

1.13 Medical and Pathological Information

Appendix D contains a list of injuries.

1.14 Fire

There was no fire in the cabin or fuselage. The fires in engines No. 3 and 4 were extinguished after the engines were shut down.

1.15 Survival Aspects

The fatal injuries were the result of the explosive nature of the decompression, which swept nine of the passengers from the airplane.

At 0210, the FAA notified the U.S. Coast Guard that a United Airlines, Inc., B-747, with a possible bomb on board, had experienced an explosion and was returning to HNL. The Coast Guard Cutter, Cape Corwin, departed Maui at 0248 to search the area for debris and the missing passengers. Ultimately, 4 shore commands, 13 surface/air units, and approximately 1,000 persons took part in the combined search and rescue (SAR) operation. The search was t™ erminated at 1200 on February 26, 1989, without recovery of any passenger bodies.

The flight attendants had approximately 20 minutes to prepare the cabin and the passengers for an imminent ocean ditching, and subsequently, for an emergency evacuation. During the 20 minutes they attended to injured flight attendants and passengers, attached the face masks to their emergency oxygen bottles, helped each other don life preservers, helped numerous passengers don life preservers, held up safety cards and life vests to call attention to these items for passengers to use, briefed "helper" passengers to assist in the evacuation, cleared debris away from the exit doors and aisles, closed the doors of the storage compartment above doors 2 left and 2 right, prepared the cabin for an emergency evacuation, and told the passengers to brace for impact.

Several problems were experienced by the flight attendants and the passengers following the decompression, while preparing for a possible ditching, and preparing for the emergency evacuation. These problems included difficulties encountered by flight attendants in connecting face masks to their portable oxygen bottles, the lack of a sufficient number of megaphones, limited visibility from a flight attendant seat, overhead storage compartment doors opening, and donning and fastening life preservers.

Federal Aviation Regulation 14 CFR 25.1447 (c)(4) requires that "portable oxygen equipment must be immediately available for each cabin attendant." Those portable oxygen bottles on N4713U, which were readily available, were not immediately usable because the masks were not attached to the regulators. The flight attendants reported difficulties in attaching the masks to the regulators.

The aft purser ran back to the flight attendant jumpseat at door 5-left for a portable oxygen bottle. However, she found no bottle at this location (none was installed). She then ran back to the 4-left jumpseat, by which time she was "light headed." After the aft purser reached jumpseat 4-left, flight attendant No. 14, who was already sitting there, placed an oxygen mask on her face. The aft purser further stated, "considering the fact that in this case there was no other available source of oxygen, you can't imagine how horrible I felt going back there needing oxygen but finding no oxygen bottle at 5-left. It was terrifying."

A portable emergency oxygen bottle was not required to be stowed at the flight attendant seat at exit 5-right; however, one was stowed in the right coat closet behind the flight attendant seat. In addition, the left side closet and rest rooms were physically separated from the right side closet and rest rooms. This arrangement requires a flight attendant, who was seated at exit 5-left to walk around to the right side of the cabin to obtain the oxygen bottle.

Communication between the flight attendants and passengers was very difficult because of the high ambient noise level in the cabin after the decompression, even though the public address (PA) system was operational. Flight attendants were located at each of the 10 exit doors, yet there were only two megaphones required to be on the airplane; one located at door 1-left and another located a 4-left.

The flight attendants, who were responsible for each of these two doors, used the megaphones to broadcast commands to passengers in their immediate areas and to other flight attendants in preparation for the landing and subsequent evacuation. The other 13 flight attendants (including the one deadheading flight attendant) had to shout, use hand signals, and show passengers how to prepare for the evacuation by holding up passenger safety cards, so passengers could review the information and also know how to put on their life preservers.

As soon as the decompression occurred, the flight attendant in the upper deck business class section went to her jumpseat and donned her oxygen mask, life preserver, and restraint system. While she waited for instructions, and because of intense cabin noise she had to communicate with passengers by holding up a safety card and a life preserver. Passengers sitting in the front rows, in turn, showed safety cards and life preservers to other passengers seated behind them. Eventually everyone understood that they were to read the safety card and put on their preservers. However, the 5 foot 3 1/2 inch flight attendant stated that her jumpseat was so low that she could not directly observe the passengers in the 4th row (last).

A two door overhead stowage compartment that had formerly stored a life raft was located above each exit door. These compartments contained blankets and passenger carry-on luggage. At doors 2-left and 2-right the doors of each compartment had opened downward and blocked each exit. Also the contents of the compartments fell to the floor at the exits. The doors had to be closed before the evacuation because they partially blocked the exit.

The chief purser was not able to tighten the life preserver's two straps around her waist and needed the deadheading flight attendant to tighten them for her. Several flight attendants and passengers had difficulties connecting the two straps around their waists. One flight attendant helped about 36 passengers don their preservers.

Safety Board investigators and United Airlines personnel examined several life preservers from each of the types of preservers produced by five manufacturers. The strap of one manufacturer's preserver was very difficult to tighten around the waist while another from the same manufacturer was easy to tighten. The two vests had different strap material and strap adjustment fittings. Also, the straps are very difficult, if not impossible, to tighten when they are pulled at an acute angle from the wearer's body, i.e. from about 45 to 70 degrees. Holding the hands and straps closer to the waist facilitates easier adjustment of the straps.

1.16 Tests and Research

1.16.1 Cargo Door Hardware Examinations

1.16.1.1 Before Recovery of the Door

The following forward cargo door closing and latching components were returned to the Safety Board's Materials Laboratory for analysis after they were documented in place on the airplane:

Two pull-in hook pins, one from the lower end of the forward side of the door body cutout forward frame, and one from the

lower end of the aft side of the body cutout aft frame, with housings;
Two mid-span pins, one from the forward side of the door body cutout forward frame, and one from the aft side of the door body cutout aft frame.
All components were initially examined while installed on the airplane. All eight forward cargo door latch pins, with housings, were removed for further laboratory examination. Also, for comparison, one of the latch pins, with housing, from the aft cargo door was also removed. For orientation purposes, the eight lower latch pin assemblies are referred to by number, with the No. 1 latch pin being the most forward on the lower door sill, and the No. 8 pin being the most aft. When referencing a circumferential location on the latch pins or mid-span pins, a clock position was used. The clock code was oriented looking forward with 12 o'clock being straight up and 9 o'clock being directly inboard.
Based on the orientation of the latching mechanisms, the fully unlatched latching cams would first contact the latch pins from about the 1:15 o'clock position to the 7:15 position as the door was closed. As the cams are being latched around the pins, they would rotate approximately 80(, making contact with the pins from about the 4:15 position to the 10:15 position (See figure 7).
Detailed examination of the exposed surface of the pins (the portion of the pins extending from the housings) revealed various types of wear and damage. In general, all of the forward door cargo latch pins had smooth wear over the entire portion of the pin area contacted by the cams during normal closing and opening of the door. The pins also had distinct roughened (smeared) areas between the 6:15 and the 7:30 positions (See figure 8). The roughened areas had evidence of "heat tinting" and transfer of cam material to the surface of the pins. On pins 1 and 8 the roughened areas extended past the pin bottom to the 5:00

position. The 7:30 position approximately corresponds to the area on the pin where the lower surface of the cam would be relative to the pin when the latch cams are in the unlatched or nearly unlatched position.

The forward pull-in hook pin was not significantly bent, but the structure to which it was attached was deformed outward, so the hook pin was deflected significantly outward. Three of the four bolts holding the aft pull-in hook pin had sheared, so the hook pin was also deflected outward. Both hook pin ends were damaged, but neither pin was significantly deformed along its length. There was significant heat tinting on the damaged area of the forward hook pin. Boeing engineering calculations determined that the pull-in hook pins would fail at a 3.5 psi differential cabin pressure with the latch cams unlatched.

The forward mid-span latch pin was relatively undamaged. The aft mid-span latch pin had definite areas of damage. Both pins had wear areas where the cams would contact the pins during latching.

1.16.1.2 After Recovery of the Door

The documentation of the recovered cargo door was divided into four areas: 1) door structure, 2) master latch lock system, 3) latch system, and 4) hook system. A description of the recovered door follows.

1. Door Structure:

The cargo door had fractured longitudinally near the mid-span lap joint near stringer 34R, just beneath the mid-span torque tubes. Except for an area of missing skin between frames 2 and 3 and a portion of frame webs where the upper latch lock torque tube had torn out, the frames and skin of the upper door piece mated to the lower door piece.2 Several areas of the upper door skin along the longitudinal fracture were bent back. In addition, a large area of lower door skin between frame 6 and the aft door edge had peeled downward from the fracture line. The two door pieces are shown together in Figures 9 and 10. Examinations of the fracture surfaces of the skin and frames revealed no evidence of pre-existing cracks. All fractures were typical of overstress separation.

Seven of the eight lock sector slots in the lower beam showed evidence of contact and scraping by the lock sectors. Only the No. 1 lock sector slot was undamaged, although the bracket forward and above the No. 1 slot did appear to have been damaged by contact from the lock sector (slots numbered 1-8, forward-aft). The direction of the scraping on the slots could not be determined conclusively.

The decal covering the latch actuator manual drive port was found broken circumferentially around the edge of the port cover, which was loose and rotated from its normal position (See figure 11). There was an impression in the decal similar to a Phillips-head screw slot in line with the center of the retainer screw securing the cover. There was also a 0.06-inch-long linear slit from 10 to 4 o'clock approximately centered over the retainer screw head (See figures 12 and 13). There was no rotational tearing and no loss of decal material in the area covering the screw head location. During examinations of the door at Boeing, it was noted that the retainer bracket on the inside of the latch actuator manual drive port cover was bowed outward; the port cover was not deformed. The retainer bracket on the inside of the hook actuator manual drive port cover was similarly bowed outward, and the port cover was bowed outward.

The hinge that attaches the cargo door to the fuselage is comprised of several hinge sections--those attached along the upper edge of the cargo door and those along the fuselage just above the cargo door cutout--interconnected with hinge pins. The hinge pins and all hinge sections from N4713U's forward cargo door were intact; all hinge sections rotated relatively easily. All attach bolts from the hinge sections on the door remained

attached; conversely, no bolts remained attached to the hinge sections on the fuselage. Several areas on the hinge sections, such as the fuselage hinge sections, showed evidence of contact from the door during overtravel (See figure 14). In addition, the fuselage forward hinge sections
were slightly bent. The upper flange of the door, to which the door hinges are attached, was not deformed. The forward cargo door can rotate open 143 degrees before the hinge would deform, permitting the door to contact the fuselage above.

Examination of the outer skin contour of the upper door piece revealed that it had been crushed inward. There were also many areas on the outer skin where blue and red paint transfer marks could be seen. These marks were generally forward of the aft pressure-relief door, and the blue marks were located above the red marks. The UAL paint pattern incorporates red and blue stripes along the fuselage above the cargo door. Figure 15 is a plot of the documented paint marks on the upper door piece.

There was no evidence of the pressure relief door shrouds found on the forward door; however, most of the inner door lining to which the shrouds attach was missing.

2. Master Latch Lock System:

All eight lock sectors were found in the locked position--actually past the fully locked position. They had been pulled through the lock sector slots in the lower beam of the cargo door. (When they are fully locked, the lock sectors should be recessed in the lower beam approximately 3/8 inch). All lock sectors had deflected off the high shoulder of the latch cams due to interference with the partially unlatched cams. Prior to disassembly of the components, the interference between the cams and the lock sectors was removed by rotating the cams to the latched position.

Examination of the lock sectors disclosed that the bottom of the lower arm of each lock sector was gouged. For seven of the eight lock sectors, the distance from the main gouge area to the location of the interference between the latch cam and the lock sector was approximately 0.75 inch. (The No. 2 lock sector was corroded and had fractured at the location of the large gouge common to the other seven lock sectors. Consequently, it was not in contact with the No. 2 latch cam when the door was retrieved).

The master latch lock handle housing and trigger were found relatively flush with the door outer skin. The top of the handle was recessed approximately 0.50 inch inward from flush, and the bottom of the handle was protruding approximately 0.40 inch outward from flush (See figure 16). This

Figure 15.--Documented paint marks on outer skin of upper door piece. Dashed line is approximately 8 degrees from horizontal.

position of the handle indicates that the lock sectors were in a position past fully locked. The fuse pin was found in three pieces but was heavily corroded. The handle housing was undamaged.

Two of the three connecting rods between the master latch lock handle and the lock sector torque tube were bowed slightly, but they were otherwise intact. No deformation was observed on any section of the lock sector torque tube, although one of the six bearings assembled on the torque tube had been damaged. The No. 3 bearing inner race and its torque tube locator sleeve were displaced forward approximately 0.20 inch from the bearing housing centerline. The outer race was broken and pushed forward out of the housing.

The lower two connecting rods between the lock sector torque tube and the torque tube below the pressure-relief doors were undamaged; however, the upper connecting rod had separated at the upper, tapered end. The torque tube below the pressure-relief doors were missing, and the pressure-relief door connecting rods had separated at the lower, tapered end. The remaining portion of each rod was undamaged, but the forward pressure-relief door was jammed open into the cutout.

3. Latch System:

All eight lower latch cams were found in a nearly unlatched position, and all of them were binding against the lock sectors except the No. 2 cam (lock sector No. 2 had broken). Latch cams 1-6 were approximately 62 degrees from the fully latched position, and cams 7 and 8 were approximately 70 degrees from fully latched. Full rotation of the latch cams is 80 degrees.
Several of the lower latch cams contained compression and smearing damage on the lower lip of the latch cam cavity ("lower" relative to an open cam). This damage is consistent with the forceful movement of the cams across the latch pins.
The four rods between the latch actuator torque tube and the four bellcranks containing the latch cams were attached and undamaged. No section of the latch actuator torque tube was damaged, and the bearings/supports along the tube were intact.
The latch actuator was removed and later disassembled. No anomalies were found.

4. Pull-in Hook System:

The forward and aft pull-in hooks were found near the closed position. Both of them exhibited wear patterns consistent with contact with the pull-in hook pins during door operation. For both the forward and aft hooks, the inboard edge of the pull-in hook channel contained compression and smearing damage consistent with a forceful movement of the hooks over the pins while the hooks were in the closed or nearly closed position.

1.16.2 Forward Cargo Door Electrical Component Examinations

1.16.2.1 Before Recovery of the Door

Several electrical components associated with the operation of the forward cargo door were examined on the airplane and were then removed for further testing. These components included the No. 2 ground handling power bus relay, the air/ground safety relay, the No. 1 auxiliary power circuit breaker, and the outside and inside door control switches. All of these components were tested for both single faults and intermittent failures. The test results showed that all of the switches/relays were functional, although a loose wire connection was found on the outside door control switch. This loose wire connection showed evidence of overheated insulation on the two terminal lugs that attach to terminal No. 5, and there was evidence of a burn (arc point) on the top of the screw head for terminal No. 5. Terminal No. 5 is associated with power for the door "close" cycle, and not the door "open" cycle.

An electrical continuity check was performed on the cockpit cargo door warning light system components that remained with the airplane. This check confirmed the integrity of the circuit from the door area to the cockpit. The examination of the two bulbs that comprise the forward cargo door warning light revealed that one bulb was inoperative. The other bulb, which is in parallel with the inoperative bulb, was found operative. The illumination of the display legend, which reads "FWD CARGO DR" on the flight engineer's panel, was discernible with one bulb inoperative. A functional check of the circuit, which allows the cockpit warning lights to be dimmed during night operations, was also performed. The check consisted of removing the card containing this circuit and installing it in another B-747. The test was satisfactory in that the dim/bright circuit functioned properly.

1.16.2.2 After Recovery of the Door

Switches--General

The cargo door was recovered with all of its position sensing switches installed in their proper locations. The electrical junction box was found attached to the door but damaged. The switches recovered and examined were: S2 Master Latch Lock; S3 Door Warning; S4 Latch Close; S5 Hook Position; S6 Fwd Mid-Span Latch Open; S7 Door Close; S8 Hook Close; and S9 Aft Mid-Span Latch Open. Figure 17 provides a diagram of the cargo door's electrical circuitry.

Five of the eight position-sensing switches installed on the door had evidence of external damage to the switch housing. The damage on four switches (S2,S3,S4,S8) consisted of primarily compression dimpling on the housing. The S5 switch exhibited mechanical impact damage on the switch housing and mounting bracket. The striker assembly for switch S8 was loose (2 of 3 rivet fasteners sheared). The electrical wiring recovered with the door exhibited signs of tensile separation from overload at all failure points examined.

Each switch was photographed and its installed position was documented. Electrical continuity readings were taken with an ohmmeter across the poles of each switch at the first point of wire separation as found on the door. After the readings were recorded, all switches were removed from the door so that photographs and x-rays of each switch could be taken. Electrical continuity readings were retaken.

Disassembly of each switch consisted of: (1) drilling two holes in the switch housing to release trapped water from the switch (2) cutting a small window in the switch housing to examine the internal basic switches (3) removing the housing, (4) removing the internal bracket, and (5) removing basic switch covers.

During the drilling step, water was released from every switch when the holes were drilled in the switch housing. The water was filtered into a glass container. The quantity was not measured but appeared to be less than 5 mL. The residue from the filtered water trapped on the filter media had a blue-green color.

After the switch housing was removed, an ohmmeter was connected across the 1-2 poles of the switches that would not transfer electrical continuity (S2,S3,S4,S6,S7) when actuated. The rivets were then drilled out of the internal bracket. After the last of the two rivets were drilled out, the switch contacts

Figure 17b.--Diagram of cargo door electrical circuitry.

transferred to the other pole on S2, S3, and S4. On S6, the used3 basic switch was held closed by its plunger. S7 transferred after the switch housing and water inside were removed.

During removal of the basic switch covers, a trend was noted in the discoloration of some of the basic switches. The used switch had a reddish-brown coloration. The unused switch was not discolored.

Each switch was found to be wired correctly to its poles and through its contacts within the basic switches. All contacts operated with light finger pressure after removal of the basic switch covers. There was no evidence of pitting, excessive corrosion, or heat distress in the contacts of any of the switches. The following sections detail pertinent observations concerning each switch.

The S2 master latch lock is given particular significance because of its function to protect against inadvertent door operation and is thus described in more detail. It is a single-pole double-throw (SPDT) switch used to sense the unlocked position of the door lock sectors. The switch is mounted in the aft lower corner of the door. A bracket attached to the No. 7 lock sector depresses the switch when the door lock sectors are rotated to their unlocked position. When the bracket attached to the lock sector contacts the switch plunger and depresses it, the circuit path through the switch is closed and 28VDC electrical control power to the door is established. When the force on the plunger is relaxed, the circuit is opened and 28VDC electrical control circuit is removed.

The wires leading to the S2 switch had been cut by the team after the recovery in an attempt to test continuity through the switch. The door recovery team reported that it found continuity through the 1-3 contacts but not through the 1-2 contacts. The switch plunger was actuated by the recovery team. The recovery team noted that the switch did not transfer continuity during these tests. The operation of the switch plunger would normally transfer continuity. Subsequent detailed examination of the S2

switch confirmed the findings of the recovery team.
The area around the upper face of the internal bracket was bent toward the basic switches and had evidence of corrosion residue. The bracket was found broken. The switch contacts transferred from the 1-3 actuated position to the 1-2 nonactuated position when the bracket was removed. Scanning electron microscope examination of the fracture surfaces revealed evidence of overload and corrosion.
The external switch housing was dented. The final examination performed on the switch consisted of removing the plastic covers on the basic switches. Prior to removal of the basic switch covers, it was noted that the cover to the used basic switch was cracked. The contacts functioned normally when exercised by light finger pressure.
Microscopic examination revealed a black discoloration near one of the lower contact posts of the used basic switch. Energy dispersive spectrometric examination of the residue disclosed the presence of gold, iron, magnesium, sodium, and chlorine. No mechanical or electrical anomalies were detected with the basic switch contacts.
Additional testing was performed by Boeing on switches of a similar design to those used on the accident airplane's cargo door. The testing was conducted to identify conditions that would result from salt water immersion at a pressure depth of 14,200 feet for 18 months. The testing verified that external damage to the switch housing occurred at pressure depths of 7,000 feet and greater. Switch seal leakage and subsequent internal corrosion was also noted. None of the testing performed by Boeing duplicated internal switch damage that caused basic switch contact closure or internal damage to the switch support bracket.
Wiring:
The electrical wiring recovered with the cargo door was documented in place before being removed for further tests.

About 40 percent or 112 feet of wire from the original length of approximately 274 feet was recovered and examined. Of this amount, about 46 feet of wire installed in the aircraft forward of the cargo door was not examined. Most of the wires leading from the door to the fuselage were not recovered. There was no visible external evidence of burning, arcing, or heat distress in any of the wires removed. Several areas of wire insulation damage were found.

Thirty five wires were identified that could provide a possible short circuit path that could drive the latch actuator open with or without failures of other door electrical components if the ground handling bus was energized. The wires were schematically coded by function. Wires coded (-..-..-) were denoted for wiring that provides open command logic to the latch actuator. Wires coded (--.--.--.) were denoted for additional wiring enabled by an activated (failed) S2 switch. Wires coded (-o-o-o-o) were denoted for wiring providing 28VDC power from the C285 circuit.

Potential short circuit paths were identified for the cargo door that could provide 28VDC to the latch actuator control circuit relay. These potential short circuit paths can cause the latch actuator to drive the latches toward their open position if 115VAC power is available to the latch actuator motor. The potential short circuit paths include two bare wires shorting against each other, bare wire-to-metal structure-to-bare wire contact, wire to conductive fluid (such as water) to wire, or a combination of the aforementioned.

Conductive contact of (-o-o-o-o) or (--.--.--) coded wire with (-..-..-) coded wire could potentially result in providing a 28VDC circuit path to the latch actuator open circuit. Direct wire-to-wire paths are coded in Figure 17 as defined above. The two-wire short circuit paths are identified as wire pairs consisting of wire 101-20 shorting with any of the following wires; 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

If the S2 master latch lock switch fails in the "Not Locked" position, there are additional wire pairs that provide short circuit paths. These are coded in Figure 17 as (--.--.--) to (-..-..-..) wire pairs.

Short Circuit Wire Damage Simulation Tests:

Tests were conducted by Boeing and United to simulate typical examples of bare wire short circuiting to determine the extent of visible wire damage that would be expected in the 28VDC cargo door control circuit.

United performed tests on BMS 13-42 wire, the wire type used in the B-747 cargo door control circuit. Visible electrical short circuit damage on bare BMS 13-42 wire surfaces was difficult to create at 28VDC. Surface damage was considered visible when detected by microscopic examination at 15X magnification. United testing simulated the relay coil resistance variations that would be found during typical in-service conditions. A current of 1.0 A at 28VDC created visible surface damage on momentary bare wire-to-bare wire contact. Multiple contacts at 1.0 A provided a more positive indication. A single momentary contact between two bare BMS 13-42 wires with 0.160 A at 28VDC did not create visible surface damage. Contact between a BMS 13-42 bare wire and Alclad 2024-T3 metal (airplane and cargo door structure) with 0.160A at 28VDC did not create visible surface damage.

Boeing performed wire tests on BMS 13-48 20 gauge wire. The test setup used the MS27418-2B door latch actuator control relay in parallel with the 60B00311-2 door restraint solenoid, the actual electrical loads used in the B-747 cargo door latch actuator control circuit. A single momentary contact of a bare 28VDC power wire, with a bare wire connecting to the relay of the solenoid, showed small pithead area developed at the point of wire contact that was visible without magnification.

Wire Examination Procedure:

All of the recovered wires were examined in the Safety Board's

Materials Laboratory on a mylar sheet to simulate their installed positions. Labels were used to identify the coded wires using the manufacturer's original wire identification numbers imprinted on each wire's insulation. Wire pairs for direct electrical short circuiting were located in two common wire bundles installed on the cargo door. One common wire bundle was associated with the P3 plug connector, the other with the P4 plug junction box. The wire bundles were examined visually for areas of obvious insulation damage. Each individual wire was also examined with a stereo-microscope. Representative wire damage features were photographed.

Wire Damage Found:

Seven wires numbered 101-20, 102-20, 105-20, 107-20, 108-20, 122-20, and 135-20 had visible damage located near a 3.8 inch position as measured from the P3 plug pin tips. This common position on the wire corresponds to a 360-degree loop in the wire bundle, which is located immediately below the junction box. Figures 18 and 19 show typical wire damage. Wire 122-20 had an open insulation area approximately 0.25 inch long. The other four wires had flattened insulation damage areas.

In the P4 plug connector wire bundle, three wires displayed insulation damage. Wires 113-20, 121-20, and 124-20 had transverse insulation nicks, which exposed bare conductors. All three had insulation nicks 3 inches from the P4 plug pin tips; wires 121-20 and 124-20 had additional insulation nicks 34 inches from the plug pin tips. The two P4 insulation damage locations corresponded to wire bundle clamp positions.

1.16.3 Pressurization System

The pressure relief valves located on the left side of the fuselage in the forward cargo compartment were removed from the airplane and subjected to bench tests at the UAL maintenance facility in San Francisco, California. No significant anomalies were discovered and both valves performed within specified tolerances.

1.16.4 General Inspection of Other UAL Airplanes

During the on-scene phase of the investigation, the Safety Board investigators examined six other B-747 airplanes while they were on the ground at HNL (four UAL airplanes and two operated by other carriers) to observe routine cargo door operations and to assess the condition of latching components. Generally, the door operations were normal. During the examination of latch pins on these airplanes, it was noted that most had a smooth wear ridge at the 9:00 position (looking forward) or were undamaged. All wear areas on the pins were smooth.

During electrical operation of the aft cargo door on one of the other UAL B-747 airplanes (N4718U), the pull-in hooks did not pull the door fully closed and the latch cams completed the closure. During operation of the latch cams, the bottom of the door moved, first circumferentially downward and then inboard. This additional movement was approximately 1/4 inch. A definite "thunking" noise was discernible as the door moved to its closed position at the end of cam rotation. On one occasion, the door would not open under electrical power. The door was "kicked" by a UAL mechanic, power was reapplied, and the door opened properly. Examination of the door by UAL mechanics, disclosed that the riveted plate holding the aft pull-in hook switch striker was loose.

All eight lower latch pins for the forward cargo door on N4718U exhibited a smooth ridge near the 9:00 position. Pins No. 1 and 2 also showed a smooth ridge at the 6:30 position with a smooth wear area between the 6:30 and 9:00 position. The forward and aft midspan cams of both forward and aft cargo doors had a heavy gouge mark corresponding to the end of the midspan latch pin. N4718U was subsequently removed from service for repair of the aft cargo door latching mechanisms.

1.17 Additional Information

1.17.1 Previous Cargo Door Incident

On March 10, 1987, a Pan American Airways B-747-122, N740PA, operating as flight 125 from London to New York, experienced an incident involving the forward cargo door. According to Pan Am and Boeing officials who investigated this incident, the flightcrew experienced pressurization problems as the airplane was climbing through about 20,000 feet. The crew began a descent and the pressurization problem ceased about 15,000 feet. The crew began to climb again, but about 20,000 feet, the cabin altitude began to rise rapidly again. The flight returned to London.

When the airplane was examined on the ground, the forward cargo door was found open about 1 1/2 inches along the bottom with the latch cams unlatched and the master latch lock handle closed. The cockpit cargo door warning light was off.

According to the persons who examined the airplane, the cargo door had been closed manually and the manual master latch lock handle was stowed, in turn closing the pressure relief doors and extinguishing the cockpit cargo door warning light. Subsequent investigation on N740PA revealed that the latch lock sectors had been damaged and would not restrain the latch cams from being driven open electrically or manually. It was concluded by Boeing and Pan Am that the ground service person who closed the cargo door apparently had back-driven (opened) the latches manually after the door had been closed and locked. The damage to the sectors, and the absence of other mechanical or electrical failures supported this conclusion.

Further testing of the door components from N740PA and attempts to recreate the events that led to the door opening in flight revealed that the lock sectors, even in their damaged condition, prevented the master latch lock handle from being stowed, until the latch cams had been rotated to within 20 turns (using the manual 1/2 inch socket drive) of being fully closed. A full cycle, from closed to open, is about 95 turns with the manual drive system.

1.17.2 FAA Surveillance of UAL Maintenance

The Denver, Colorado, FAA Flight Standards District Office (FSDO) holds the operating certificate for United Airlines, Inc. The FAA FSDO in San Francisco, California, has the primary surveillance and oversight responsibility for UAL maintenance.

The FAA's PMI has the responsibility to oversee an airline's compliance with Federal Regulations with respect to maintenance, preventive maintenance, and alteration programs. The PMI determines the need for, and then establishes work programs for, surveillance and inspection of the airline to assure adherence to the applicable regulations. A portion of the PMIs position description reads as follows:

Provides guidance to the assigned air carrier in the development of required maintenance manuals and recordkeeping systems. Reviews and determines adequacy of manuals associated with the air carrier's maintenance programs and revisions thereto. Assures that manuals and revisions comply with regulatory requirements, prescribe safe practices, and furnish clear and specific instructions governing maintenance programs. Approves operations specifications and amendments thereto.

Determines if overhaul and inspection time limitations warrant revision.

Determines if the air carrier's training program meets the requirements of the FARs, is compatible with the maintenance program, is properly organized and effectively conducted, and results in trained and competent personnel.

Directs the inspection and surveillance of the air carrier's continuous airworthiness maintenance program. Monitors all phases of the air carrier's maintenance operation, including the following: maintenance, engineering, quality control, production control, training, and reliability programs.

At the Safety Board's public hearing on this accident, the PMI for United Airlines at the time of the flight 811 accident stated that he was trained as an FAA air carrier inspector and had been assigned to United Airlines since November 25, 1985. In addition to attending the normal FAA indoctrination course, he had received training in accident investigation, compliance enforcement, nondestructive testing, enforcement, and composite materials. To qualify for the position of PMI, he had completed a 3-week management training course at Lawton, Oklahoma. This was supplemented by a 2-week course on management training systems.

According to the PMI, FAA surveillance of UAL B-747 maintenance activities was organized around the daily work schedule of the FAA air safety inspector, specifically assigned to the UAL B-747 fleet by the PMI. The schedule for surveillance is normally prepared a year in advance by the FAA computerized Work Planning Management System (WPMS). Each FAA inspector is assigned specific responsibilities in the surveillance and monitoring of the airplane fleet to which he is assigned.

The PMI stated that assigned inspectors conducted surveillance of the UAL airplanes while they were in light or heavy maintenance and when they were released to service or in the process of preparing for a flight. Postflight surveillance was also performed. He said, as a routine, the inspectors visually inspected the airplanes and reviewed the airplane log records either during en route checks, while in flight, or upon termination of various flights. He said that inspectors conduct spot ramp inspections; however, they do not routinely observe ramp service operations as part of the surveillance program.

He said that FAA inspectors are not required to inspect the airplanes, but merely are to observe ramp service activities. Deficiencies or malfunctions were to be noted. The assigned inspector or the PMI would then report these observations to the

UAL quality assurance liaison person or directly to UAL management.

The PMI stated that the FAA had conducted five special surveillance inspections of UAL in the previous 3 years and 5 months. The last special inspection, an MEL Survey Inspection, was completed in 1988. That inspection primarily addressed how many deferred maintenance items were being carried or deferred on each aircraft during a specified time period.

The PMI stated that his office does not approve the method by which the carrier complies with an AD, unless specified in the AD. However, a scheduled surveillance method was in place to review the carrier's AD compliance process and the ADs applicable to certain fleets. Each assigned inspector had a schedule for performing this oversight in his work program. The PMI or his staff review a monthly report from the carrier listing ADs applicable to a particular fleet and their compliance. The FAA's surveillance of the carrier's AD compliance process involved a review of this list, not actual shop visits to verify compliance.

The inspector assigned to the UAL B-747 fleet stated that approximately 30 percent of his time was spent on actual ramp maintenance surveillance. Other activities included: en route inspections, station inspections, meetings, classes and administrative paper work. Spot ramp inspections were scheduled as a normal routine, as well as by mandate in a particular AD.

The PMI stated that foreign contract maintenance bases were inspected once a year at a minimum. The PMI had the prerogative to use geographical surveillance inspectors (inspectors from other FAA offices), or inspectors from his office more familiar with UAL maintenance procedures to conduct inspections or investigations.

The PMI and the B-747 maintenance inspector assigned to UAL testified that, prior to this accident, they were not aware of any problems involving the operation of B-747 cargo doors, including the problems reported with N4713U during December 1988. The PMI testified that he could always use more inspectors to "conduct more in-depth surveillance and monitor UAL's fleet more adequately."

The extensive documentation of maintenance performed on UAL B-747 airplanes was forwarded to the PMI's official library by US mail. The data were ultimately channeled to the B-747 maintenance inspector. The PMI and maintenance inspector testified that the voluminous paperwork and work schedules precluded their monitoring the information to determine trends on problem areas.

1.17.3 Corrective Actions

On March 31, 1989, the FAA issued telegraphic (AD) ADT 89-05-54. This AD superseded AD 88-12-04 and required certain procedures to be accomplished when operating the cargo doors. These included: confidence checks of the door mechanical and electrical systems, inspections of the door locking mechanisms, and repairs if necessary. The AD also accelerated the schedule for terminating action to place steel doublers on the latch lock sectors, and it reinstituted the procedures for using the eight view ports to verify the position of the latch cams, after the door is latched and locked.

The FAA, in conjunction with the Air Transport Association, the manufacturers, and other interested parties, are collectively working to address the human factor issues in the readability and understandability of ADs and SBs by line maintenance personnel. They are also reviewing the entire range of design, maintenance, and operation of outward opening doors to develop advisory information for pertinent parties.

FAA representatives stated at the Safety Board's public hearing that the FAA is increasing their operations and airworthiness inspector staffing by approximately 1,000 new hires in the next 3 fiscal years.

The PMI for UAL at the time of the accident stated at the Safety Board's public hearing that, as a result of the accident, "we have intensified our surveillance on the cargo door activities to the point where the assigned inspectors and inspectors who are not assigned to that particular fleet, 747s, are doing night surveillance, early morning surveillance, and we have intensified our surveillance on the cargo door in watching the operation of the cargo door to comply with the Airworthiness Directive."

On August 23, 1989, the Safety Board issued three safety recommendations (A-89-92 through -94) to the FAA. The recommendations urged the FAA to:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams.

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently.

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions.

Section 4.0 contains the FAA's response to the recommendations and the status of the followup actions.

On October 12, 1989, the FAA issued NPRM 89-NM-148-AD, which proposed the amendment of ADT-89-05-54. The proposed revisions would require modification of the warning systems for the forward and aft cargo door, and the main deck cargo door, if installed. The modifications would provide visual warnings to flightcrew and ground crew when the doors are not fully closed, the latch cams are not rotated to the closed position, or the lock sectors are not in the locked position. Further, the source for the warning signal would monitor the position of the latch cams. Public comments for the NPRM were due by December 27, 1989.

Boeing has completed tests that have verified the integrity of the upgraded latch lock sectors to prove that the latch cams cannot be back-driven through the lock sectors mechanically or electrically. Boeing also has been conducting tests on the B-747 cargo door to evaluate the effects of unrepaired damage and abuse on the latch/lock system. The tests, which determined the allowable damage limits on the latch lock system and mechanism support structures, were completed in March 1990. Additionally, Boeing conducted tests to evaluate any unlatching tendencies under cabin pressure loads. These tests were completed in November 1990 and included the measurement of loads in the latch system as the latch cams are rotated incrementally from the fully latched position to the unlatched position under pressurization loads.

The first series of tests included electrical backdriving of the latch cams into the lock sectors (both steel and steel reinforced were tested) with a modified latch actuator (the maximum output torque of the modified latch actuator was roughly twice that of a normal, torque-limiting latch actuator.) During these tests, the maximum cam rotation was 22.2 degrees against steel reinforced lock sectors and 18.8 degrees against the all-steel lock sectors.

During the second set of tests, which measured the effects of internal pressure loads on partially unlatched cams, it was discovered that pressurization did not create any significant loads in the latch mechanism with the door fully closed and the latch cams positioned up to 45 degrees from the fully latched position.

Both series of tests show that if the latch cams were somehow electrically backdriven by a latch actuator that had no torque-limiting ability, the steel or steel-reinforced lock sectors would limit the amount of cam rotation such that the partially unlatched cams would still prevent pressure loads from forcing the door open.

1.17.4 Boeing 747 Cargo Door Certification

Title 14 CFR 25.783, Amendment 25-15, effective October 24, 1967, was the original certification basis for Boeing 747 cargo doors. Specifically, Part 25.783(e) and (f) applied to doors for which the initial opening movement is outward (non-plug type doors). Those rules specified that:

(e) There must be a provision for direct visual inspection of the locking mechanism by crewmembers to determine whether external doors, for which the initial opening movement is outward (including passenger, crew, service, and cargo doors), are fully locked. In addition, there must be a visual means to signal to appropriate crewmembers when normally used external doors are closed and fully locked.

(f) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure.

Amendment 25-23, effective May 8, 1970, added the following text to paragraph (f): "...or failure of a single structural element." Amendment 25-23 did not apply to the initial certification basis for the B-747.

Amendment 25-54, effective October 14, 1980, expanded Part 25.783 (e), (f), and (g) to read:

(e) There must be a provision for direct visual inspection of the locking mechanism to determine if external doors, for which the initial opening movement is not inward (including passenger, crew, service and cargo doors), are fully closed and locked. The provision must be discernible under operational lighting conditions by appropriate crewmembers using a flashlight or equivalent lighting source. In addition, there must be a visual warning means to signal the appropriate flight crewmembers if any external door is not fully closed and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed and locked indication is improbable for doors for which the initial opening movement is not inward.

(f) External doors must have provisions to prevent the initiation of pressurization of the airplane to an unsafe level if the door is not fully closed and locked. In addition, it must be shown by safety analysis that inadvertent opening is extremely improbable.

(g) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure or failure of a single structural element.

At the Safety Board's public hearing, the FAA and the Boeing representatives acknowledged that during certification of the Boeing 747 the loss of a lower lobe cargo door was not considered to be an "acceptable event." Therefore, redundant mechanical devices and operational procedures were incorporated to protect against loss of the door in flight. Initial FAA certification approval of the Boeing cargo door design and operation included the installation and use of eight view ports on the door for ground personnel to observe the alignment of paint stripes on the latch cams with arrows on the latch pin support fitting, thereby complying with the requirements of 14 CFR 25.783(e), which require a ". . . provision for direct visual inspection of the door locking mechanism ...," to determine if the door is closed and locked.

In correspondence dated November 24, 1969, and May 15, 1970, Boeing requested that the FAA approve the use of a visual inspection of the pressure relief doors of the cargo doors as an alternate method for determining the locked condition of the door. This design also provided a visual indication to the flightcrew via the cargo door warning light on the flight engineer's warning light annunciator panel. Boeing's request stated that this means of compliance "... provides a simpler check whereby only the pressure relief doors need to be checked ...," by the ground crew, in lieu of actually observing the latch cams and alignment stripes through the eight view ports. Boeing also provided a Failure Analysis to support its request. The conclusion of the Failure Analysis reads: "Any failure, mechanical or electrical, within the latching system which results in open latches will always be indicated by open pressure relief doors." The FAA approved their alternate method on June 8, 1970. Subsequently, the procedures for maintaining the view ports and the alignment stripes in a serviceable condition, which had been included in the UAL MM were removed. Also, the provision for observing the alignment stripes as part of the door closing procedure were not required for B-747 airline operators.

At the Safety Board's public hearing, a Boeing witness, in answer to a question relative to Boeing's possible consideration of modifications or design changes to the B-747 cargo door indication system to install a position switch directly on the latch cams, stated, "We are looking into the best possible designs that would provide indication on the cams and door closed, both exterior to the aircraft and in the flight deck. We are going to look into that.... However, we want to achieve the required indication in the most reliable method and we have not yet determined what that will be, or any changes (that) are necessary, or would make it more reliable than the way the system operates currently."

1.17.5 Advisory Circular AC 25.783-1

Advisory Circular (AC) 25.783-1 was issued December 10, 1986, on the subject, "Fuselage Doors, Hatches, and Exits." AC 25.783-1 set forth the acceptable means of compliance with the provisions of Part 25 of the FAR's dealing with the certification of fuselage doors. Specifically, it provides for an acceptable method for showing compliance with the provisions of Part 25.783, Amendment 25-54.

Neither the provisions of Part 25.783, Amendment 25-54, nor the guidelines of AC 25.783-1 were part of the certification basis of the Boeing 747.

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.

The airplane was being prepared for flight at the UAL maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.

The aft cargo door was cranked open manually, the C-288 circuit breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident. With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage. UAL personnel notified the Safety Board of the occurrence, and the airplane was examined at JFK by representatives of the Safety Board, United Airlines, and Boeing. After the wires in the damaged area were electrically isolated, electrical operation of the door was normal when the door was unlocked. When the door was locked (master latch lock handle closed), activation of the door control switches had no effect on the door. This indicated that the S2 master latch lock switch was operating as expected (removing power from the door when it was locked). After the on-site examinations, the wiring bundle was cut from the airplane and taken to the Safety Board's materials laboratory for further examination.

The wiring bundle with the damaged wires contained all electric control wires (28 volt DC) and power wires (115 volt AC) that pass between the fuselage and the aft cargo door. From the forward side of the J-4 junction box, the bundle progresses in the forward direction, just above the forward pressure relief door, then upward, following the forward lift actuator arms. The bundle then enters an empty space between two floor beams, where the bundle has an approximate 180-degree bend when the door is closed. From this location, the wiring bundle progresses inboard, through a fore-to-aft intercostal between two floor beams. The wiring bundle then splits, with wires going in several directions.

The bundle is covered by the flexible conduit approximately from the lower end of the lift actuator arms to the fore-to-aft intercostal between the floor beams.

The conduit covering the wiring bundle is intended to prevent the wire bundle from being damaged during opening and closing of the door and during cargo handling operations. The conduit is a sealed flexible interconnector consisting of a convoluted helical brass innercore covered by a bronze braid. The innercore is soldered at every other convolute, and should be capable of withstanding pressures exceeding 1,000 pounds per square inch (psi). Boeing has indicated that the conduit is an evolutionary improvement and that it has been installed on all B-747 airplanes produced since 1981 (from line number 489 on). Airplane N152UA was delivered in April 1987.

Airplanes produced prior to 1981, including N4713U, used a bungee retraction system, to retract the cargo door wire bundle. Guidelines for the replacement of the bungee sys tem with the flexible conduit were covered in Boeing Service Bulletin 747-752-2170, dated August 1981. The service bulletin was prompted by reports that the wire bundle bungee retraction system had not retracted the wire bundle sufficiently to prevent trapping the bundle between the cargo door and the door frame. UAL did not perform the retrofit on N4713U, which was line number 89, nor was the company required to do so.

Examination of the wires in the damaged area on the wiring bundle revealed that four of the wires were similar in appearance, with insulation breaches that progressed through to the underlying conductor. Adjacent to the breach on these four wires, the insulation was blackened, as if it had been burned. Another wire contained an extensive breach but no evidence of burned insulation. The damaged area was located on the bundle at a position approximately corresponding to a conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism. This support bracket was found bent in the forward direction. In addition, mechanical damage was noted on adjacent components in this area.

A second damaged area was noted on the wiring bundle at a position approximately corresponding to the conduit swivel clamp at the elbow between the two arms of the forward lift actuator mechanism. Wires in this area were missing portions of their exterior coating, but no breaches to the underlying conductors were noted.

The exterior braid on the conduit contained minor rub marks and was slightly kinked at a position corresponding to the area on the wires with breached insulation. Additional examinations revealed that the innercore of the conduit contained multiple circumferential cracks in the areas corresponding to the damage areas on the wires. The cracks were in the convoluted innercore directly adjacent to the inside diameter of the conduit.

The lock sectors, latch cams, and latch pins from the aft cargo door were examined on the incident airplane and were generally in excellent condition. There was no evidence to suggest that the cams had ever been electrically (or manually) driven into or through the lock sectors.

Boeing also informed the Safety Board that, in May of 1991, a B-747 operated by Quantas was found to have chafing of the wires in the wire bundle to the aft cargo door. This airplane also had a flexible conduit protecting the wires, and the chafing was located approximately at the standoff pin on the bracket at the upper arm of the forward lift actuator.

The Safety Board determined that the chafing of the wires on the airplane involved in the JFK occurrence was caused by, or was greatly accelerated by, the circumferential cracks in the conduit and that the cracks in the conduit were caused either by repeated flexing of the conduit as the cargo door opens and shuts or by unusual stresses on the conduit generated concurrently with damage to the conduit guide bracket and attached standoff pin on the upper end of the forward lift actuator upper arm.

A portion of the wire bundle for the forward cargo door on many B-747 airplanes is also covered by a flexible conduit that is very similar to the conduit for the aft cargo door. However, there are substantial differences between the orientation of the flexible conduits for the two doors, and the Safety Board has not become aware of problems associated with the flexible conduit for the forward door.

Nevertheless, because of the concerns about the chafed wires and possible electrical short circuits, on August 28, 1991, the Safety Board recommended that the FAA:

Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between the fuselage and aft cargo door to require an expedited inspection of:

(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test method or visual examination);

(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;

(3) the flexible conduit for the presence of cracking in the convoluted innercore.

Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an appropriate cyclic interval. (Class II, Priority Action) (A-91-83)

Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in A-91-83. (Class II, Priority Action) (A-91-84)

The FAA responded to these safety recommendations on November 1, 1991, stating that it agreed with the intent of the recommendations and that the issuance of an NPRM was being considered to address the issues in the safety recommendations. The Safety Board replied on November 27, 1991, classifying each of the recommendations as "Open--Acceptable Response," pending the completion of the rulemaking process. Since that exchange of correspondence, the FAA has published an NPRM which is now being reviewed by the Safety Board. Safety Recommendations A-91-83 and -84 will continue to be classified as "Open--Acceptable Response" until an acceptable final rule is published.

2. ANALYSIS

2.1 General

This analysis is based on the facts gathered during the initial investigation phase, without the benefit of the evidence from the cargo door, updated to include the findings from the subsequent examinations of the door after it was recovered.

The flightcrew and flight attendants were trained and qualified in accordance with the applicable Federal regulations and UAL standards and requirements. There were no air traffic control or weather factors related to the cause of this accident.

The airplane had been properly maintained, with the exception of certain requirements pertaining to the cargo doors. Those discrepancies will be discussed in detail in this analysis.

The evidence examined by the Safety Board during its investigation revealed conclusively that this accident was precipitated by the sudden loss of the forward lower lobe cargo door, which led to an explosive decompression. There was no evidence of preexisting metal fatigue or corrosion in the structure surrounding the cargo door. All breaks were the result of overload at the time of the loss of the door. There was no evidence of a bomb or similar device that caused an explosion on the airplane.

The explosive decompression of the cabin when the cargo door separated caused the nine fatalities. The floor structure and seats where the nine fatally injured passengers had been seated were subjected to the destructive forces of the decompression and the passengers were lost through the hole in the fuselage. Their remains were not recovered. Most of the injuries sustained by the survivors were caused by the events associated with the decompression, such as baro-trauma to ears, and cuts and abrasions from the flying debris in the cabin. Other injuries were incurred during the emergency evacuation.

The loss of power to the Nos. 3 and 4 engines was caused by foreign object damage when debris were ejected from the cargo compartment and cabin during the explosive decompression. The debris also caused damage to the right wing leading edge flap pneumatic ducting, and other areas along the right side and empennage of the airplane.

During the approach to HNL, all of the leading edge flaps had extended, except the outboard sections 22 through 26 on the right wing. The reason that they failed to extend probably was the damage to the pneumatic duct caused by the ejected debris. The pneumatic pressure probably was too low to actuate the most outboard flaps to the extended position.

The failure of the flightcrew and passenger oxygen systems was caused by structural deformation and damage to the supply lines in the area adjacent to the cargo door and failed fuselage structure.

The Safety Board's analysis of this accident concentrated on the reasons for the loss of the cargo door and the events that led to its loss in flight. The analysis included an evaluation of the design, certification, and approval processes for the B-747 cargo doors, and the operational, maintenance, and inspection processes for the doors. Also, the analysis included an evaluation of the historical events that had occurred over the past months and years that eventually led to this accident.

2.2 Loss of the Cargo Door

The calculated pressure differential at the time of the loss was about 6.5 psi, which would have exerted a load on a properly closed and locked door that was substantial, but well within design limits.

There was no evidence of a structural problem with the cargo door that could have caused it to fail from metal fatigue or corrosion. Although the cargo door was recovered in two pieces on the floor of the ocean, there was no evidence of a preseparation structural failure of the door. All fractures and damage found on the door were determined to be the result of the sudden opening of the door rather than the cause. The evidence showed that the door was intact when it flew open violently and that its integrity was compromised when it struck the upper fuselage structure and most likely when it struck the water. The fracture in the cargo door occurred just below the midspan latch cams. Paint marks on the outer surface of the door that matched upper fuselage structure paint pattern, damage to the latch pins, pull-in hooks and hook pins, as well as damage to the floor structure near the upper door hinge area were consistent evidence that the door was intact when it flew open.

The evidence was also conclusive that the failure of the door did not result from the failure of the structure surrounding the door. The damage to the cabin floor beam structure, adjacent to the cargo door hinge area, showed that decompression loads in the cabin broke the beams downward when pressure was released from the cargo compartment. The fuselage skin above the door was torn away during the decompression as the door separated violently from the airplane. Unfortunately, the upper skin structure was not recovered from the sea.

There are no reasonable means by which the door could open in flight with the cams properly closed and locked. If the lock sectors were in proper condition, and were properly situated over the closed latch cams, the lock sectors had sufficient strength to prevent the cams from vibrating to the open position during ground operation and flight. Thus, the only ways in which the cargo door could open while in flight involve the placement of the cams in a partially latched or unlatched position. Either the latching mechanisms were forced open electrically through the lock sectors after the door was secured, or the door was not properly latched and locked before departure. Then the door opened when the pressurization loads reached a point at which the latches could not hold.

2.3 Partially Closed Door

Examination of the eight latch pins that had been removed from the lower sill of the forward cargo door revealed smooth wear patterns where the latch cams had normally rotated around the pins. These wear patterns indicate that interference had existed during normal operation between the cams and the pins over an extended period of time. All eight pins also had roughened areas from approximately the 6:15 position to the 7:30 position (clock references are as looking forward, 9:00 being directly inboard). The 7:30 position corresponds closely to the area where the lower surface of the cam first contacts the pin as the door reaches the nearly closed position, before the cams are rotated to the latched position.

The hoop stresses generated by pressurization of the airplane create a bearing load against the cam/pin contacting points. Even if the cams are in the unlatched position, and the airplane is pressurized, this bearing load could act as a frictional latch between the cams and the pins and would tend to keep the door in the closed position.

Transferred cam material and heat tinting of the pin surface was found to extend from the point where the cam-to-pin interface at the near fully open position of the latch cams (7:30 position) to a position corresponding to the bottom of the pin (6:15 position). This evidence was found on the roughened areas on all of the pins. The heat tinting and metal transfer are indicative of the high stress and rapid movement of the cam across the pin when the door separation occurred. Therefore, the location of this evidence indicates the probable location of the cams just before, and at the time of, separation of the door. The Safety Board concludes that these markings and their location on the pins resulted from a very fast, high bearing stress, separation of the cams across the pins, when the cams were in or very close to the unlatched position. Further, examination of the recovered cargo door confirmed that the latch cams were in a nearly unlatched position at the time the separation occurred. The lock sectors were found in the locked position jammed against the cams. Therefore, the cargo door latch cams had been closed, the master latch lock handle had been closed, and the lock sectors had moved to the locked position. Subsequently, the cams had been back-driven to the near-open position, deforming the lock sectors.

The pull-in hooks and pull-in hook pins would also counteract the pressurization loads in the outward direction, providing that the latch cams were not engaged on the latch pins and carrying the pressurization loads. However, Boeing studies showed that the pull-in hooks would fail at a pressure differential of about 3.5 psi, assuming that the cams are in the unlatched position and that there is no bearing load on the pins. Therefore, based on the probable pressure differential of about 6.5 psi just before the door separated, it is concluded that forces other than the pull-in hooks/pins were holding the door closed. Since the flightcrew and passengers reported no pressurization difficulties until the explosive decompression, it is reasonable to conclude that the door was being held closed by the bearing stresses of the cam-to-pin interfaces as well as by the pull-in hooks.

The Safety Board believes that the approximate 1.5 to 2.0 seconds between the first sound (a thump) and the second very loud noise recorded on the CVR at the time of the door separation was probably the time difference between the initial failure of the latches at the bottom of the door, and the subsequent separation of the door, explosive decompression, and destruction of the cabin floor and fuselage structure. The door did not fail and separate instantaneously; rather, it first opened at the bottom and then flew open violently. As the door separated, it tore away the hinge and surrounding structure as the pressure in the cabin forced the floor beams downward in the area of the door to equalize with the loss of pressure in the cargo compartment.

Three possible theories to explain why the latch cams could have been in a partially latched condition during flight are examined: (1) they were never closed fully before the door was "locked" before takeoff. (2) they were backdriven manually after the door had been fully latched and locked or (3) they were back-driven electrically after the door had been fully latched and locked.

2.4 Incomplete Latching of the Door During Closure

The Safety Board considered the possibility that the master latch lock handle had not been closed before the airplane departed the gate, and the possibility that the shrouds recommended by SB-747-52-2097 for the cargo door pressure relief doors were not installed on the forward door. If this were the case, it is possible that this condition allowed the pressure relief doors to be rotated closed when the airplane pressurized.

The Safety Board believes that these events were very unlikely based on the statements of the ramp personnel, line maintenance personnel, and the flightcrew. The ramp and maintenance personnel would have to have missed seeing the master latch lock handle in the unstowed position and the pressure relief doors open before departure. Also, the flightcrew would have to have missed seeing the cockpit cargo door warning light indication.

The examination of the recovered forward cargo door did not provide confirmation that the pressure relief door shrouds were actually installed on the forward door, although UAL records showed that they had been installed on both cargo doors of N4713U, in accordance with SB-747-52-2097. However, the shrouds were found not to be installed on the aft door, contrary to UAL records, and therefore may not have been installed on the forward door. Without the shrouds, the pressure relief doors could have rotated shut during the pressurization cycle. Because the closure of the pressure relief doors would back-drive the lock sectors, this scenario would presume previous damage to the sectors, which would permit the sectors to move over the unlatched cams.

Before recovery of the cargo door, the Safety Board believed that the lock sectors might have been damaged some time prior to the accident flight to the extent that they could have been moved to the locked position even though the latching cams were not fully closed.

During closure of the door, the latch actuator may not be able to rotate the cams to the fully closed position because of excessive binding forces between the latch cams and pins. This could occur if the cargo door is misaligned (out of rig) or if the pull-in hooks do not pull the door in far enough to properly engage the cams around the pins. There is sufficient evidence of wear on the pins and from the previous discrepancies with the door to indicate that the door was misaligned and not properly rigged.

The smooth wear areas found on the pins from N4713U are signs of heavy contact (interference) between the cams and pins during numerous past closings and openings of the door. This wear, other evidence from the door, and the maintenance history of the door, suggest strongly that the door was out of rig during the weeks and months before the accident.

The wear pattern damage to the pull-in hook pins also showed interference during the normal ground operations prior to the accident. This is further evidence of an out-of-rig door. It is also possible that the excessive binding force acting over a period of time precipitated a failure of the latch actuator. Regardless of the reason(s), the conditions of the latch pins and pull-in hook pins showed prolonged out-of-rig operation.

Most of the previous discrepancies with the forward cargo door on N4713U during December 1988 involved problems with closing the door electrically. These problems always occurred when the airplane was fully or nearly fully loaded, just before departure. The trouble-shooting and corrective actions by UAL maintenance, which on some occasions only involved cycling the door and finding it functional, were performed when the airplane was not fully loaded, during overnight maintenance inspections. The flexing of the fuselage with a full load of fuel, cargo, and passengers could have caused distortion of the door frame and resulted in misalignment between the cams and pins. In this case, the pull-in hooks may not have pulled the door fully in before the cam actuator attempted to latch the door. The wear evidence on the latch pins from N4713U suggests that this event had been occurring before the accident.

Safety Board investigators also witnessed this event during inspection and operation of the aft door on another UAL B-747, N4718U, in HNL. It was noted that the door on N4718U was not being pulled in fully by the pull-in hooks, so the latch cams completed the closing cycle with significant interference and "thunking" sounds. In fact, the out-of-rig door on N4718U failed to operate electrically at one point during its examination.

By design, any attempt to close the master latch lock handle and move undamaged lock sectors into place would not be successful unless the cams were rotated to near the fully latched position. This condition was substantiated by Boeing tests. Even with severely damaged lock sectors, as found on the Pan Am B-747, if the cams were more than 20 turns from the fully closed position on the Pan Am airplane, the master latch lock handle could not be stowed. Examination of the recovered N4713U door indicated that the door lock sectors were generally intact and jammed against the cams that had been back-driven into the lock sectors. Consequently, if the latch cams had been in the nearly unlatched position as found on the recovered door at the time the cargo handler attempted to move the master latch lock handle, the interference between the cams and the lock sectors would have prevented the master latch lock handle from moving to the closed position. Furthermore, this interference would have prevented the closure of the pressure relief doors as the airplane pressurized, irrespective of the possible absence of the pressure relief door shrouds. This conclusion is supported by extensive testing of the latch/lock mechanisms following the recovery of the door.

Therefore, based upon the examination of the lock sectors and the tests that were conducted, the Safety Board concludes that the latches were fully closed and that the locking handle was placed in the stowed position after the cargo was loaded.

2.5 Manual Unlatching of the Door Following Closure

It is possible that the cams could have been manually back-driven (about 95 turns) after the door had been secured; however, the UAL ramp personnel involved with dispatching the flight stated that the door was operated electrically. Furthermore, it seems unlikely that the ramp personnel would have driven the manual latch actuator 95 turns toward the open position after the door was fully latched.

The placard/seal located over the latch actuator manual drive on the recovered door was found with damage that initially suggested it had been previously compromised. If this were the case, it would indicate that someone may have used the manual drive to operate the door latches on an earlier flight or possibly immediately before the accident flight. However, the Safety Board believes that an insertion of a screw driver and rotation of the plate retaining screw would have caused rotational tearing around the circumference of the screw head. There was no such tear. Rather, the damage to the placard/seal was more consistent with that which would occur from impact and underwater pressure forces. Therefore, the evidence strongly suggests that manual operation of the latch actuator by ground service personnel after the door was properly closed is unlikely.

2.6 Electrical Unlatching of the Door Following Closure

2.6.1 Conditions or Malfunctions Required to Support Hypothesis

It was determined in 1987, after the Pan Am incident, that the locking sectors for B-747's, including those installed on N4713U, could be overcome by the force of the latch cam actuator, electrically or mechanically. If the latch cam actuator had been energized for some reason with the originally designed unstrengthened lock sectors installed, the latch actuator motor was capable of driving the latch cams open through properly positioned lock sectors, whether they were damaged or undamaged. Therefore, the locking sectors installed as original equipment for B-747's, and those installed on N4713U, would not perform the locking function as intended by the design. They would not "lock" the latches in place as implied by the name "lock sectors."

The investigation has shown that there are several conditions that must be met before the latch actuator will electrically drive the latch cams to the unlatched position on the B-747 after the door has been properly closed and locked. First, the ground handling power bus must be energized by having external power connected, or the APU must be operating and the APU generator field switch in the cockpit must be set to power the bus via the No. 2 ground handling power relay. Second, the air/ground relay must be in the "airplane on the ground" position. These two conditions are normally present when the airplane is on the ground before engine startup. Third, there must be a signal to the door open position in one of the two door open/close switches. Fourth, the S2 master latch lock switch, which cuts off power to the door actuators when the handle is stowed, must sense "not locked."

Therefore, it would take several independent conditions and some failures to provide for electrical power to be available to drive the door open electrically once it is closed and locked. The number of conditions and combinations depend upon the phase of operation of the airplane.

While the airplane was on the ground, before engine startup, with the master latch lock handle stowed, the external power connected (or with the APU running), and the ground handling bus powered, an "open" signal to the cargo door latch actuator would have occurred if any of the following combinations of conditions had been met: (1) a malfunction of the S2 master latch lock switch and the placement by someone of one of the door control switches to the "open" position; (2) a malfunction of the S2 master latch lock switch and certain short circuits; or (3) a two-wire short circuit path consisting of wire 101-20 shorting with any of the following wires: 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

While the airplane was on the ground, after engine startup, and with the cargo door master latch lock handle stowed and the APU running, an "open" signal to the door latch actuator would have occurred if the following conditions had been met: (1) an energized ground handling bus resulting from the flightcrew reenergizing the APU generator field or failure of the No. 2 ground handling power relay; (2) a malfunction of the S2 master latch lock switch; (3) a malfunction of either of the door open/close switches or the placement of the switch in the "open" position by someone. An "open" signal would have also occurred had certain wire short circuits been present with condition (1) alone, or with conditions (1) and (2).

Regardless of the cause, electrical power to the latch actuator would have had to persist for the time necessary to rotate the cams to the nearly open position. If the electrical power had been applied for a longer time, the latch cams could have opened fully and caused the pull-in hooks to rotate open, a situation that would have prevented the airplane from pressurizing after takeoff. However, it is also possible that the latch actuator stalled before they opened fully because of the forces of the interference between the lock sectors and the cams as they were back-driven.

After takeoff, electrical operation of the door latch actuator would have required: (1) the APU to be running; (2) malfunction of the air/ground relay, (3) malfunction of the No. 2 ground handling power relay; and (4) malfunction of the S2 master latch lock switch and one of the cargo door open/close switches or a short circuit of the aforementioned wire pairs. Although the flightcrew could conceivably energize the ground handling bus from the APU by actuating the APU generator "field" switch, there was no evidence that they did so.

Thus, regardless of the phase of operation, either a wiring short circuit or a failure of the S2 master latch lock switch combined with some other anomaly or action would be required to cause the latches to move toward the open position. Before the recovery of the door, the Safety Board was able to examine two of the electrical relays and the door open/close switches from N4713U that would have to have failed to allow electrical operation of the cargo door in flight, with the APU running. These were the No. 2 ground handling power relay, the air/ground relay, and the internal and external door open/close switches. The examination of the relays and switches revealed no evidence of a single fault or conditions that might have caused an intermittent failure mode. The arcing noted on the No. 5 terminal of the outside door control switch was on the door "close" circuit and could not have been related to a short to the open mode. Further, because the flightcrew did not note a cargo door warning light, and the fact that the airplane was able to be pressurized, confirms that the master latch lock handle was in the closed position before takeoff. This position would actuate the master latch lock switch to disconnect power to the door opening actuators.

According to the flightcrew testimony and the pilots' comments recorded on the CVR during the flight, the APU was shut down shortly after takeoff and remained in that condition. Engine generators cannot power the ground handling bus from which the cargo door actuating mechanisms are powered. Once the APU was shut down, there was no power available to any of the cargo door electrical components. Therefore, an electrical actuation of the latch cam actuator at the time of the door loss was not possible.

The Safety Board believes that there is another reason why the opening of the door could not have been caused by electrical actuation shortly before the explosive decompression. Because the door carries the structural loads (hoop stresses) through its hinge and latches, the latch cams would be heavily loaded against the latch pins when the airplane was pressurized to the 6.5 psi differential pressure that was calculated to have been present at the time of the decompression. In that case, the torque limiter within the actuator would probably slip well before the actuator could achieve the torque necessary to drive the cams open against the frictional lock produced by the high bearing stresses resulting from pressurization.

2.6.2 Electrical Switches and Wiring Examinations--Recovered Door

All cargo door position sensing switches (S2 through S9) were found installed in their proper position. The cargo door recovery team found the S2 master latch lock switch in the "not-locked" position immediately after the door was aboard the recovery ship. This position would be consistent with the master latch lock handle being open. Further tests of the S2 switch revealed damage that probably resulted from the pressures under the sea. The only notable exception was a broken internal bracket that may have affected the operation of the switch prior to the accident. Other similar switches did not exhibit this failure. It is therefore possible that the S2 master latch lock switch failed prior to the accident, allowing more possibilities for electrical short circuits to power the latch actuator. Nevertheless, despite extensive testing, it could not be determined whether the S2 switch was functional before the accident.

The examination of 35 wires that remained with the recovered cargo door revealed several areas of damaged insulation that could have permitted an electrical short circuit to power the latch actuator. However, no evidence was noted of arcing that was indicative of short circuits. Furthermore, a significant number of the wires that had the potential for allowing for short circuits to power the latch actuator were not recovered. Testing conducted by Boeing and by UAL was inconclusive regarding whether a short circuit would have left detectable evidence of arcing. Therefore, the Safety Board was unable to determine whether the latch actuator was inadvertently powered by a short circuit in the cargo door wires.

The incident involving a UAL Boeing 747 at JFK Airport on June

13, 1991, confirmed that electrical short circuits in the cargo door wiring could cause the door to open. In this case, the short circuits were in the fuselage-to-cargo door wiring bundle where the bundle was covered by a flexible conduit. Although N4713U did not have a flexible conduit installed at the forward door position, its wiring was routed over the top of the door hinge where exposure to damage could occur. That portion of the wiring from N4713U was not recovered from the sea. The wires located at the door hinge area are more susceptible to in-service damage from movement during the open/close cycle, as compared with the wires mounted on the door that are normally static.

Following the incident at JFK, UAL directed that the circuit breaker that terminates power to the cargo doors be pulled after the door is closed and before departure of every B-747 flight. UAL obtained approval for this practice from the FAA and requested Boeing and the FAA to make such a practice part of the approved manual for the airplane. Neither Boeing nor the FAA acted on UAL's request.

Nevertheless, the Safety Board believes that the FAA should initiate rulemaking to include design considerations for nonplug transport category aircraft cargo doors that would deactivate the electrical circuitry to the door actuators after the doors are closed and locked. The catastrophic nature of the loss of a cargo door dictates the need to provide additional redundancies and fail-safe features in the door mechanisms to supplement the hardware safety features.

2.6.3 Possibility of Electrical Malfunction

Due to the lack of physical evidence, the Safety Board was unable to conclude that an electrical short caused the cargo door actuator to move the latch cams to the nearly open position, allowing the door to separate when the cabin pressure exceeded the load-carrying capability of the door latches. Neither could this possibility be eliminated. A momentary actuation of the door open switch by someone on the ground in the presence of a faulty S2 switch could also have caused the latches to open through the closed lock sectors. However, no evidence has been found that someone actuated the switch after the door was initially closed and locked.

The Safety Board concludes that it was not possible for the cargo door to have opened electrically at the time of the loss of the door. There was no power to the ground handling bus to power the actuator, even if there had been an electrical short. Further, the Safety Board concludes that it is highly improbable that an electrical short could have caused the latches to open after the airplane was airborne. Although the ground handling bus could conceivably have been powered, failures of other components that were tested as functional would also have been necessary.

The Safety Board believes that the electrical operation of the latch actuators from the fully closed and locked position most likely occurred before the engines were started when the ground handling bus was powered. The precise source of the electrical actuation could not be determined. Once the engines were started, the possibility of an electrical short decreases significantly because the ground handling bus is disengaged from the APU when the engines start. There was no evidence that the flightcrew reengaged the ground handling bus.

Because the preaccident condition of the S2 master latch lock switch could not be determined, it could also not be determined whether its proper functioning would have prevented the accident. The Safety Board did not determine whether damaged cargo door wires or a malfunctioning S2 switch could have been found by UAL maintenance had they been more aggressive in troubleshooting the cargo door problem in the weeks prior to the accident.

2.7 Design, Certification, and Continuing Airworthiness Issues

The Safety Board's analysis of this accident went beyond the conclusions about how the door failed. The Safety Board also examined the initial design and certification of the B-747 cargo door, and the continuing airworthiness system that should have prevented this accident, to identify the breakdowns in this system that led to the accident. As is the case with most aviation accidents, there are many factors that led up to the actual failure of the door on flight 811.

The Safety Board found that there were multiple opportunities during the design, certification, operation, and maintenance of the forward cargo door for N4713U for persons to have taken actions that could have precluded the accident involving flight 811. The circumstances that led to this accident exemplify the need for human factors considerations in the promulgation of regulations, the application of regulatory policies, the design of airplane systems, and the quality of airline operational and maintenance practices.

The first opportunity to prevent this accident occurred during the design and certification of the B-747 cargo door mechanical systems, when the design was chosen and approved, which allowed for the overriding of the lock sectors by either mechanical or electrical actuation. It is apparent that the original design was not tested sufficiently to verify that the locking sectors in fact "locked" the latch cams in the closed position. This shortcoming should have become apparent during the initial certification testing and approval process. Later, it should have become apparent when Boeing applied for, and the FAA granted, an alternative method of compliance with the certification regulations (25.783 [e]) that permitted the elimination of operational practices that included a visual verification of the cargo door latch positions via view ports in the doors.

The failure mode analysis performed by Boeing, and the FAA's acceptance of its content in granting the exemption, probably were based on the assumption that the lock sectors would always prevent the master latch lock handle from being in a stowed position when the latch cams were not fully closed. This assumption was not valid, as evidenced by the findings in 1987 following the Pan Am incident that the lock sectors could not prevent the latch cams from being driven from the fully latched position with the master latch lock handle stowed, while a false indication was provided to the flightcrew that the cargo door was properly latched and locked. At the time that Boeing sought approval of the alternative compliance, Boeing and the FAA should have reviewed the design and required testing of the door latch/lock mechanisms to verify their integrity. Thus, the procedure for direct viewing of the latches via the view ports before the airplane could be dispatched should not have been eliminated without adequate verification that the lock sectors were totally effective.

The next opportunity for the FAA and Boeing to have reexamined the original assumptions and conclusions about the B-747 cargo door design and certification was after the findings of the Turkish Airline DC-10 accident in 1974 near Paris, France. The concerns for the DC-10 cargo door latch/lock mechanisms and the human and mechanical failures, singularly and in combination, that led to that accident, should have prompted a review of the B-747 cargo door's continuing airworthiness. In the Turkish Airlines case, a single failure by a ramp service agent, who closed the door, in combination with a poorly designed latch/lock system, led to a catastrophic accident. The revisions to the DC-10 cargo door mechanisms mandated after that accident apparently were not examined and carried over to the design of the B-747 cargo doors.

Specifically, the mechanical retrofit of more positive locking mechanisms on the DC-10 cargo door to preclude an erroneous locked indication to the flightcrew, and the incorporation of redundant sensors to show the position of the latches/locks, were not required to be retrofitted at that time for the B-747. Of similar concern is the fact that the cargo doors for the L-1011 required redundant latch/lock indication sensors at initial certification, during the approximate same time frame the DC-10 and B-747 were certificated.

More recently, when Boeing and the FAA learned about the circumstances of the Pan Am cargo door opening incident in March 1987, more timely and positive corrective actions should have been taken. The Safety Board believes that the findings of that incident investigation should have called into question the assumptions and conclusions about the original design and certification of the B-747 cargo door, especially the alternative method for verifying that the door was latched and locked that was sought by Boeing and was granted by the FAA. Since a B-747 cargo door opening in flight was considered to be an "unacceptable event", once a door did come open in flight, the FAA and Boeing should have acted much quicker to prevent another failure.

It took nearly 16 months from the date of the Pan Am Incident (March 10, 1987) until the FAA issued AD-88-12-04 (July 1, 1988). And then, the AD allowed 18 or 24 months, depending on the model B-747, from the date of its issuance for compliance with the terminating actions of the AD. The fact that Boeing had issued an Alert SB as a result of the Pan Am incident is an indication of the apparent urgency with which Boeing treated this issue. Alert SB's are issued for "safety of flight" reasons, while regular SB's deal with "reliability" and not necessarily safety of flight items. Despite this, the terminating action, issued as revision 3 to the Alert SB, on August 27, 1987, was not mandated by the FAA for 11 months.

The Safety Board found no evidence that the FAA or Boeing reassessed the original design and certification conclusions regarding the safety of the B-747 cargo door during this period. Several opportunities for preventive action were also missed by UAL during this period. First, UAL delayed the completion of the terminating actions of Alert SB 52A2206 (Rev 3 and AD-88-12-04. In fact, there was no evidence that UAL had intended to comply with the terminating action of the Alert SB, until it was mandated by the FAA.

It is understandable that an airline would not take its aircraft out of service to incorporate revisions that do not appear to be safety critical. Although by definition an Alert SB is safety related, there was no implication from Boeing's and FAA's actions regarding this matter that urgency was required. The airlines rely on the airframe manufacturers and the FAA to evaluate the need for urgent airworthiness actions that might take airplanes out of revenue service. In this case, UAL had scheduled completion of its B-747 fleet modifications in accordance with the terminating actions for AD-88-12-04 before the final allowable date; however, the schedule was based on other heavy maintenance schedules to prevent unnecessary down-time of its airplanes.

UAL personnel stated after the UAL 811 accident that its personnel did not fully appreciate the importance, or safety implications, of the terminating actions, or they would have incorporated the improvements much earlier. The usual difficulties in setting short suspense dates for performing terminating actions in AD's, such as parts availability, did not seem to exist in this case, because the parts were not complex components and probably could have been fabricated fairly quickly in-house by most airlines.

Human performance certainly contributed to UAL's failure to incorporate an important inspection step into its maintenance program as mandated by AD-88-12-04. When UAL obtained an advance draft copy of the forthcoming NPRM that eventually led to the AD, the airline began preparing its work orders to implement the forthcoming the AD requirements into its B-747 fleet (30 airplanes at the time). UAL developed its maintenance work sheets from the text of the draft NPRM, which was virtually identical to the text of the final rule. As a result of a clerical error, one of the important inspection steps required by the AD was omitted.

Apparently, UAL maintenance personnel never compared the work sheets they received with the actual requirements of the AD, or if they did, the omission was not detected. FAA inspectors responsible for oversight of UAL's maintenance program also did not detect this error because normal surveillance of AD compliance merely involved verifying the correctness of UAL's paperwork that listed the applicable AD's and compliance dates. The inspectors did not actually verify UAL's compliance action by shop visits, or by comparison of work sheets with AD provisions. These omissions by the UAL maintenance and quality assurance personnel, and the limitations of the FAA surveillance procedures were probably significant in setting the stage for the events that led to the actual cause of the door separation from N4713U.

Another matter of concern is the quality of UAL's trend analysis program. There was no indication that the repeated discrepancies with the forward cargo door on N4713U "raised a flag" within the UAL maintenance department. A quality assurance or trend analysis program should have detected an adverse trend and should have prompted efforts to resolve the repeated problems. If it had, any faults in the door electrical system or damage to mechanical components might have been detected.

In summary, the Safety Board concludes that there were several opportunities wherein Boeing, the FAA, and UAL could have taken action during the initial design and certification of the B-747 cargo door, as well as during the operation and maintenance of the cargo door installed on N4713U, to ensure the continuing airworthiness of the cargo door. The Safety Board further concludes that these deficiencies and oversights contributed to the cause of this accident.

2.8 Survival Aspects

The Hickam ARFF units and the airport's ARFF units operated on separate radio networks and thus they could not communicate directly on-scene by radio. This situation required them to communicate by voice. Although the two ARFF services had a common radio frequency (as per the Airport Emergency Plan), procedures for its use had not yet been developed. The Safety Board believes that such communication procedures should be expeditiously developed.

The use of camouflage paint schemes on military ARFF vehicles may be appropriate for military purposes; however, the Safety Board believes that camouflage is not appropriate for ARFF vehicles that are operated at a joint- use airport. It is obvious that these vehicles must be conspicuous to be seen by other responding vehicles and by persons who are involved in the accident, such as airport and airline personnel, crew and passengers, and off-airport firefighting and rescue vehicles.

The National Fire Protection Association Standards recommend for primary firefighting, rapid intervention and combined agent vehicles, that, "Paint finish shall be selected for maximum visibility and shall be resistant to damage from firefighting agents."4 Furthermore, Federal Aviation Regulation 14 CFR 139.319 (f) (2) requires emergency vehicles, "Be painted or marked in colors to enhance contrast with the background environment and optimize daytime and nighttime visibility and identification." Further guidance for the high visibility color of ARFF vehicles is provided in a Federal Aviation Administration Advisory Circular where the vehicle paint color is specified as, "lime yellow" Dupont No. 7744 UH or its equivalent.5

Because flight attendants are vital to the safety and survival of the passengers following a decompression, measures should be taken to prevent flight attendants from being incapacitated by hypoxia. The Safety Board believes that oxygen masks should be attached to the emergency oxygen bottles to avoid any delay in their use in order to be in compliance with the intent of 14 CFR 25.1447 (c)(4). Therefore, the FAA should direct its inspector staff to survey B-747 airplanes for compliance with 14 CFR 25.1447(c)(4), and correct deficiencies found.

In this accident, the use of megaphones was vital because of the inability to be heard over the public address (PA) system. Title 14CFR 121.309 (f)(1) requires one megaphone on each airplane with a seating capacity of more that 60 and less that 100 passengers; 14 CFR 121.309 (f)(2) requires two megaphones in the cabins on each airplane with a seating capacity of more than 99 passengers. As this decompression demonstrated, additional megaphones are necessary on wide-body and large narrow-body airplanes to ensure communication in the cabin during emergencies when the PA system is inoperative.

Had there been a need for an immediate evacuation, or a water ditching, rapid egress would not have been possible at doors 2-left and 2-right because they were blocked by open storage compartments and spilled contents. The possibility also exists that a compartment door could release during a hard landing or turbulence and swing down and injure a flight attendant. Thus, the Safety Board believes that improved latches should be installed and the downward movement of stowage compartments doors should be restricted to prevent the doors from striking a seated flight attendant or block the exit door.

The Safety Board believes that the problems with life preserver donning and adjustment demonstrated in this accident should be addressed by the FAA. The straps and fittings on life preservers need to be evaluated to determine where improvements can be made, and clearer donning instructions should be developed. TSO-C13d, Life Preservers 1/3/83 prescribes the minimum performance standards for life preservers. With regard to donning, the TSO requires:

Donning. It must be demonstrated that an adult, after receiving only the customary preflight briefing on the use of life preservers, can don the life preserver within 15 seconds unassisted while seated. It must be demonstrated that an adult can install the life preserver on another adult, a child, or an infant within 30 seconds unassisted. The donning demonstration is begun with the unpackaged life preserver in hand.

Based on flight attendant interviews and information obtained from passengers these donning times were exceeded in many instances.

The Safety Board has made numerous recommendations to the FAA in the past regarding needed improvements in life preserver donning instructions, donning procedures, and timing of donning.6 The FAA has adopted most of the Safety Board's recommendations in its April 23, 1986, revision to TSO-C13e, Life Preservers, which now requires the wearer to be able to secure the preserver with no more than one attachment and make no more than one adjustment for fit. Also, donning tests are required for age groups of users starting with 20-29 years and ending with 60-69 years. At least 60% of the test subjects in each age group must be able to don then life preserver within 25 seconds unassisted with their seatbelts fastened starting with the life preserver in its storage package. TSO-C13e contains requirements that would have eliminated some of the problems that passengers had in this accident in correctly donning and adjusting their life preservers.

The Safety Board has recommended (A-85-35 through-37) to the FAA to amend 14 CFR 121, 125, and 135 to require air carriers to install life preservers that meet TSO-C13e within a reasonable time. The FAA adopted TSO-C13e on April 23, 1986, and originally had specified an effective date of April 23, 1988, after which all newly manufactured life preservers approved under the TSO system would have to meet the requirements of TSO-C13e. The objective of the cut off date was to introduce life preservers into the fleets with the higher performance level as specified in TSO-C13e by assuring that replacement articles met the higher standards. On March 3, 1988, the FAA rescinded the cut off date to seek further public comments of fleet retrofit in accord with the proposed rulemaking. See Section 4.0 for FAA action and status of the recommendations.

3. CONCLUSIONS

3.1 Findings

1. There were no flightcrew or cabincrew factors in the cause of the accident or injuries.
2. There were no air traffic control or weather factors in the cause of the accident.
3. The airplane had not been maintained in accordance with the provisions of AD-88-12-04 that required an inspection of the cargo door locking mechanisms after each time the door was operated manually and restored to electrical operation. However, this circumstance was determined not to be a factor in the accident.
4. All but one of the electrical components remaining with the airplane or found with the cargo door that were necessary to have malfunctioned in order to cause an inadvertent electrical opening of the cargo door after dispatch were found to function properly.
5. The forward cargo door lock sectors were found in the locked position (actually in an "over-locked" position) and jammed against the latch cams. The latch cams were found in the nearly open position.
6. The latch actuator manual drive port seal was found damaged from the forces involved in the separation of the door and did not indicate that the drive port had been used to open the

door latches manually before the accident.

7. Electrical continuity tests indicated that the S2 master latch lock switch was in the "not locked" position when it was recovered with the cargo door. Because it had sustained damage from being submerged in the sea, its preaccident condition could not be determined.

8. An S2 switch functioning as found after recovery would permit electrical power to the door during ground operation so that additional failure modes or activation of the door control switch could result in movement of the latching cams.

9. All other switches associated with operation of the cargo door were found damaged from being submerged in the sea; however, they were determined to be properly installed and probably functional.

10. Short circuit paths in the cargo door circuit were identified that could have led to an uncommanded electrical actuation of the latch actuator; this situation occurred most likely before engine start, although limited possibilities for an uncommanded electrical actuation exist after engine start while an airplane is on the ground with the APU running.

11. It was not possible for electrical short circuits to command the cargo door to open at the time of the loss of the door, and it is highly improbable that such an event occurred when the airplane was airborne during the short period while the APU was running.

12. Insulation breaches were found on recovered portions of the cargo door wires that could have allowed short circuiting and power to the latch actuator, although no evidence of arcing was noted. All of the wires were not recovered, and tests showed that arcing evidence may not be detectable.

13. An uncommanded movement of cargo door latches that occurred on another UAL B-747 on June 13, 1991, was attributed to insulation damage and a consequent short between wires in

the wiring bundle between the fuselage and the moveable door. Because the S2 switch functioned properly on that airplane, movement of the latches would not have occurred after the door was locked.

14. UAL's maintenance trend analysis program was inadequate to detect an adverse trend involving the cargo door on N4713U. This circumstance was determined not to be a factor in the accident.

15. FAA oversight of the UAL maintenance and inspection program did not ensure adequate trend analysis and adherence to the provisions of airworthiness directives. This circumstance was determined not to be a factor in the accident.

16. The smooth wear patterns on the latch pins of the forward cargo door installed on N4713U were signs that the door was not properly aligned (out of rig) for an extended period of time, causing significant interference during the normal open/close cycle.

17. The rough heat-tinted wear areas on the latch pins of the forward cargo door installed on N4713U marked the positions of the cams at the time the door opened in flight.

18. The design of the B-747 cargo door locking mechanisms did not provide for the intended "fail-safe" provisions of the locking and indicating systems for the door.

19. Boeing's Failure Analysis, which was the basis upon which the FAA granted an alternative method of compliance with the provisions of 14 CFR 25.783(e), was not valid as evidenced by the findings of the Pan Am incident in 1987, and the accident involving flight 811.

20. Boeing and the FAA did not take immediate action to require the use of the cam position view ports following the Pan Am incident, and did not include this requirement in the provisions of the Alert Service Bulletins or AD-88-12-04.

21. There were several opportunities for the manufacturer and

the FAA to have taken action during the service life of the Boeing 747 that might have prevented this accident.

22. The fact that the crash fire rescue vehicles responding to this accident did not use a common radio frequency led to problems in communication among the responding vehicles.

23. The camouflage paint scheme of the military fire rescue units led to reduced visibility of these units and resulted in at least one near-collision.

24. Megaphones were used in flight to communicate with passengers because of the high ambient noise level. However, more megaphones would have afforded better communication in all parts of the cabin.

25. Some flight attendants and passengers had difficulties tightening straps of their life preservers around their waists because of the fabric used, the design of the adjustment fittings, and the angle the straps were pulled.

26. Articles that fell to the floor from stowage bins above the L-2 and R-2 exits and galley service items had to be cleared away from the exits before the emergency evacuation could be initiated.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

4. RECOMMENDATIONS

As a result of the investigation, including evidence from the recovered cargo door and a June 13, 1991, incident involving the uncommanded electrical operation of a cargo door on a UAL Boeing 747 at JFK Airport, the National Transportation Safety Board recommends that the FAA:

Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits. (Class II, Priority Action) (A-92-21)

As a result of this investigation, on August 23, 1989, the Safety Board issued the following safety recommendations to the FAA:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams. (Class II, Priority Action)(A-89-92)

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently. (Class II, Priority Action)(A-89-93)

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions. (Class II, Priority Action)(A-89-94)

The FAA responded to Safety Recommendations A-89-92 through

-94 on November 3, 1989. During its evaluation of Safety Recommendation A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with AD 88-12-04, cannot be overridden during mechanical or
least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this, Safety Recommendation A-89-92 has been classified as "Closed--Reconsidered."

The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all jetpowered transport-category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight. The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100 certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as "Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using nonplug doors and that the FAA should not be limiting this review to only those transports which are jetpowered.

On November 29, 1990, Boeing issued service bulletin number 747-52-2224 applicable to all 747-100, 747-200, and 747-300 airplanes to add a new "door latch" switch to all 747 cargo doors.

In addition to the door warning switch that monitors the position of the pressure relief doors, the new door latch switch is activated by the latch cam bellcrank to separately sense the position of the latch cams. The existing "door closed" switch is also replaced with a double pole switch. The additional pole is used to separately sense the position of the door. Another single pole switch is also added to redundantly sense the position of the door. If any of these switches are not actuated, the warning light on the flight engineer's panel and a new light added to pilot's glareshield panel will be illuminated. The modification also requires installation of new cargo door control panels on the forward and aft lower cargo doors. The new panel incorporates an additional light to indicate proper door locking.

The FAA mandated the incorporation of this service bulletin within 18 months by AD 90-09-06, Amendment 39-6581, effective May 29, 1990.

Also, as a result of this accident, on May 4, 1990, the National Transportation Safety Board issued the following safety recommendations to the FAA:

Amend 14 CFR 25.1447(c)(4) to require that face masks be attached to the regulators of portable emergency oxygen bottles. (Class II, Priority Action) (A-90-54)

Require, in accordance with the requirements of 14 CFR 25.1447 (c)(4), that a portable oxygen bottle be located at the flight attendant stations at exit door 5 right and at exit door 5 left in B-747 airplanes. (Class II, Priority Action) (A-90-55)

Require that no articles be placed in storage compartments that are located over emergency exit doors. (Class II, Priority Action) (A-90-56)

Amend 14 CFR 121.309(f) to require a readily accessible megaphone at each seat row at which a flight attendant is stationed. (Class II, Priority Action) (A-90-57)

Take corrective action to improve direct visibility to passengers

from the upper level flight attendant jumpseat in the B-747 airplanes using eye reference data contained in Federal Aviation Administration report FAA-AM-75-2 "Anthropometry of Airline Stewardesses." (Class II, Priority Action) (A-90-58)
Issue an Airworthiness Directive to require that stronger latches be installed in oversized storage compartments that formerly held liferafts on all B-747 airplanes and also limit the distance that these compartments can be opened. (Class II, Priority Action) (A-90-59)
Demonstrate for each make and model of life preserver that it can be donned, adjusted, and tightened within the elapsed time required by TSO-C13d. Direct particular attention to the ease with which straps pass through adjustment fittings when the straps are pulled at all possible angles. (Class II, Priority Action) (A-90-60)
Establish a cutoff date of [within 1 year of this recommendation letter] after which all life preservers manufactured for passengercarrying aircraft would be required to meet the specifications of TSO-C13e. (Class II, Priority Action) (A-90-61)
The FAA first responded to these safety recommendations in a July 26, 1990, letter. Further responses to various safety recommendations in the group came in letters dated October 26, 1990 (A-90-59); May 13, 1991 (A-90-58); September 23, 1991 (A-90-55, -56, and -59); and March 9, 1992 (A-90-59). The current status of each safety recommendation is:
A-90-54: "Open--Acceptable Response," pending outcome of potential rulemaking initiative by the FAA.
A-90-55: "Open--Unacceptable Response," pending a review by the FAA of B-747 airplanes for compliance with portable oxygen bottle placement and securement requirements and for modifications that do not meet the intent of the type certification.
A-90-56: "Open--Unacceptable Response," pending a reexamination by the FAA of the potential for contents of compartments spilling out during an emergency and obstructing

passengers.
A-90-57: "Open--Unacceptable Response," pending the FAA's review of its position regarding a requirement for multiple megaphones on passenger airplanes.
A-90-58: "Closed--Reconsidered" as a result of the Safety Board's acceptance of the FAA position that the cabin jumpseat design on B-747's does not constitute an unsafe condition.
A-90-59: "Open--Acceptable Response," pending the issuance of an Airworthiness Directive to require stronger latches on oversized storage compartments on B-747 airplanes.
A-90-60: "Open--Acceptable Response," pending the implementation of the latest iteration of TSO-C13.
A-90-61: "Open--Unacceptable Response," pending inclusion in TSO-C13 (latest iteration) of a cutoff date after which all life preservers manufactured for passenger-carrying aircraft would be required to meet the specifications of the TSO.
The FAA's March 9, 1992, response to Safety Recommendation A-90-59 included the final AD addressing this issue. The AD does meet the intent of the recommendation, which is now classified as "Closed--Acceptable Action."
Also as a result of this accident, on May 4, 1990, the Safety Board reiterated the following recommendations to the FAA:
A-85-35
Amend 14 CFR 121 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; ensure that 14 CFR 25 is consistent with the amendments to Part 121.
A-85-36
Amend 14 CFR 125 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most

current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; amend Part 125 to require approved flotation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR 25 is consistent with the amendments of Part 125.

A-85-37

Amend 14 CFR 135 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; Amend Part 135 to require approved floatation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR SFAR No. 23 is consistent with the amendments to Part 135.

In a November 28, 1988, letter to the FAA, the Safety Board recommended that a cutoff date January 1, 1989, be reestablished. Based on this accident, the Safety Board's again urges the FAA to establish a cutoff date by which life preservers meeting TSO-C13e would be introduced into the fleets within a reasonable time (A-85-36). The Safety Board recognizes that the FAA has complied with the part of this recommendation pertaining to the flotation-type seat cushions.

Safety Recommendations A-85-35 and -37 are being held in an "Open--Acceptable Action" status pending the publication of the final rule. Safety Recommendation A-85-36 is being held in an "Open--Unacceptable Action" status because Part 125 operations were not included in the FAA rulemaking action.

As a result of its investigation, on May 4, 1990, the Safety Board also recommended that the State of Hawaii, Department of Transportation, Airports Division:

Develop, in cooperation with the Department of Defense, procedures for direct radio communication between aircraft rescue and fire fighting vehicles operated by the State of Hawaii and Hickam Air Force Base that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-62)

Additionally, as a result of its investigation, on May 4, 1990, the Safety Board recommended that the Department of Defense:

Develop, in cooperation with the State of Hawaii Department of Transportation, procedures for direct radio communication between aircraft rescue and firefighting vehicles operated by Hickam Air Force Base and the State of Hawaii that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-63)

Comply with Federal Regulation 14 CFR 139.319(f)(2) and the guidance contained in Federal Aviation Administration Advisory Circular 150/5220-14 by using high visibility color for aircraft rescue and firefighting vehicles that operate at Honolulu International Airport. (Class II, Priority Action) (A-90-64)

The Department of Defense responded to Safety Recommendations A-90-63 and -64 on August 17, 1990, citing the establishment of emergency radio communication ability between ARFF vehicles operated by Hickam Air Force Base and the State of Hawaii at Honolulu International Airport. Based on this action, Safety Recommendation A-90-63 was classified as "Closed--Acceptable Action" on December 12, 1990. With the establishment of the communications system as recommended, the Safety Board now classifies Safety Recommendation A-90-62 as "Closed--Acceptable Action."

Also, with regard to Safety Recommendation A-90-64, the Department of Defense pointed out that the Air Force has initiated a program to rep™ aint the vehicles over a 3-year period to spread out funding concerns. This safety recommendation is being held as "Open--Acceptable Response," pending the completion of the repainting program in 1993.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

SUSAN COUGHLIN
Acting Chairman
JOHN K. LAUBER
Member
CHRISTOPHER A. HART
Member
JOHN HAMMERSCHMIDT
Member
JAMES L. KOLSTAD
Member
March 18, 1992

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Washington Headquarters of the National Transportation Safety Board was notified of the United Airlines accident within a short time after the occurrence. A full investigation team departed Washington, D.C. at 1400 eastern daylight time on the same day and arrived in Honolulu at 0030 Hawaiian standard time the next day.

The team was composed of the following investigation groups: Operations, Structures/Systems, Maintenance Records, Metallurgy, and Survival Factors. In addition, specialist reports were prepared relevant to the CVR, FDR and radar plots.

Parties to the field investigation were United Airlines, the FAA, the Boeing Commercial Airplane Company, the Air Line Pilots Association, the International Association of Machinists, and the Association of Flight Attendants.

2. Public Hearing

A 3-day public hearing was held in Seattle, Washington, beginning on April 25, 1989. Parties represented at the hearing were the FAA, United Airlines, the Boeing Commercial Airplanes

Company, the Air Line Pilots Association, and the International Association of Machinists.

APPENDIX B

PERSONNEL INFORMATION

Captain David Cronin

Captain David Cronin, 59, was hired by UAL on December 10, 1954. The captain holds Airline Transport Pilot (ATP) Certificate No. 1268493 with airplane multiengine land ratings and commercial privileges in airplane single-engine land, sea and gliders. The captain is type rated in the B747, DC10, DC8, B727, Convair (CV) 440, CV340, CV240 and the learjet. The captain was issued a first class medical certificate on November 1, 1988, with no limitations.

The captain's initial operating experience (IOE) check out in the B747 occurred in December, 1985. The captain's latest line and proficiency checks in the B747 were completed in August and December, 1988, respectively. Training in ditching and evacuation was included with the proficiency check. The captain had flown a total of about 28,000 hours, 1,600 to 1,700 hours of which were in the B747. During the 24-hour, 72-hour and 30-day periods, prior to the accident, the captain had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 76 hours, 18 minutes, respectively.

First Officer Gregory Slader

First Officer Gregory Slader, 48, was hired by UAL on June 15, 1964. The first officer holds ATP Certificate No. 1528630 with airplane multiengine land ratings and commercial privileges in airplane single-engine land. The first officer is type rated in B747, DC10, B727, and B737. The first officer was issued a first class medical certificate on February 14, 1989, with no limitations.

The first officer's initial operating experience (IOE) check out in the B747 occurred in August, 1987. The first officer's latest proficiency check in the B747 was completed in October, 1988. Training on ditching and evacuation was included with the proficiency check. The first officer had flown a total of about 14,500 hours, 300 hours of which were in the B747. During the 24-hours, 72-hour and 30-day periods prior to the accident, the first officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Second Officer Randal Thomas

Second Officer Randal Thomas, 46, was hired by UAL on May 22, 1969. The second officer holds Flight Engineer Certificate No. 1947041 for turbo jet powered airplanes, issued July 18, 1969. The second officer holds commercial pilot certificate No. 1585899 with ratings and limitations of airplane single and multiengine land with instrument privileges. The second officer was issued a first class medical certificate on December 6, 1988, with no limitations. The second officer's IOE check out in the B747 occurred in March, 1987. The second officer's latest proficiency check in the B747 was completed in October, 1988. Training in ditching and evacuation was included with the proficiency check. He had flown a total of about 20,000 hours, about 1,200 hours of which were as second officer on the B747. During his 24-hour, 72-hour and 30 day-periods, prior to the accident, the second officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Flight Attendant and Chief Purser Laura Brentlinger

Flight attendant Laura Brentlinger, 38, was employed by UAL in May 1982; and had completed B747 recurrent training on September 19, 1988.

Flight Attendant and AFT Purser Sarah Shanahan

Flight attendant Sarah Shanahan, 42, was employed by UAL in August 1967; and had completed B747 recurrent training on October 10, 1988.

Flight Attendant Richard Lam

Flight attendant Richard Lam, 41, was employed by UAL on April 1970; and had completed B747 recurrent training on

September 16, 1988.

Flight Attendant John Horita

Flight attendant John Horita, 44, was employed by UAL in June 1970; and had completed B747 recurrent training on November 1, 1988.

Flight Attendant Curtis Christensen

Flight attendant Curtis Christensen, 34, was initially employed by PAA in May 1978. He was subsequently employed by UAL in February 1986 when UAL purchased PAA Pacific Division. Flight attendant Chrisensen had completed B747 recurrent training on December 12, 1988.

Flight Attendant Tina Blundy

Flight attendant Tina Blundy, 36, was employed by UAL in May 1973; and had completed B747 recurrent training on October 28, 1988.

Flight Attendant Jean Nakayama

Flight attendant Jane Nakayama, 37, was employed by UAL in August 1973; and had completed B747 recurrent training on December 6, 1988.

Flight Attendant Mae Sapolu

Flight attendant Mae Sapolu, 38, was initially employed by Pan American Airlines (PAA) in March 1973. She was subsequently employed by UAL in February 1986; when UAL purchased PAA Pacific Division. Flight attendant Sapolu completed B747 recurrent training on October 13, 1988.

Flight Attendant Robyn Nakamoto

Flight attendant Robyn Nakamoto, 26, was employed by UAL in April, 1986, and transferred to the Inflight Service Division in May, 1988. She was initially trained on the B747 in May 1988; and had not attended recurrent training.

Flight Attendant Edward Lythgoe

Flight attendant Edward Lythgoe, 37, was employed by UAL in December 1978; and had completed B747 recurrent training on

October 21, 1988.

Flight Attendant Sharol Preston

Flight attendant Sharol Preston, 39, was employed by UAL in July 1970; and had completed B747 recurrent training on July 29, 1988.

Flight Attendant Ricky Umehira

Flight attendant Ricky Umehira, 35, was employed by UAL in November 1983; and had completed B747 recurrent training on November 15, 1988.

Flight Attendant Darrell Blankenship

Flight attendant Darrell Blankenship, 28, was employed by UAL in February 1984; and had completed B747 recurrent training on February 10, 1988.

Flight Attendant Linda Shirley

Flight attendant Linda Shirley, 30, was employed by UAL in March 1979; and had completed B747 recurrent training on November 3, 1989.

Flight Attendant Ilona Benoit

Flight attendant Ilona Benoit, 48, was initially employed by PAA in November 1969. She was subsequently employed by UAL in February 1986; and had completed B747 recurrent training on November 17, 1988.

Lead Ramp Serviceman Paul Engalla

Lead ramp serviceman Paul Engalla was employed by UAL in 1959. Because of his extensive ramp service experience, Mr. Engalla was selected as a ramp service trainer in 1986.

Ramp Serviceman Daniel Sato

Ramp serviceman Daniel Sato was employed by UAL in May 1987. Company records indicate that his proficiency in the opening and closing of B747 cargo doors and the operation of container loads was attained in September 1988.

Ramp Serviceman Brian Kitaoka

Ramp serviceman Brian Kitaoka was employed by UAL in November 1986. Company records indicate that his proficiency in the operation of container loaders was attained in November 1987. His proficiency in the opening and closing of B747 cargo doors was attained in October 1988.

Dispatch Mechanic Steve Hajanos

Dispatch mechanic Steve Hajanos was employed as an airplane mechanic by UAL on October 30, 1986. He holds FAA Airplane and Powerplants Certificate No. 362583850, issued November 14, 1981. He was formerly employed by Aloha Airlines as a maintenance supervisor and by World Airways as a mechanic and maintenance supervisor. He began his aviation career as an airplane mechanic in the United States Air Force.

APPENDIX C

AIRPLANE INFORMATION

Type of Date of Maximum Inspection Inspection Cycles Interval Service No. 1 Current 02/23/89 58,814:24 15,027 Note 1 Previous 02/23/89 58,809:02 15,026 Service No. 2 Current 02/22/89 58,802:35 15,024 65 Hours Previous 02/18/89 58,747:12 15,016 Note 2 A Check Current 02/14/89 58,710:14 15,009 350 Hours Previous 01/16/89 58,368:57 14,947 B Check Current 11/28/88 57,751:44 14,839 131 Days Previous 07/28/88 56,635:36 14,632 C Check Current 11/28/88 57,751:44 14,839 393 Days Previous 11/19/87 53,789:00 14,146 MPV Check Current 04/30/84 43,731:0 11,857 5 Years Previous 01/30/80 30,906:0

D Check Current 04/30/84 43,731 19,237 9 Years Previous 09/09/76 19,237 Note 1: Service No. 1 to be accomplished on through flights or at trip termination whenever time is less than 12 hours per Maintenance Manual Procedures BX 12-0-1-1.

Note 2: Aircraft with layover of 12 hours or more will receive a Service No. 2 not to exceed 65 flight hours between checks.

APPENDIX D

INJURY INFORMATION

Flight Crewmember.--The second officer sustained minor superficial brush burns to both elbows and forearms, during the evacuation.

Cabin Crewmembers.--The cabin crewmembers sustained the following injuries during the evacuation:

Flight attendant No. 1 sustained a strained left shoulder;

Flight attendant No. 2 sustained acute thoracic and lumbosacral strain;

Flight attendant No. 3 sustained a mild right bicep strain;

Flight attendant No. 4 sustained a left elbow contusion, left shoulder dislocation, and mild lumbosacral strain;

Flight attendant No. 5 sustained a left calf contusion;

Flight attendant No. 6 sustained a mild left elbow bruise;

Flight attendant No. 7 sustained mild left arm and lower back strain;

Flight attendant No. 8 sustained a soft tissue injury to the back;

Flight attendant No. 9 sustained abrasions to both palms and the left knee;

Flight attendant No. 10 sustained a fracture of the left tenth rib;

Flight attendant No. 11 sustained a minimal injury to the right middle finger PIP joint and left first MP joint;

Flight attendant No. 12 sustained a pulled muscle on the left side of the neck;

Flight attendant No. 13 sustained a comminuted fracture of the right ulna and radius;

Flight attendant No. 14 sustained a mild thoracic back strain;

Flight attendant No. 15 sustained a non-displaced fracture of C-6, a cerebral concussion, a fracture of the proximal right humerus, and multiple lacerations;

A flight attendant, flying as a passenger, sustained mild lumbosacral strain, a laceration of the right little finger, and a left elbow abrasion.

Passengers.--Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH, and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally injured in the accident.

Passengers seated in the indicated seats sustained the following injuries:

Seat

7C - Barotrauma to both ears

9C - Half-inch laceration to the upper left arm, superficial abrasions to left arm and hand, barotrauma to both ears

9E - Superficial abrasions and contusions to the left hand, mild barotrauma to both ears

10B - Superficial abrasions to the left elbow and left middle finger

10E - Superficial abrasions to the torso and left forearm, bruising of the left hand and fingers

11E - Laceration on the right ankle tendon, multiple bruises

11F - Slight contusion of the right shoulder

13D - Barotrauma to both ears

13E - Bleeding in both ears

13H - Contusion to the left periorbital area

14A - Laceration in the parietal occipital area, barotrauma to both ears

15J - Comminuted fracture of the lateral epicondyle of the left distal humerus (about 5mm separation)

16B - Superficial abrasions to the right arm

16J - Barotrauma to both ears

16K - Right temporal abrasions

26A - Barotrauma to both ears

26B - barotrauma to both ears

26H - Barotitis to both ears, low back pain, irritation to the right eye due to foreign bodies

27A - Barotrauma to the right ear

28J - Superficial abrasions and a contusion to the left hand, mild barotrauma to both ears

1The flap track canoe fairings are numbered 1 through 8, from left outboard to right outboard.
2For ease in reference, the following numbering was used to relate forward cargo door frames to fuselage body stations (BS): frame 1--BS 567.10, frame 2--BS 580.95, frame 3--BS 596.75, frame 4--BS 608.15, frame 5--BS 623.96, frame 6--BS 636.02, frame 7--BS 651.50, frame 8--BS 662.90.
3 The "used" switch is the switch through which electricity passes; the "unused" switch does not have electricity pass through it.
4NFPA 414 - Aircraft Rescue and Fire Fighting Vehicles, National Fire Protection Association, 1984, Batterymarch Park, Quincy, MA 02269.
5Airport Fire and Rescue Vehicle Specification Guide, AC 150/5220-14, March 15, 1979, Federal Aviation Administration, Washington, D.C. 20591.
6 Air Carrier Overwater Emergency Equipment and Procedures" (NTSB/SS-85/02)

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:47 PM PDT
To: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Subject: **PA 103 AAR**

http://www.open.gov.uk/aaib/n739pa.htm

Air Accidents Investigation Branch
Aircraft Accident Report No 2/90 (EW/C1094)

Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21December 1988

Contents

Operator: Pan American World Airways
Aircraft Type: Boeing 747-121
Nationality: United States of America
Registration: N 739 PA
Place of Accident Lockerbie, Dumfries, Scotland
Latitude 55¡ 07' N
Longitude 003¡ 21' W
Date and Time (UTC): 21 December 1988 at 19.02:50 hrs
All times in this report are UTC
SYNOPSIS

The accident was notified to the Air Accidents Investigation Branch at 19.40 hrs on the 21 December 1988 and the investigation commenced that day. The members of the AAIB team are listed at Appendix A.

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind. Major portions of the wreckage of the aircraft fell on the town of Lockerbie with other large parts landing in the countryside to the east of the town. Lighter debris from the aircraft was strewn along two trails, the longest of which extended some 130 kilometres to the east coast of England. Within a few days items of wreckage were retrieved upon which forensic scientists found conclusive evidence of a detonating high explosive. The airport security and criminal aspects of the accident are the subject of a separate investigation

and are not covered in this report which concentrates on the technical aspects of the disintegration of the aircraft.

The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie. Five recommendations are made of which four concern flight recorders, including the funding of a study to devise methods of recording violent positive and negative pressure pulses associated with explosions. The final recommendation is that Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft's structure and systems to explosive damage.

1. FACTUAL INFORMATION

1.1 History of the Flight

Boeing 747, N739PA, arrived at London Heathrow Airport from San Francisco and parked on stand Kilo 14, to the south-east of Terminal 3. Many of the passengers for this aircraft had arrived at Heathrow from Frankfurt, West Germany on a Boeing 727, which was positioned on stand Kilo 16, next to N739PA. These passengers were transferred with their baggage to N739PA which was to operate the scheduled Flight PA103 to New York Kennedy. Passengers from other flights also joined Flight PA103 at Heathrow. After a 6 hour turnround, Flight PA103 was pushed back from the stand at 18.04 hrs and was cleared to taxy on the inner taxiway to runway 27R. The only relevant Notam warned of work in progress on the outer taxiway. The departure was unremarkable.

Flight PA103 took-off at 18.25 hrs. As it was approaching the Burnham VOR it took up a radar heading of 350¡ and flew below the Bovingdon holding point at 6000 feet. It was then cleared to climb initially to flight level (FL) 120 and subsequently to FL 310. The aircraft levelled off at FL 310 north west of Pole Hill VOR at 18.56 hrs. Approximately 7 minutes later, Shanwick Oceanic Control transmitted the aircraft's oceanic clearance but this transmission was not acknowledged. The secondary radar return from Flight PA103 disappeared from the radar screen during this transmission. Multiple primary radar returns were then seen fanning out downwind for a considerable distance. Debris from the aircraft was strewn along two trails, one of which extended some 130 km to the east coast of England. The upper winds were between 250¡ and 260¡ and decreased in strength from 115 kt at FL 320 to 60 kt at FL 100 and 15 to 20 kt at the surface.

Two major portions of the wreckage of the aircraft fell on the town of Lockerbie; other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Residents of Lockerbie reported that, shortly after 19.00 hrs, there was a rumbling noise like thunder which rapidly increased to deafening proportions like the roar of a jet engine under power. The noise appeared to come from a meteor-like object which was trailing flame and came down in the north-eastern part of the town. A larger, dark, delta shaped object, resembling an aircraft wing, landed at about the same time in the Sherwood area of the town. The delta shaped object was not on fire while in the air, however, a very large fireball ensued which was of short duration and carried large amounts of debris into the air, the lighter particles being deposited several miles downwind. Other less well defined objects were seen to land in the area.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	16	243	11
Serious	-	-	2
Minor/None	-	-	3

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1.3 Damage to aircraft

The aircraft was destroyed

1.4 Other damage

The wings impacted at the southern edge of Lockerbie, producing a crater whose volume, calculated from a photogrammetric survey, was approximately 560 cubic metres. The weight of material displaced by the wing impact was estimated to be well in excess of 1500 tonnes. The wing impact created a fireball, setting fire to neighbouring houses and carrying aloft debris which was then blown downwind for several miles. It was subsequently established that domestic properties had been so seriously damaged as a result of fire and/or impact that 21 had to be demolished and an even greater number of homes required substantial repairs. Major portions of the aircraft, including the engines, also landed on the town of Lockerbie and other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Lighter debris from the aircraft was strewn as far as the east coast of England over a distance of 130 kilometres.

1.5 Personnel information

1.5.1 Commander: Male, aged 55 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 720, Lockheed L1011 and Douglas DC3
Medical Certificate: Class 1,valid to April 1989, with the limitation that the holder shall wear lenses that correct for distant vision and possess glasses that correct for near vision

Flying experience:
Total all types: 10,910 hours
Total on type: 4,107 hours
Total last 28 days 82 hours
Duty time: Commensurate with company requirements
Last base check: 11 November 1988
Last route check: 30 June 1988
Last emergencies check: 8 November 1988

1.5.2 Co-pilot: Male, aged 52 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 727
Medical Certificate: Class 1, valid to April 1989, with the limitation that the holder shall possess correcting glasses for near vision
Flying experience:
Total all types: 11,855 hours
Total on type: 5,517 hours
Total last 28 days: 51 hours
Duty time: Commensurate with company requirements
Last base check: 30 November 1988
Last route check: Not required
Last emergencies check: 27 November 1988

1.5.3 Flight Engineer: Male, aged 46 years

Licence: USA Flight Engineer's Licence
Aircraft ratings: Turbojet
Medical certificate: Class 2, valid to June 1989, with the limitation that the holder shall wear correcting glasses for near vision
Flying experience:
Total all types: 8,068 hours
Total on type: 487 hours
Total last 28 days: 53 hours
Duty time: Commensurate with company requirements
Last base check: 30 October 1988
Last route check: Not required
Last emergencies check: 27 October 1988

1.5.4 Flight Attendants: There were 13 Flight Attendants on the aircraft, all of whom met company proficiency and medical requirements
CLICK HERE TO RETURN TO INDEX
1.6 Aircraft information

1.6.1 Leading particulars
Aircraft type: Boeing 747-121
Constructor's serial number: 19646
Engines: 4 Pratt and Whitney JT9D-7A turbofan

1.6.2 General description

The Boeing 747 aircraft, registration N739PA, was a conventionally designed long range transport aeroplane. A diagram showing the general arrangement is shown at Appendix B, Figure B-1 together with the principal dimensions of the aircraft.

The fuselage of the aircraft type was of approximately circular section over most of its length, with the forward fuselage having a diameter of 21† feet where the cross-section was constant. The pressurised section of the fuselage (which included the forward and aft cargo holds) had an overall length of 190 feet, extending from the nose to a point just forward of the tailplane. In normal cruising flight the service pressure differential was at the maximum value of 8.9 pounds per square inch. The fuselage was of conventional skin, stringer and frame construction, riveted throughout, generally using countersunk flush riveting for the skin panels. The fuselage frames were spaced at 20 inch intervals and given the same numbers as their stations, defined in terms of the distance in inches from the datum point close to the nose of the aircraft [Appendix B, Figure B-2]. The skin panels were joined using vertical butt joints and horizontal lap joints. The horizontal lap joints used three rows of rivets together with a cold bonded adhesive.

Accommodation within the aircraft was predominately on the main deck, which extended throughout the whole length of the pressurised compartment. A separate upper deck was incorporated in the forward part of the aircraft. This upper deck was reached by means of a spiral staircase from the main deck and incorporated the flight crew compartment together with additional passenger accommodation. The cross-section of the forward fuselage differed considerably from the near circular section of the remainder of the aircraft, incorporating an additional smaller radius arc above the upper deck section joined to the main circular arc of the lower cabin portion by elements of straight fuselage frames and flat skin.

In order to preserve the correct shape of the aircraft under pressurisation loading, the straight portions of the fuselage frames in the region of the upper deck floor and above it were required to be much stiffer than the frame portions lower down in the aircraft. These straight sections were therefore of very much more substantial construction than most of the curved sections of frames lower down and further back in the fuselage. There was considerable variation in the gauge of the fuselage skin at various locations in the forward fuselage of the aircraft.

The fuselage structure of N739PA differed from that of the majority of Boeing 747 aircraft in that it had been modified to carry special purpose freight containers on the main deck, in place of seats. This was known as the Civil Reserve Air Fleet (CRAF) modification and enabled the aircraft to be quickly converted for carriage of military freight containers on the main deck during times of national emergency. The effect of this modification on the structure of the fuselage was mainly to replace the existing main deck floor beams with beams of more substantial cross-section than those generally found in passenger carrying Boeing 747 aircraft. A large side loading door, generally known as the CRAF door, was also incorporated on the left side of the main deck aft of the wing.

Below the main deck, in common with other Boeing 747 aircraft, were a number of additional compartments, the largest of which were the forward and aft freight holds used for the storage of cargo and baggage in standard air-transportable containers. These containers were placed within the aircraft hold by means of a freight handling system and were carried on a system of rails approximately 2 feet above the outer skin at the bottom of the aircraft, there being no continuous floor, as such, below these baggage containers. The forward freight compartment had a length of approximately 40 feet and a depth of approximately 6 feet. The containers were loaded into the forward hold through a large cargo door on the right side of the aircraft.

1.6.3 Internal fuselage cavities

Because of the conventional skin, frame and stringer type of construction, common to all large public transport aircraft, the fuselage was effectively divided into a series of 'bays'. Each bay, comprising two adjacent fuselage frames and the structure between them, provided, in effect, a series of interlinking cavities bounded by the frames, floor beams, fuselage skins and cabin floor panels etc. The principal cavities thus formed were:

(i) A semi-circular cavity formed in between the fuselage frames in the lower lobe of the hull, i.e. from the crease beam (at cabin floor level) on one side down to the belly beneath the containers and up to the opposite crease beam, bounded by the fuselage skin on the outside and the containers/cargo liner on the inside [Appendix B, Figure B-3, detail A].

(ii) A horizontal cavity between the main cabin floor beams, the cabin floor panels and the cargo bay liner. This extended the full width of the fuselage and linked the upper ends of the lower lobe cavity [Appendix B, Figure B-3, detail B].

(iii) A narrow vertical cavity between the two containers [Appendix B, Figure B-3, detail C].

(iv) A further narrow cavity around the outside of the two containers, between the container skins and the cargo bay liner, communicating with the lower lobe cavity [Appendix B, Figure B-3, detail D].

(v) A continuation of the semi-circular cavity into the space behind the cabin wall liner [Appendix B, Figure B-3, detail E]. This space was restricted somewhat by the presence of the window assembly, but nevertheless provided a continuous cavity extending upwards to the level of the upper deck floor. Forward of station 740, this cavity was effectively terminated at its upper end by the presence of diaphragms which formed extensions of the upper deck floor panels; aft of station 740, the cavity communicated with the ceiling space and the cavity in the fuselage crown aft of the upper deck.

All of these cavities were repeated at each fuselage bay (formed between pairs of fuselage frames), and all of the cavities in a given bay were linked together, principally at the crease beam area [Appendix B, Figure B-3, region F]. Furthermore, each of the set of bay cavities was linked with the next by the longitudinal cavities formed between the cargo hold liner and the outer hull, just below the crease beam [Appendix B, Figure B-3, detail F]; i.e. this cavity formed a manifold linking together each of the bays within the cargo hold.

The main passenger cabin formed a large chamber which communicated directly with each of the sub floor bays, and also with the longitudinal manifold cavity, via the air conditioning and cabin/cargo bay de-pressurisation vent passages in the crease beam area. (It should be noted that a similar communication did not exist between the upper and lower cabins because there were no air conditioning/depressurisation passages to bypass the upper deck floor.)

1.6.4 Aircraft weight and centre of gravity

The aircraft was loaded within its permitted centre of gravity limits as follows:

Loading:	lb	kg
Operating empty weight	366,228	166,120
Additional crew	130	59
243 passengers (1)	40,324	18,291
Load in compartments:		
1	11,616	5,269
2	20,039	9,090
3	15,057	6,830
4	17,196	7,800
5	2,544	1,154
Total in compartments (2)	66,452	30,143
Total traffic load	106,776	48,434
Zero fuel weight	472,156	214,554
Fuel (Take-off)	239,997	108,862
Actual take-off weight(4)	713,002	323,416
Maximum take-off weight	733,992	332,937

Note 1:
Calculated at standard weights and including cabin baggage.

Note 2:

Despatch information stated that the cargo did not include dangerous goods, perishable cargo, live animals or known security exceptions.

1.6.5 Maintenance details

N739PA first flew in 1970 and spent its whole service life in the hands of Pan American World Airways Incorporated. Its Certificate of Airworthiness was issued on 12 February 1970 and remained in force until the time of the accident, at which time the aircraft had completed a total of 72,464 hours flying and 16,497 flight cycles. Details of the last 4 maintenance checks carried out during the aircraft's life are shown below:

DATE	SERVICE	HOURS	CYCLES
27 Sept 88	C Check (Interior upgrade)	71,502	16,347
2 Nov 88	B Service Check	71,919	16,406
27 Nov 88	Base 1	72,210	16,454
13 Dec 88	Base 2	72,374	16,481

The CRAF modification programme was undertaken in September 1987. At the same time a series of modifications to the forward fuselage from the nose back to station 520 (Section 41) were carried out to enable the aircraft to continue in service without a continuing requirement for structural inspections in certain areas.

All Airworthiness Directives relating to the Boeing 747 fuselage structure between stations 500 and 1000 have been reviewed and their applicability to this aircraft checked. In addition, Service Bulletins relating to the structure in this area were also reviewed. The applicable Service Bulletins, some of which implement the Airworthiness Directives are listed below together with their subjects. The dates, total aircraft times and total aircraft cycles at which each relevant inspection was last carried out have been reviewed and their status on aircraft N739PA at the time of the accident has been established.

N739PA Service Bulletin compliance:

SB 53-2064 Front Spar Pressure Bulkhead Chord Reinforcement and Drag Splice Fitting Rework.
Modification accomplished on 6 July 1974.
Post-modification repetitive inspection IAW (in accordance with) AD 84-18-06 last accomplished on 19 November 1985 at 62,030 TAT hours (Total Aircraft

Time) and 14,768 TAC (Total Aircraft Cycles).
SB 53-2088 Frame to Tension Tie Joint Modification - BS760 to 780.
Repetitive inspection IAW AD 84-19-01 last accomplished on 19 June 1985 at 60,153 hours TAT and 14,436 TAC.
SB 53-2200 Lower Cargo Doorway Lower Sill Truss and Latch Support Fitting Inspection Repair and Replacement.
Repetitive inspection IAW AD 79-17-02 R2 last accomplished 2 November 1988 at 71,919 hours TAT and 16,406 TAC.
SB 53-2234 Fuselage - Auxiliary Structure - Main Deck Floor - BS 480 Floor Beam Upper Chord Modification.
Repetitive inspection per SB 53A2263 IAW AD 86-23-06 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
SB 53-2237 Fuselage - Main Frame - BS 540 thru 760 and 1820 thru 1900 Frame Inspection and Reinforcement.
Repetitive inspection IAW AD 86-18-01 last accomplished on 27 February 1987 at 67,088 hours TAT and 15,627 TAC.
SB 53-2267 Fuselage - Skin - Lower Body Longitudinal Skin Lap Joint and Adjacent Body Frame Inspection and Repair.
Terminating modification accomplished 100% under wing-to-body fairings and approximately 80% in forward and aft fuselage sections on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
Repetitive inspection of unmodified lap joints IAW AD 86-09-07 R1 last accomplished on 18 August 1988 at 71,043 hours TAT and 16,273 TAC.
SB 53A2303 Fuselage - Nose Section - station 400 to 520 Stringer 6 Skin Lap Splice Inspection, Repair and Modification.
Repetitive inspection IAW AD 89-05-03 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.

This documentation, when viewed together with the detailed content of the above service bulletins, shows the aircraft to have been in compliance with the requirements laid down in each of those bulletins. Some maintenance items were outstanding at the time the aircraft was despatched on the last flight, however, none of these items relate to the structure of the aircraft and none had any relevance to the accident.

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1.7 Meteorological Information

1.7.1 General weather conditions

An aftercast of the general weather conditions in the area of Lockerbie at about 19.00 hrs was obtained from the Meteorological Office, Bracknell. The synoptic situation included a warm sector covering northern England and most of Scotland with a cold front some 200 nautical miles to the west of the area moving eastwards at about 35 knots. The weather consisted of intermittent rain or showers. The cloud consisted of 4 to 6 oktas of stratocumulus based at 2,200 feet with 2 oktas of altocumulus between 15,000 and 18,000 feet. Visibility was over 15 kilometers and the freezing level was at 8,500 feet with a sub-zero layer between 4,000 and 5,200 feet.

1.7.2 Winds

There was a weakening jet stream of around 115 knots above Flight Level 310. From examination of the wind profile (see below), there appeared to be insufficient shear both vertically and horizontally to produce any clear air turbulence but there may have been some light turbulence.

Flight Level	Wind
320	260¡/115 knots
300	260¡/ 90 knots
240	250¡/ 80 knots
180	260¡/ 60 knots
100	250¡/ 60 knots
050	260¡/ 40 knots
Surface	240¡/ 15 to 20 gusting 25 to 30 knots

1.8 Aids to navigation

Not relevant.

1.9 Communications

The aircraft communicated normally on London Heathrow aerodrome, London control and Scottish control frequencies. Tape recordings and transcripts of all radio telephone (RTF) communications on these frequencies were available.

At 18.58 hrs the aircraft established two-way radio contact with Shanwick Oceanic Area Control on frequency 123.95 MHz. At 19.02:44 hrs the clearance delivery officer at Shanwick transmitted to the aircraft its oceanic route clearance. The aircraft did not acknowledge this message and made no subsequent transmission.

1.9.1 ATC recording replay

Scottish Air Traffic Control provided copy tapes with time injection for both Shanwick and Scottish ATC frequencies. The source of the time injection on the tapes was derived from the British Telecom "TIM" signal.

The tapes were replayed and the time signals corrected for errors at the time of the tape mounting.

1.9.2 Analysis of ATC tape recordings

From the cockpit voice recorder (CVR) tape it was known that Shanwick was transmitting Flight PA103's transatlantic clearance when the CVR stopped. By synchronising the Shanwick tape and the CVR it was possible to establish that a loud sound was heard on the CVR cockpit area microphone (CAM) channel at 19.02:50 hrs ±1 second.

As the Shanwick controller continued to transmit Flight PA103's clearance instructions through the initial destruction of the aircraft it would not have been possible for a distress call to be received from N739PA on the Shanwick frequency. The Scottish frequency tape recording was listened to from 19.02 hrs until 19.05 hrs for any unexplained sounds indicating an attempt at a distress call but none was heard.

A detailed examination and analysis of the ATC recording together with the flight recorder, radar, and seismic recordings is contained in Appendix C.

1.10 Aerodrome information

Not relevant

1.11 Flight recorders

The Digital Flight Data Recorder (DFDR) and the Cockpit Voice Recorder (CVR) were found close together at UK Ordnance Survey (OS) Grid Reference 146819, just to the east of Lockerbie, and recovered approximately 15 hours after the accident. Both recorders were taken directly to AAIB Farnborough for replay. Details of the examination and analysis of the flight recorders together with the radar, ATC and seismic recordings are contained in Appendix C.

1.11.1 Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded and that the recorder had simply stopped at 19.02:50 hrs ±1 second.

1.11.2 Cockpit voice recorder

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1 Flight Engineer's RTF.
Channel 2 Co-Pilot's RTF.
Channel 3 Pilot's RTF.
Channel 4 Cockpit Area Microphone.

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings were audible on the RTF channels. The CAM channel was particularly noisy, probably due to the combination of the inherently noisy flight deck of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high flight deck noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified and could have been of either acoustic or electrical origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19.02:50 hrs ±1 second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC.

1.12 Wreckage and impact information

1.12.1 General distribution of wreckage in the field

The complete wing primary structure, incorporating the centre section, impacted at the southern edge of Lockerbie. Major portions of the aircraft, including the engines, also landed in the town. Large portions of the aircraft fell in the countryside to the east of the town and lighter debris was strewn to the east as far as the North Sea. The wreckage was distributed in two trails which became known as the northern and southern trails respectively and these are shown in Appendix B, Figure B-4. A computer database of approximately 1200 significant items of wreckage was compiled and included a brief description of each item and the location where it was found

Appendix B, Figures B-5 to B-8 shows photographs of a model of the aircraft on which the fracture lines forming the boundaries of the separate items of structure have been marked. The model is colour coded to illustrate the way in which the wreckage was distributed between the town of Lockerbie and the northern and southern trails.

1.12.1.1 The crater

The aircraft wing impacted in the Sherwood Crescent area of the town leaving a crater approximately 47 metres (155 feet) long with a volume calculated to be 560 cubic metres.

The projected distance, measured parallel from one leading edge to the other wing tip, of the Boeing 747-100 was approximately 143 feet, whereas the span is known to be 196 feet. This suggests that impact took place with the wing structure yawed. Although the depth of the crater varied from one end to the other, its widest part was clearly towards the western end suggesting that the wing structure impacted whilst orientated with its root and centre section to the west.

The work carried out at the main crater was limited to assessing the general nature of its contents. The total absence of debris from the wing primary structure found remote from the crater confirmed the initial impression that the complete wing box structure had been present at the main impact.

The items of wreckage recovered from or near the crater are coloured grey on the model at Appendix B, Figures B-5 to B-8.

1.12.1.2 The Rosebank Crescent site

A 60 feet long section of fuselage between frame 1241 (the rear spar attachment) and frame 1960 (level with the rear edge of the CRAF cargo door) fell into a housing estate at Rosebank Crescent, just over 600 metres from the crater. This section of the fuselage was that situated immediately aft of the wing, and adjoined the wing and fuselage remains which produced the crater. It is colour coded yellow on the model at Appendix B, Figures B-5 to B-8. All fuselage skin structure above floor level was missing except for the following items:

Section containing 3 windows between door 4L and CRAF door;
The CRAF door itself (latched) apart from the top area containing the hinge;
Window belt containing 8 windows aft of 4R door aperture
Window belt containing 3 windows forward of 4R door aperture;
Door 4R.

Other items found in the wreckage included both body landing gears, the right wing landing gear, the left and right landing gear support beams and the cargo door (frames 1800-1920) which was latched. A number of pallets, luggage containers and their contents were also recovered from this site.

1.12.1.3 Forward fuselage and flight deck section.

The complete fuselage forward of approximately station 480 (left side) to station 380 (right side) and incorporating the flight deck and nose landing gear was found as a single piece [Appendix B, Figure B-9] in a field approximately 4 km miles east of Lockerbie at OS Grid Reference 174808. It was evident from the nature of the impact damage and the ground marks that it had fallen almost flat on its left side but with a slight nose-down attitude and with no discernible horizontal velocity. The impact had caused almost complete crushing of the structure on the left side. The radome and right nose landing gear door had detached in the air and were recovered in the southern trail.

Examination of the torn edges of the fuselage skin did not indicate the presence of any pre-existing structural or material defects which could have accounted for the separation of this section of the fuselage. Equally so, there were no signs of explosive blast damage or sooting evident on any part of the structure or the interior fittings. It was noted however that a heavy, semi-eliptical scuff mark was present on the lower right side of the fuselage at approximately station 360. This was later matched to the intake profile of the No 3 engine.

The status of the controls and switches on the flight deck was consistent with normal operation in cruising flight. There were no indications that the crew had attempted to react to rapid decompression or loss of control or that any emergency preparations had been actioned prior to the catastrophic disintegration.

1.12.1.4 Northern trail

The northern trail was seen to be narrow and clearly defined, to emanate from a point very close to the main impact crater and to be orientated in a direction which agreed closely with the mean wind aftercast for the height band from sea level to 20,000 ft. Also at the western end of the northern trail were the lower rear fuselage at Rosebank Crescent, and the group of Nos. 1, 2 and 4 engines which fell in Lockerbie.

The trail contained items of structure distributed throughout its length, from the area slightly east of the crater, to a point approximately 16 km east, beyond which only items of low weight / high drag such as insulation, interior trim, paper etc, were found. For all practical purposes this trail ended at a range of 25 km.

The northern trail contained mainly wreckage from the rear fuselage, fin and the inner regions of both tailplanes together with structure and skin from the upper half of the fuselage forward to approximately the wing mid-chord position. A number of items from the wing were also found in the northern trail, including all 3 starboard Kreuger flaps, most of the remains of the port Kreuger flaps together with sections of their leading edge attachment structures, one portion of outboard aileron approximately 10 feet long, the aft ends of the flap-track fairings (one with a slide raft wrapped around it), and fragments of glass reinforced plastic honeycombe structure believed to be from the flap system, i.e. fore-flaps, aft-flaps, mid-flaps or adjacent fairings. In addition, a number of pieces of the engine cowlings and both HF antennae (situated projecting aft from the wing-tips) were found in this trail.

All items recovered from the northern trail, with the exception of the wing, engines, and lower rear fuselage in Rosebank Crescent, are coloured red on the model of the aircraft in Appendix B, Figures B-5 to B-8.

1.12.1.5 Southern trail

The southern trail was easily defined, except within 12 km of Lockerbie where it tended to merge with the northern trail. Further east, it extended across southern Scotland and northern England, essentially in a straight band as far as the North Sea. Most of the significant items of wreckage were found in this trail within a range of 30 km from the main impact crater. Items recovered from the southern trail are coloured green on the model of the aircraft at Appendix B, Figures B-5 to B-8.

The trail contained numerous large items from the forward fuselage. The flight deck and nose of the aircraft fell in the curved part of this trail close to Lockerbie. Fragments of the whole of the left tailplane and the outboard portion of the right tailplane were distributed almost entirely throughout the southern trail. Between 21 and 27 km east of the main impact point (either side of Langholm) substantial sections of tailplane skin were found, some bearing distinctive signs of contact with debris moving outwards and backwards relative to the fuselage. Also found in this area were numerous isolated sections of fuselage frame, clearly originating from the crown region above the forward upper deck.

1.12.1.6 Datum line

All grid references relating to items bearing actual explosive evidence, together with those attached to heavily distorted items found to originate immediately adjacent to them on the structure, were plotted on an Ordnance Survey (OS) chart. These references, 11 in total, were all found to be distributed evenly about a mean line orientated 079¡(Grid) within the southern trail and were spread over a distance of 12 km. The distance of each reference from the line was measured in a direction parallel to the aircraft's track and all were found to be within 500 metres of the line, with 50% of them being within 250 metres of the line. This line is referred to as the datum line and is shown in Appendix B, Figure B-4.

1.12.1.7 Distribution of wreckage within the southern trail

North of the datum line and parallel to it were drawn a series of lines at distances of 250, 300, 600 and 900 metres respectively from the line, again measured in a direction parallel to the aircraft's track. The positions on the aircraft structure of specific items of wreckage, for which grid references were known with a high degree of confidence, within the bands formed between these lines, are shown in Appendix B, Figures B-10 to 13. In addition, a separate assessment of the grid references of tailplane and elevator wreckage established that these items were distributed evenly about the 600 metre line.

1.12.1.8 Area between trails

Immediately east of the crater, the southern trail converged with the northern trail such that, to an easterly distance of approximately 5 km, considerable wreckage existed which could have formed part of either trail. Further east, between 6 and 11 km from the crater, a small number of sections and fragments of the fin had fallen outside the southern boundary of the northern trail. Beyond this a large area existed between the trails in which there was no wreckage.

1.12.2 Examination of wreckage at CAD Longtown

The debris from all areas was recovered by the Royal Air Force to the Army Central Ammunition Depot Longtown, about 20 miles from Lockerbie. Approximately 90% of the hull wreckage was successfully recovered, identified, and laid out on the floor in a two-dimensional reconstruction [Appendix B, Figure B-14]. Baggage container material was incorporated into a full three-dimensional reconstruction. Items of wreckage added to the reconstructions was given a reference number and recorded on a computer database together with a brief description of the item and the location where it was found.

1.12.2.1 Fuselage

The reconstruction revealed the presence of damage consistent with an explosion on the lower fuselage left side in the forward cargo bay area. A small region of structure bounded approximately by frames 700 & 720 and stringers 38L & 40L, had clearly been shattered and blasted through by material exhausting directly from an explosion centred immediately inboard of this location. The material from this area, hereafter referred to as the 'shatter zone', was mostly reduced to very small fragments, only a few of which were recovered, including a strip of two skins [Appendix B, Figure B-15] forming part of the lap joint at the stringer 39L position.

Surrounding the shatter zone were a series of much larger panels of torn fuselage skin which formed a 'star-burst' fracture pattern around the shatter zone. Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range. In contrast, the star-burst fractures, outside the boundary of the shatter zone, displayed evidence of more typical overload tearing, though some tears appeared to be rapid and, in the area below the missing panels, were multi-branched. These surrounding skin panels were moderately sooted in the regions adjacent to the shatter zone, but otherwise were lightly sooted or free of soot altogether. (Forensic analysis of the soot deposits on frame and skin material from this area confirmed the presence of explosive residues.) All of these skin panels had pulled away from the supporting structure and had been bent and torn in a manner which indicated that, as well as fracturing in the star burst pattern, they had also petalled outwards producing characteristic, tight curling of the sheet material.

Sections of frames 700 and 720 from the area of the explosion were also recovered and identified. Attached to frame 720 were the remnants of a section of the aluminium baggage container (side) guide rail, which was heavily distorted and displayed deep pitting together with very heavy sooting, indicating that it had been very close to the explosive charge. The pattern of distortion and damage on the frames and guide rail segment matched the overall pattern of damage observed on the skins.

The remainder of the structure forming the cargo deck and lower hull was, generally, more randomly distorted and did not display the clear indications of explosive processes which were evident on the skin panels and frames nearer the focus of the explosion. Nevertheless, the overall pattern of damage was consistent with the propagation of explosive pressure fronts away from the focal area inboard of the shatter zone. This was particularly evident in the fracture and bending characteristics of several of the fuselage frames ahead of, and behind station 700.

The whole of the two-dimensional fuselage reconstruction was examined for general evidence of the mode of disintegration and for signs of localised damage, including overpressure damage and pre-existing damage such as corrosion or fatigue. There was some evidence of corrosion and dis-bonding at the cold-bond lap joints in the fuselage. However, the corrosion was relatively light and would not have compromised significantly the static strength of the airframe. Certainly, there was no evidence to suggest that corrosion had affected the mode of disintegration, either in the area of the explosion or at areas more remote. Similarly, there were no indications of fatigue damage except for one very small region of fatigue, involving a single crack less than 3 inches long, which was remote from the bomb location. This crack was not in a critical area and had not coincided with a fracture path.

No evidence of overpressure fracture or distortion was found at the rear pressure bulkhead. Some suggestion of 'quilting' or 'pillowing' of skin panels between stringers and frames, indicative of localised overpressure, was evident on the skin panels attached to the larger segments of lower fuselage wreckage aft of the blast area. In addition, the mode of failure of the butt joint at station 520 suggested that there had been a rapid overpressure load in this area, causing the fastener heads to 'pop' in the region of stringers 13L to 16L, rather than producing shear in the fasteners. Further evidence of localised overpressure damage remote from the source of the explosion was found during the full three-dimensional reconstruction, detailed later in paragraph 1.12.3.2.

An attempt was made to analyse the fractures, to determine the direction and sequence of failure as the fractures propagated away from the region of the explosion. It was found that the directions of most of the fractures close to the explosion could be determined from an analysis of the fracture surfaces and other features, such as rivet and rivet hole distortions. However, it was apparent that beyond the boundary of the petalled region, the disintegration process had involved multiple fractures taking place simultaneously - extremely complex parallel processes which made the sequencing of events not amenable to conventional analysis.

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1.12.2.2 Wing structure and adjacent fuselage area

On completion of the initial layout at Longtown it became evident that, in the area from station 1000 to approximately station 1240 the only identifiable fuselage structure consisted of elements of fuselage skin, stringers and frames from above the cabin window belts. The wreckage from in and around the crater was therefore sifted to establish more accurately what sections of the aircraft had produced the crater. All of the material was highly fragmented, but it was confirmed that the material comprised mostly wing structure, with a few fragments of fuselage sidewall and passenger seats. The badly burnt state of these fragments made it clear that they were recovered from the area of the main impact crater, the only scene of significant ground fire. Amongst these items a number of cabin window forgings were recovered with sections of thick horizontal panelling attached having a length equivalent to the normal window spacing/frame pitch. This arrangement, with skins of this thickness, is unique to the area from station 1100 to 1260. It is therefore reasonable to assume that these fragments formed parts of the missing cabin sides from station 1000 to station 1260, which must have remained attached to the wing centre section at the time of its impact. Because of the high degree of fragmentation and the relative insignificance of the wing in terms of the overall explosive damage pattern, a reconstruction of the wing material was not undertaken. The sections of the aircraft which went into the crater are colour coded grey in Appendix B, Figures B-5 to B-8.

1.12.2.3 Fin and aft section of fuselage

Examination of the structure of the fin revealed evidence of in-flight damage to the leading edge caused by the impact of structure or cabin contents. This damage was not severe or extensive and the general break-up of the fin did not suggest either a single readily defined loading direction, or break-up due to the effects of leading edge impact. A few items of fin debris were found between the northern and southern trails.

A number of sections of fuselage frame found in the northern trail exhibited evidence of plastic deformation of skin attachment cleats and tensile overload failure of the attachment rivets. This damage was consistent with that which would occur if the skin had been locally subjected to a high loading in a direction normal to its plane. Although this was suggestive of an internal overpressure condition, the rear fuselage revealed no other evidence to support this possibility. Examination of areas of the forward fuselage known to have been subjected to high blast overpressures revealed no comparable evidence of plastic deformation in the skin attachment cleats or rivets, most skin attachment failures appearing to have been rapid.

Calculations made on the effects of internal pressure generated by an open ended fuselage descending at the highest speed likely to have been experienced revealed that this could not generate an internal pressure approaching that necessary to cause failure in an intact cabin structure.

1.12.2.4 Baggage containers

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited damage consistent with being close to a detonating high explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence of explosive damage. It was evident, from the main wreckage layout, that the explosion had occurred in the forward cargo hold and, although all baggage container wreckage was examined, only items from this area which showed the relevant characteristics were considered for the reconstruction. Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to Lockerbie, whilst that from the forward hold was scattered along the southern wreckage trail.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this, two adjacent containers, one of metal construction the other fibreglass, were identified as exhibiting damage likely to have been caused by the explosion. Those parts which could be positively identified as being from these two containers were assembled onto one of three simple wooden frameworks, one each for the floor and superstructure of the metal container and one for the superstructure of the fibreglass container. From this it was positively determined that the explosion had occurred within the metal container (serial number AVE 4041 PA), the direct effects of this being evident also on the forward face of the adjacent fibreglass container (serial number AVN 7511 PA) and on the local airframe on the left side of the aircraft in the region of station 700. It was therefore confirmed that this metal container had been loaded in position 14L in agreement with the aircraft loading records. While this work was in progress a buckled section of the metal container skin was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device (IED).

The reconstruction of these containers and their relationship to the aircraft structure is described in detail in Appendix F. Examination of all other components of the remaining containers revealed only damage consistent with ejection into the high speed slipstream and/or ground impact, and that only one device had detonated within the containers on board the aircraft.

1.12.3 Fuselage three-dimensional reconstruction

1.12.3.1 The reconstruction

The two-dimensional reconstruction successfully established that there had been an explosion in the forward hold; its location was established and the general damage characteristics in the vicinity of the explosion were determined. However, the mechanisms by which the failure process developed from local damage in the immediate vicinity of the explosion to the complete structural break-up and separation of the whole forward section of the fuselage, could not be adequately investigated without recourse to a more elaborate reconstruction.

To facilitate this additional work, wreckage forming a 65 foot section of the fuselage (approximately 30 feet each side of the explosion) was transported to AAIB Farnborough, where it was attached to a specially designed framework to form a fully three-dimensional reconstruction [Appendix B, Figures B-16 and B-17] of the complete fuselage between stations 360 & 1000 (from the separated nose section back to the wing cut out). The support framework was designed to provide full and free access to all parts of the structure, both internally and externally. Because of height constraints, the reconstruction was carried out in two parts, with the structure divided along a horizontal line at approximately the upper cabin floor level. The previously reconstructed containers were also transported to AAIB Farnborough to allow correlation of evidence with, and partial incorporation into, the fuselage reconstruction.

Structure and skin panels were attached to the supporting framework by their last point of attachment, to provide a better appreciation of the modes and direction of curling, distortion, and ultimate separation. Thus, the panels of skin which had petalled back from the shatter zone were attached at their outer edges, so as to identify the bending modes of the panels, the extent of the petalled region, and also the size of the resulting aperture in the hull. In areas more remote from the explosion, the fracture and tear directions were used together with distortion and curling directions to determine the mode of separation, and thus the most appropriate point of attachment to the reconstruction. Cabin floor beam segments were supported on a steel mesh grid and a plot of the beam fractures is shown at Appendix B, Figure B-18.

The cargo container base elements were separated from the rest of the container reconstruction and transferred to the main wreckage reconstruction, where the re-assembled container base was positioned precisely onto the cargo deck. To assist in the correlation of the initial shatter zone and petalled-out regions with the position of the explosive device, the boundaries of the skin panel fractures were marked on a transparent plastic panel which was then attached to the reconstruction to provide a transparent pseudo-skin showing the positions of the skin tear lines. This provided a clear visual indication of the relationship between the skin panel fractures and the explosive damage to the container base, thus providing a more accurate indication of the location of the explosive device.

1.12.3.2 Summary of explosive features evident

The three-dimensional reconstruction provided additional information about the region of tearing and petalling around the shatter zone. It also identified a number of other regions of structural damage, remote from the explosion, which were clearly associated with severe and rapidly applied pressure loads acting normal to the skin's internal surface. These were sufficiently sharp-edged to pre-empt the resolution of pressure induced loads into membrane tension stresses in the skin: instead, the effect was as though these areas of skin had been struck a severe 'pressure blow' from within the hull.

The two types of damage, i.e. the direct blast/tearing/petalling damage and the quite separate areas of 'pressure blow' damage at remote sites were evidently caused by separate mechanisms, though it was equally clear that each was caused by explosive processes, rather than more general disintegration.

The region of petalling was bounded (approximately) by frames 680 and 740, and extended from just below the window belt down nearly to the keel of the aircraft [Appendix B, Figure B-19, region A]. The resulting aperture measured approximately 17 feet by 5 feet. Three major fractures had propagated beyond the boundary of the petalled zone, clearly driven by a combination of hull pressurisation loading and the relatively long term (secondary) pressure pulse from the explosion. These fractures ran as follows:

(i) rearwards and downward in a stepped fashion, joining the stringer 38L lap joint at around station 840, running aft along stringer 38L to around station 920, then stepping down to stringer 39L and running aft to terminate at the wing box cut-out [Appendix B, Figure B-19, fracture 1].
(ii) downwards and forward to join the stringer 44L lap joint, then running forward along stringer 44L as far as station 480 [Appendix B, Figure B-19, fracture 2].
(iii) downwards and rearward, joining the butt line at station 740 to run under the fuselage and up the right side to a position approximately 18 inches above the cabin floor level [Appendix B, Figures B-19 and B-20, fracture 3].

The propagation of tears upwards from the shatter zone appeared to have taken the form of a series of parallel fractures running upwards together before turning towards each other and closing, forming large flaps of skin which appear to have separated relatively cleanly.

Regions of skin separation remote from the site of the explosion were evident in a number of areas. These principally were:

(i) A large section of upper fuselage skin extending from station 500 back to station 760, and from around stringers 15/19L up as far as stringer 5L [Appendix B, Figures B-19 and B-20, region B], and probably extending further up over the crown. This panel had separated initially at its lower forward edge as a result of a pressure blow type of impulse loading, which had popped the heads from the rivets at the butt joint on frame 500 and lifted the skin flap out into the airflow. The remainder of the panel had then torn away rearwards in the airflow.
A region of 'quilting' or 'pillowing', i.e. spherical bulging of skin panels between frames and stringers, was evident on these panels in the region between station 560 and 680, just below the level of the upper deck floor, indicative of high internal pressurisation loading [Appendix B, Figure B-19, region C].
(ii) A smaller section of skin between stations 500 and 580, bounded by stringers 27L and 34L [Appendix B, Figure B-19, region D], had also been 'blown' outwards at its forward edge and torn off the structure rearwards. A characteristic curling of the panel was evident, consistent with rapid, energetic separation from the structure.
(iii) A section of thick belly skin extending from station 560, stringers 40R to 44R, and tapering back to a point at stringer 45R/station720 [Appendix B, Figure B-19 and B-20, region E], had separated from the structure as a result of a very heavy 'pressure blow' load at its forward end which had popped the heads off a large number of substantial skin fasteners. The panel had then torn away rearwards from the structure, curling up tightly onto itself as it did so - indicating that considerable excess energy was involved in the separation process (over and above that needed simply to separate the skin material from its supporting structure).
(iv) A panel of skin on the right side of the aircraft, roughly opposite the explosion, had been torn off the frames, beginning at the top edge of the panel situated just below the window belt and tearing downwards towards the belly [Appendix B, Figure B-20, region F]. This panel was curled downwards in a manner which suggested significant excess energy.

Appendix B, Figure B-21 shows a plot of the fractures noted in the fuselage skins between stations 360 and 1000.

The cabin floor structure was badly disrupted, particularly in the general area above the explosion, where the floor beams had suffered localised upward loading sufficient to fracture them, and the floor panels were missing. Elsewhere, floor beam damage was mainly limited to fractures at the outer ends of the beams and at the centreline, leaving sections of separated floor structure comprising a number of half beams joined together by the Nomex honeycomb floor panels.

1.12.3.3 General damage features not directly associated with explosive forces.

A number of features appeared to be a part of the general structural break-up which followed on from the explosive damage, rather than being a part of the explosive damage process itself. This general break-up was complex and, to a certain extent, random. However, analysis of the fractures, surface scores, paint smears and other features enabled a number of discreet elements of the break-up process to be identified. These elements are summarised below.

(i) Buckling of the window belts on both sides of the aircraft was evident between stations 660 and 800. That on the left side appeared to be the result of in-plane bending in a nose up sense, followed by fracture. The belt on the right side had a large radius curve suggesting lateral deflection of the fuselage possibly accompanied by some longitudinal compression. This terminated in a peeling failure of the riveted joint at station 800.

(ii) On the left side three fractures, apparently resulting from in-plane bending/buckling distortion, had traversed the window belt [Appendix B, Figure B-21, detail G]. Of these, the forward two had broken through the window apertures and the aft fracture had exploited a rivet line at the region of reinforcement just forward of the L2 door aperture. On the right side, the window belt had peeled rearwards, after buckling had occurred, separating from the rest of the fuselage, following rivet failure, at the forward edge of the R2 door aperture.

(iii) All crown skins forward of frame 840 were badly distorted and a number of pieces were missing. It was clearly evident that the skin sections from this region had struck the empennage and/or other structure following separation.

(iv) The fuselage left side lower lobe from station 740 back to the wing box cut-out, and from the window level down to the cargo deck floor (the fracture line along stringer 38L), had peeled outwards, upwards and rearwards - separating from the rest of the fuselage at the window belt. The whole of this separated section had then continued to slide upwards and rearwards, over the fuselage, before being carried back in the slipstream and colliding with the outer leading edge of the right horizontal stabiliser, completely disrupting the outer half. A fragment of horizontal stabiliser spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and

forward of, the L2 door [Appendix B, Figure B-22].
(v) A large, clear, imprint of semi-eliptical form was apparent on the lower right side at station 360 which had evidently been caused by the separating forward fuselage section striking the No 3 engine as it swung rearwards and to the right (confirmed by No 3 engine fan cowl damage).

1.12.3.4 Tailplane three-dimensional reconstruction

The tailplane structural design took the form of a forward and an aft torque box. The forward box was constructed from light gauge aluminium alloy sheet skins, supported by closely pitched, light gauge nose ribs but without lateral stringers. The aft torque box incorporated heavy gauge skin/stringer panels with more widely spaced ribs. The front spar web was of light gauge material. Leading edge impacts inflicted by debris would therefore have had the capacity to reduce the tailplane's structural integrity by passing through the light gauge skins and spar web into the interior of the aft torque box, damaging the shear connection between top and bottom skins in the process and thereby both removing the bending strength of the box and opening up the weakened structure to the direct effects of the airflow.

Examination of the rebuilt tailplane structure at AAIB Farnborough left little doubt that it had been destroyed by debris striking its leading edges. In addition, the presence on the skins of smear marks indicated that some unidentified soft debris had contacted those surfaces whilst moving with both longitudinal and lateral velocity components relative to the aircraft.

The reconstructed left tailplane [Appendix B, Figure B-23] showed evidence that disruption of the inboard leading edge, followed respectively by the forward torque box, front spar web and main torque box, occurred as a result of frontal impact by the base of a baggage container. Further outboard, a compact object appeared to have struck the underside of the leading edge and penetrated to the aft torque box. In both cases, the loss of the shear web of the front spar appeared to have permitted local bending failure of the remaining main torque box structure in a tip downwards sense, consistent with the normal load direction. For both events to have occurred it would be reasonable to assume that the outboard damage preceded that occurring inboard.

The right tailplane exhibited massive leading edge impact damage on the outboard portion which also appeared to have progressed to disruption of the aft torsion box. A fragment of right tailplane spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door and it is clear that this area of forward left fuselage had travelled over the top of the aircraft and contributed to the destruction of the outboard right tailplane.

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1.12.4 Examination of engines

All four engines had struck the ground in Lockerbie with considerable velocity and therefore sustained major damage, in particular to most of the fan blades. The No 3 engine had fallen 1,100 metres north of the other three engines, striking the ground on its rear face, penetrating a road surface and coming to rest without any further change of orientation i.e. with the front face remaining uppermost. The intake area contained a number of loose items originating from within the cabin or baggage hold. It was not possible initially to determine whether any of the general damage to any of the engine fans or the ingestion noted in No 3 engine intake occurred whilst the relevant engines were delivering power or at a later stage.

Numbers 1, 2 and 3 engines were taken to British Airways Engine Overhaul Limited for detailed examination under AAIB supervision in conjunction with a specialist from the Pratt and Whitney Engine Company. During this examination the following points were noted:

(i) No 2 engine (situated closest to the site of the explosion) had evidence of blade "shingling" in the area of the shrouds consistent with the results of major airflow disturbance whilst delivering power. (This effect is produced when random bending and torsional deflection occurs, permitting the mid-span shrouds to disengage and repeatedly strike the adjacent aerofoil surfaces of the blades). The interior of the air intake contained paint smears and other evidence suggesting the passage of items of debris. One such item of significance was a clear indentation produced by a length of cable of diameter and strand size similar to that typically attached to the closure curtains on the baggage containers.

(ii) No 3 engine, identified on site as containing ingested debris from within the aircraft, nonetheless had no evidence of the type of shingling seen on the blades of No 2 engine. Such evidence is usually unmistakable and its absence is a clear indication that No 3 engine did not suffer a major intake airflow disturbance whilst delivering significant power. The intake structure was found to have been crushed longitudinally by an impact on the front face although, as stated earlier, it had struck the ground on its rear face whilst falling vertically.

(iii) All 3 engines had evidence of blade tip rubs on the fan cases having a combination of circumference and depth greater than hitherto seen on any investigation witnessed on Boeing 747 aircraft by the Pratt and Whitney specialists. Subsequent examination of No 4 engine confirmed that it had a similar deep, large circumference tip rub. These tip-rubs on the four engines were centred at slightly different clock positions around their respective fan cases.

The Pratt and Whitney specialists supplied information which was used to interpret the evidence found on the blades and fan cases including details of engine dynamic behaviour necessary to produce the tip rub evidence. This indicated that the depth and circumference of tip rubs noted would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left.

Pratt and Whitney also advised that:

(i) Airflow disruption such as that presumed to have caused the shingling observed on No 2 engine fan blades was almost invariably the result of damage to the fan blade aerofoils, resulting from ingestion or blade failure.
(ii) Tip rubs of a depth and circumference noted on all four engines could be expected to reduce the fan rotational energy on each to a negligible value within approximately 5 seconds.
(iii) Airflow disruption sufficient to cause the extent of shingling noted on the fan blades of No 2 engine would also reduce the rotational fan energy to a negligible value within approximately 5 seconds.

1.13 Medical and pathological information

The results of the post mortem examination of the victims indicated that the majority had experienced severe multiple injuries at different stages, consistent with the in-flight disintegration of the aircraft and ground impact. There was no pathological indication of an in-flight fire and no evidence that any of the victims had been injured by shrapnel from the explosion. There was also no evidence which unequivocally indicated that passengers or cabin crew had been killed or injured by the effects of a blast. Although it is probable that those passengers seated in the immediate vicinity of the explosion would have suffered some injury as a result of blast, this would have been of a secondary or tertiary nature.

Of the casualties from the aircraft, the majority were found in areas which indicated that they had been thrown from the fuselage during the disintegration. Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section. The fragmented remains of 13 passengers who had been allocated seats around the eight missing persons were found in or near the crater formed by the wing. Whilst there is no unequivocal proof that the missing people suffered the same fate, it would seem from the pattern that the missing passengers remained attached to the wing structure until impact.

1.14 Fire

Of the several large pieces of aircraft wreckage which fell in the town of Lockerbie, one was seen to have the appearance of a ball of fire with a trail of flame. Its final path indicated that this was the No 3 engine, which embedded itself in a road in the north-east part of the town. A small post impact fire posed no hazard to adjacent property and was later extinguished with water from a hosereel. The three remaining engines landed in the Netherplace area of the town. One severed a water main and the other two, although initially on fire, were no risk to persons or property and the fires were soon extinguished.

A large, dark, delta shaped object was seen to fall at about the same time in the Sherwood area of the town. It was not on fire while in the air, however, a fireball several hundred feet across followed the impact. It was of relatively short duration and large amounts of debris were thrown into the air, the lighter particles being carried several miles downwind, while larger pieces of burning debris caused further fires, including a major one at the Townfoot Garage, up to 350 metres from the source. It was determined that the major part of both wings, which included the aircraft fuel tanks, had formed the crater. A gas main had also been ruptured during the impact.

At 19.04 hrs the Dumfries Fire Brigade Control received a call from a member of the public which indicated that there had been a "huge boiler explosion" at Westacres, Lockerbie, however, subsequent calls soon made it clear that it was an aircraft which had crashed. At 19.07 hrs the first appliances were mobile and at 1910 hrs one was in attendance in the Rosebank area. Multiple fires were identified and it soon became apparent that a major disaster had occurred in the town and the Fire Brigade Major Incident Plan was implemented. During the initial phase 15 pumping appliances from various brigades were deployed but this number was ultimately increased to 20.

At 22.09 hrs the Firemaster made an assessment of the situation. He reported that there was a series of fires over an area of the town centre extending 1† by € mile. The main concentration of the fire was in the southwest of the town around Sherwood Park and Sherwood Crescent. Appliances were in attendance at other fires in the town, particularly in Park Place and Rosebank Crescent. Water and electricity supplies were interrupted and water had to be brought into the town.

By 02.22 hrs on 22 December, all main seats of fire had been extinguished and the firemen were involved in turning over and damping down. At 04.42 hrs small fires were still occurring but had been confined to the Sherwood Crescent area.

1.15 Survival aspects

1.15.1 Survivability

The accident was not survivable.

1.15.2 Emergency services

A chronology of initial responses by the emergency services is listed below:-

Time Event
19.03 hrs Radio message from Police patrol in Lockerbie to Dumfries and Galloway Constabulary reporting an aircraft crash at Lockerbie.
19.04 hrs Emergency call to Dumfries and Galloway Fire Brigade.
19.37 hrs First ambulances leave for Dumfries and Galloway Royal Infirmary with injured town residents. (2- serious; 3- minor)
19.40 hrs Sherwood Park and Sherwood Crescent residents evacuated to Lockerbie Town Hall.
20.25 hrs Nose section of N739PA discovered at Tundergarth (approximately 4 km east of Lockerbie).

During the next few days a major emergency operation was mounted using the guidelines of the Dumfries and Galloway Regional Peacetime Emergency Plan. The Dumfries and Galloway Constabulary was reinforced by contingents from Strathclyde and Lothian & Borders Constabularies. Resources from HM Forces were made available and this support was subsequently authorised by the Ministry of Defence as Military Aid to the Civil Power. It included the provision of military personnel and a number of helicopters used mainly in the search for and recovery of aircraft wreckage. It was apparent at an early stage that there were no survivors from the aircraft and the search and recovery of bodies was mainly a Police task with military assistance.

Many other agencies were involved in the provision of welfare and support services for the residents of Lockerbie, relatives of the aircraft's occupants and personnel involved in the emergency operation.

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1.16 Tests and research

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity spherically propagating shock wave which will expand outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant because it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter, irrespective of charge size, thus providing a means of calculating the standoff distance of the explosive charge from the fuselage skin. Calculations suggest that a charge standoff distance of aproximately 25 inches would result in a shattered region approximately 18 to 20 inches in diameter, comparable to the size of the shattered region evident in the wreckage. This aspect is covered in greater detail in [Appendix G].

1.17 Additional information

1.17.1 Recorded radar information

Recorded radar information on the aircraft was available from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen from which it was clear that the flight had progressed in a normal manner until secondary surveillance radar (SSR) was lost.

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. The last secondary return from the aircraft was recorded at 19.02:46.9 hrs, identifying N739PA at Flight Level 310, and at the next radar return there is no SSR data, only 4 primary returns. It was concluded that the aircraft was, by this time, no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items had been ejected at high speed probably to both right and left of the aircraft.

Each rotation of the radar head thereafter showed the number of returns increasing, with those first identified across track having slowed down very quickly and followed a track along the prevailing wind line. The radar evidence then indicated that a further break-up of the aircraft had occurred and formed a parallel wreckage trail to the north of the first. From the absence of any returns travelling along track it was concluded that the main wreckage was travelling almost vertically downwards for much of the time.

A detailed analysis of the recorded radar information, together with the radar, ATC and seismic recordings is contained in Appendix C.

1.17.2 Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event measuring 1.6 on the Richter scale and, with appropriate corrections for the times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

An analysis of the seismic recording, together with the radar, ATC and radar information is contained in Appendix C.

1.17.3 Trajectory analysis

A detailed trajectory analysis was carried out by Cranfield Institute of Technology in an effort to provide a sequence for the aircraft disintegration. This analysis comprised several separate processes, including individual trajectory calculations for a limited number of key items of wreckage and mathematical modelling of trajectory paths adopted by a series of hypothetical items of wreckage encompassing the drag/weight spectrum of the actual wreckage.

The work carried out at Cranfield enabled the reasons for the two separate trails to be established. The narrow northern trail was shown to be created by debris released from the aircraft in a vertical dive between 19,000 and 9,000 feet overhead Lockerbie. The southern trail, longer and straight for most of its length, appeared to have been created by wreckage released during the initial disintegration at altitude whilst the aircraft was in level flight. Those items falling closest to Lockerbie would have been those with higher density which would travel a significant distance along track before losing all along-track velocity, whilst only drifting a small distance downwind, owing to the high speed of their descent. The most westerly items thus showed the greatest such effect. The southern trail therefore had curved boundaries at its western end with the curvature becoming progressively less to the east until the wreckage essentially fell in a straight band. Thus wreckage in the southern trail positioned well to the east could be assumed to have retained negligible velocity along aircraft track after separation and the along-track distribution could be used to establish an approximate sequence of initial disintegration.

The analysis calculated impact speeds of 120 kts for the nose section weighing approximately 17,500 lb and 260 kts for the engines and pylons which each weighed about 13,500 lb. Based on the best available data at the time, the analysis showed that the wing (approximately 100,000 lb of structure containing an estimated 200,000 lb of fuel) could have impacted at a speed, in theory, as high as 650 kts if it had 'flown' in a streamlined attitude such that the drag coefficient was minimal. However, because small variations of wing incidence (and various amounts of attached fuselage) could have resulted in significant increases in drag coefficient, the analysis also recognized that the final impact speed of the wing could have been lower.

1.17.4 Space debris re-entry

Four items of space debris were known to have re-entered the Earth's atmosphere on 21 December 1988. Three of these items were fragments of debris which would not have survived re-entry, although their burn up in the upper atmosphere might have been visible from the Earth's surface. The fourth item landed in the USSR at 09.50 hrs UTC.

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2 ANALYSIS

2.1 Introduction

The airport security and criminal aspects of the destruction of Boeing 747 registration N739PA near Lockerbie on 21 December 1988 are the subjects of a separate investigation and are not covered in this report. This analysis discusses the technical aspects of the disintegration of the aircraft and considers possible ways of mitigating the effects of an explosion in the future.

2.2 Explosive destruction of the aircraft

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage, including those exhibiting positive evidence of a detonating high performance plastic explosive. The scatter of these items about the datum line may have been due partly to velocities imparted by the force of the detonating explosive and partly by the difficulty experienced in pinpointing the location of the wreckage accurately in relatively featureless terrain and poor visibility. However, the random nature of the scatter created by these two effects would have tended to counteract one another, and a major error in any one of the eleven grid references would have had little overall effect on the whole line. There is, therefore, good reason to have confidence in the validity of the datum line.

The items used to define the datum line, included those exhibiting positive evidence of a detonating high performance plastic explosive, would have been the first pieces to have been released from the aircraft. The datum line was projected westwards until it intersected the known radar track of the aircraft in order to derive the position of the aircraft along track at which the explosive items were released and therefore the position at which the IED had detonated. This position was OS grid reference 146786 and is annotated Point C in Appendix B, Figure B-4. Point C was well within the circle of accuracy (±525 metres) of the position at which the loud noise was heard on the CVR (Point B). There can, therefore, be no doubt that the loud noise on the CVR was directly associated with the detonation of the IED and that this explosion initiated the disintegration process and directly caused the loss of the aircraft.

2.3 Flight recorders

2.3.1 Digital flight data recordings

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to € second. These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the recording from the DFDR fitted to N739PA, which is detailed in Appendix C, showed that the recorded data simply stopped. Following careful examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19.02:50 hrs ±1 second. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or was old data from a previous recording.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when the aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

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2.3.2 Cockpit voice recorders

The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the CVR when it stopped at 19.02:50 hrs ±1 second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

2.3.3 Detection of explosive occurrences

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985, RARDE were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems. This recommendation was accepted.

Preliminary results from the trials indicate that, if a suitable sensor can be developed, its output will need to be recorded in real time and therefore it may require wiring to the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

2.4 IED position within the aircraft

From the detailed examination of the reconstructed luggage containers, discussed at paragraph 1.12.2.4 and in Appendix F, it was evident that the IED had been located within a metal container (serial number AVE 4041 PA), near its aft outboard quarter as shown in Appendix F, Figure F-13. It was also clear that the container was loaded in position 14L of the forward hold which placed the explosive charge approximately 25 inches inboard from the fuselage skin at frame 700. There was no evidence to indicate that there was more than one explosive charge.

2.5 Engine evidence

To produce the fan blade tip rub damage noted on all engines by means of airflow inclined to the axes of the nacelles would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left while all of the engines were attached to the wing.

The shingling damage noted on the fan blades of No 2 engine can only be attributed to airflow disturbance caused by ingestion related fan blade damage occurring when substantial power was being delivered. This is readily explained by the fact that No 2 engine intake is positioned some 27 feet aft and 30 feet outboard of the site of the explosion and that the interior of the intake exhibited a number of prominent paint smears and general foreign object damage. This damage included evidence of a strike by a cable similar to that forming part of the closure curtain of a typical baggage container. It is inconceivable that an independent blade failure could have occurred in the short time frame of this event. By similar reasoning, the absence of such shingling damage on blades of No 3 engine was a reliable indication that it suffered no ingestion until well into the accident sequence.

The combination of the position of the explosive device and the forward speed of the aircraft was such that significant sized debris resulting from the explosion would have been available to be ingested by No 2 engine within milliseconds of the explosion. In view of the fact that the tip rub damage observed on the fan case of No 2 engine is of similar magnitude to that observed on the other three engines it is reasonable to deduce that a manoeuvre of the aircraft occurred before most of the energy of the No 2 engine fan was lost due to the effect of ingestion (seen only in this engine). Since this shingling effect could only readily be produced as a by-product of ingestion whilst delivering considerable power, it is reasonable to assume that this was also occurring before loss of major fan energy due to tip rubbing took place. Hence both phenomena must have been occurring simultaneously, or nearly so, to produce the effects observed and must have occupied a time frame of substantially less than 5 seconds. The onset of this time period would have been the time at which debris from the explosion first inflicted damage to fan blades in No 3 engine and, since the fan is only approximately 40 feet from the location of the explosive device, this would have been an insignificant time interval after the explosion.

It was therefore concluded from this evidence that the wing with all of the engines attached had achieved a marked nose down and left roll attitude change well within 5 seconds of the explosion.

2.6 Detachment of forward fuselage

Examination of the three major structural elements either side of the region of station 800 on the right side of the fuselage makes it clear that to produce the curvature of the window belt and peeling of the riveted joint at the R2 door aperture requires the door pillar to be securely in position and able to react longitudinal and lateral loads. This in turn requires the large section of fuselage on the right side between stations 760 and 1000 (incorporating the right half of the floor) to be in position in order to locate the lower end of the door pillar. Thus both these sections must have been in position until the section from station 560 to 800 (right side) had completed its deflection to the right and peeled from the door pillar. Separation of the forward fuselage must thus have been complete by the time all three items mentioned above had fallen free.

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2.7 Speed of initial disintegration

The distribution of wreckage in the bands between the datum line and the 250, 300, 600 and 900 metre lines was examined in detail. The positions of these items of structure on the aircraft are shown in Appendix B, Figures B-10 to B-13. It should be noted that the position on the ground of these items, although separated by small distances when measured in a direction along aircraft track, were distributed over large distances when measured along the wreckage trail. All were recovered from positions far enough to the east to be in that part of the southern trail which was sufficiently close, theoretically, to a straight line for any curvature effect to be neglected.

The wreckage found in each of the bands enabled an approximate sequence of break-up to be established. It was clear that as the distance travelled from the datum line increased, items of wreckage further from the station of the IED were encountered. The items shown on the diagram as falling on the 250 metre band also include those fragments of lower forward fuselage skin having evidence of explosive damage and presumed to have separated as a direct result of the blast. However, a few portions of the upper forward fuselage were also found within the 250 metre band, suggesting that these items had also separated as a result of the blast.

By the time the 300 metre line was reached much of the structure from the right side in the region of the explosive device had been shed. This included the area of window belt, referred to in paragraph 2.6 above, which gave clear indications that the forward structure had detached to the right and finally peeled away at station 800. It also included the areas of adjacent structure immediately to the rear of station 800 about which the forward structure would have had to pivot. By the time the 600 metre line was reached, there was clearly insufficient structure left to connect the forward fuselage with the remainder of the aircraft. Wreckage between the 600 and 900 metre lines consisted of structure still further from the site of the IED.

There is evidence that a manoeuvre occurred at the time of the explosion which would have produced a significant change of the aircraft's flight path, however, it is considered that the change in the horizontal velocity component in the first few seconds would not have been great. The original groundspeed of the aircraft was therefore used in conjunction with the distribution of wreckage in the successive bands to establish an approximate time sequence of break-up of the forward fuselage. Assuming the original ground speed of 434 Kts, the elapsed flight times from the datum to each of the parellel lines were calculated to be:

Distance (metres)	250	300	600	900

Time (seconds)	1.1	1.3	2.7	4.0

Thus, there is little doubt that separation of the forward fuselage was complete within 2 to 3 seconds of the explosion.

The separate assessment of the known grid references of tailplane and elevator wreckage in the southern trail revealed that those items were evenly distributed about the 600 metre line and therefore that most of the tailplane damage occurred after separation of the forward fuselage was complete.

2.8 The manoeuvre following the explosion

The engine evidence, timing and mode of disintegration of the fuselage and tailplane suggests that the latter did not sustain significant damage until the forward fuselage disintegration was well advanced and the pitch/roll manoeuvre was also well under way.

Examination of the three dimensional reconstruction makes it clear that both main and upper deck floors were disrupted by the explosion. Since pitch control cables are routed through the upper deck floor beams and the roll control cables through the main deck beams, there is a strong possibility that movement of the beams under explosive forces would have applied inputs to the control cables, thus operating control surfaces in both axes.

2.9 Secondary disintegration

The distribution of fin debris between the trails suggests that disintegration of the fin began shortly before the vertical descent was established. No single mode of failure was identified and the debris which had struck the leading edge had not caused major disruption. The considerable fragmentation of the thick panels of the aft torque box was also very different from that noted on the corresponding structure of the tailplanes. It was therefore concluded that the mode of failure was probably flutter.

The finding, in the northern trail, of a slide raft wrapped around a flap track fairing suggests that at a later stage of the disintegration the rear of the aircraft must have experienced a large angle of sideslip. The loss of the fin would have made this possible and also subjected the structure to large side loads. It is possible that such side loading would have assisted the disintegration of the rear fuselage and also have caused bending failure of the pylon attachments of the remaining three engines.

2.10 Impact speed of components

The trajectory analysis carried out by Cranfield Institute of Technology calculated impact speeds of 120 kts for the nose section, and 260 kts for the engines and pylons. These values were considered to be reliable because the drag coefficients could be estimated with a reasonable degree of confidence. Based on the best available data at the time, the analysis also showed that the wing could have impacted at a speed, in theory, as high as 650 kts if it had flown in a streamlined attitude such that the drag coefficient was minimal. However, it was also recognized that relatively small changes in the angle of incidence of the wing would have produced a significant increase in drag with a consequent reduction in impact speed. Refinement of timing information and radar data subsequent to the Cranfield analysis has enabled a revised estimate to be made of the mean speed of the wing during the descent.

The engine evidence indicated that there had been a large nose down attitude change of the aircraft early in the event. The Cranfield analysis also showed that the rear fuselage had disintegrated while essentially in a vertical descent between 19,000 and 9,000 feet over Lockerbie. Assuming that, following the explosion, the wing followed a straight line descending flight profile from 31,000 feet to 19,000 feet directly overhead Lockerbie and then descended vertically until impact, the wing would have travelled the minimum distance practicable. The ground distance between the geographical position at which the disintegration started (Figure B-4, Point B) and the crater made by the wing impact was 2997 ±525 metres (9833 ±1722 feet). The time interval between the explosion and the wing impact was established in Appendix C as 46.5 ±2 seconds. Based on the above times and distances the mean linear speed achieved by the wing would have been about 440 kts.

The impact location of Nos 1, 2, and 4 engines closely grouped in Lockerbie was consistent with their nearly vertical fall from a point above the town. If they had separated at about 19,000 feet and the wing had then flown as much as one mile away from the overhead position before tracking back to impact, the total flight path length of the wing would not have required it to have achieved a mean linear speed in excess of 500 kts.

Any speculation that the flight path of the wing could have been longer would have required it to have undergone manoeuvres at high speed in order to arrive at the 19,000 feet point. The manoeuvres involved would almost certainly have resulted in failure of the primary wing structure which, from distribution of wing debris, clearly did not occur. Alternatively the wing could have travelled more than one mile from Lockerbie after reaching the 19,000 feet point, but this was considered unlikely. It is therefore concluded that the mean speed of the wing during the descent was in the region of 440 to 500 kts.

2.11 Sequence of disintegration

Analysis of wreckage in each of the bands, taken in conjunction with the engine evidence and the three-dimensional reconstruction, suggests the following sequence of disintegration:

(i) The initial explosion triggered a sequence of events which effectively destroyed the structural integrity of the forward fuselage. Little more then remained between stations 560 and 760 (approximately) than the window belts and the cabin sidewall structure immediately above and below the windows, although much of the cargo-hold floor structure appears to have remained briefly attached to the aircraft. [Appendix B, Figure B-24]

(ii) The main portion of the aircraft simultaneously entered a manoeuvre involving a marked nose down and left roll attitude change, probably as a result of inputs applied to the flying control cables by movement of structure.

(iii) Failure of the left window belt then occurred, probably in the region of station 710, as a result of torsional and bending loads on the fuselage imparted by the manoeuvre (i.e. the movement of the forward fuselage relative to the remainder of the aircraft was an initial twisting motion to the right, accompanied by a nose up pitching deflection).

(iv) The forward fuselage deflected to the right, pivoting about the starboard window belt, and then peeled away from the structure at station 800. During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation was apparently complete within 3 seconds of the explosion.

(v) Structure and contents of the forward fuselage struck the tail surfaces contributing to the destruction of the outboard starboard tailplane and causing substantial damage to the port unit. This damage occurred approximately 600 metres track distance after the explosion and therefore appears to have happened after the fuselage separation was complete.

(vi) Fuselage structure continued to break away from the aircraft and the separated forward fuselage section as they descended.

(vii) The aircraft maintained a steepening descent path until it reached the vertical in the region of 19,000 feet approximately over the final impact point. Shortly before it did so the tail fin began to disintegrate.

(viii) The mode of failure of the fin is not clear, however, flutter of its structure is suspected.

(ix) Once established in the vertical dive, the fin torque box continued to disintegrate, possibly permitting the remainder of the aircraft to yaw sufficiently to cause side load separation of Nos 1, 2 and 4 engines, complete with their pylons.

(x) Break-up of the rear fuselage occurred during the vertical descent, possibly as a result of loads induced by the yaw, leaving a section of cabin floor and baggage hold from approximately stations 1241 to 1920, together with 3 landing gear units, to fall into housing at Rosebank Terrace.

(xi) The main wing structure struck the ground with a high yaw angle at Sherwood Crescent.

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2.12 Explosive mechanisms and the structural disintegration

The fracture and damage pattern analysis was mainly of an interpretive nature involving interlocking pieces of subtle evidence such as paint smears, fracture and rivet failure characteristics, and other complex features. In the interests of brevity, this analysis will not discuss the detailed interpretation of individual fractures or damage features. Instead, the broader 'damage picture' which emerged from the detailed work will be discussed in the context of the explosive mechanisms which might have produced the damage, with a view to identifying those features of greatest significance.

It is important to keep in mind that whilst the processes involved are considered and discussed separately, the timescales associated with shock wave propagation and the high velocity gas flows are very short compared with the structural response timescales. Consequently, material which was shattered or broken by the explosive forces would have remained in place for a sufficiently long time that the structure can be considered to have been intact throughout much of the period that these explosive propagation phenomena were taking place.

2.12.1 Direct blast effect

2.12.1.1 Shock wave propagation

The direct effect of the explosive detonation within the container was to produce a high intensity spherically propagating shock wave which expanded from the centre of detonation close to the side of the container, shattering part of the side and base of the container as it passed through into the gap between the container and the fuselage skin. In breaking out of the container, some internal reflection and Mach stem interaction would have occurred, but this would have been limited by the absorptive effect of the baggage inboard, above, and forward of the charge. The force of the explosion breaking out of the container would therefore have been directed downwards and rearwards.

The heavy container base was distorted and torn downwards, causing buckling of the adjoining section of frame 700, and the container sides were blasted through and torn, particularly in the aft lower corner. Some of the material in the direct path of the explosive pressure front was reduced to shrapnel sized pieces which were rapidly accelerated outwards behind the primary shock front. Because of the overhang of the container's sloping side, fragments from both the device itself and the container wall impacted the projecting external flange of the container base edge member, producing micro cratering and sooting. Metallurgical examination of the internal surfaces of these craters identified areas of melting and other features which were consistent only with the impact of very high energy particles produced by an explosion at close quarters. Analysis of material on the crater surfaces confirmed the presence of several elements and compounds foreign to the composition of the edge member, including material consistent with the composition of the sheet aluminium forming the sloping face of the container.

On reaching the inner surface of the fuselage skin, the incident shock wave energy would partially have been absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of its energy would have been transmitted, as a shock wave, through the skin and into the atmosphere [Appendix B, Figure B-25], but a significant amount of energy would have been returned as a reflected shock wave, back into the cavity between the container and the fuselage skin where Mach stem shock waves would have been formed. Evidence of rapid shattering was found in a region approximately bounded by frames 700 & 720 and stringers 38L & 40L, together with the lap joint at 39L.

The shattered fuselage skin would have taken a significant time to move, relative to the timescales associated with the primary shock wave propagation. Clear evidence of soot and small impact craters were apparent on the internal surfaces of all fragments of container and structure from the shatter zone, confirming that the this material had not had time to move before it was hit by the cloud of shrapnel, unburnt explosive residues and sooty combustion products generated at the seat of the explosion.

Following immediately behind the primary shock wave, a secondary high pressure wave - partly caused by reflections off the baggage behind the explosive material but mainly by the general pressure rise caused by the chemical conversion of solid explosive material to high temperature gas - emerged from the container. The effect of this second pressure front, which would have been more sustained and spread over a much larger area, was to cause the fuselage skin to stretch and blister outwards before bursting and petalling back in a star-burst pattern, with rapidly running tear fractures propagating away from a focus at the shatter zone. The release of stored energy as the skin ruptured, combined with the outflow of high pressure gas through the aperture, produced a characteristic curling of the skin 'petals' - even against the slipstream. For the most part, the skins which petalled back in this manner were torn from the frames and stringers, but the frames and stringers themselves were also fractured and became separated from the rest of the structure, producing a very large jagged hole some 5 feet longitudinally by 17 feet circumferentially (upwards to a region just below the window belt and downwards virtually to the centre line).

From this large jagged hole, three of the fractures continued to propagate away from the hole instead of terminating at the boundary. One fracture propagated longitudinally rearwards as far as the wing cut-out and another forwards to station 480, creating a continuous longitudinal fracture some 43 feet in length. A third fracture propagated circumferentially downwards along frame 740, under the belly, and up the right side of the fuselage almost as far as the window belt - a distance of approximately 23 feet.

These extended fractures all involved tearing or related failure modes, sometimes exploiting rivet lines and tearing from rivet hole to rivet hole, in other areas tearing along the full skin section adjacent to rivet lines, but separate from them. Although the fractures had, in part, followed lap joints, the actual failure modes indicated that the joints themselves were not inherently weak, either as design features or in respect of corrosion or the conditions of the joints on this particular aircraft.

Note: The cold bond process carried out at manufacture on the lap joints had areas of disbonding prior to the accident. This disbonding is a known feature of early Boeing 747 aircraft which, by itself, does not detract from the structural integrity of the hull. The cold bond adhesive was used to improve the distribution of shear load across the joint, thus reducing shear transfer via the fasteners and improving the resistance of the joint to fatigue damage; the fasteners were designed to carry the full static loading requirements of the joint without any contribution from the adhesive. Thus, the loss of the cold bond integrity would only have been significant if it had resulted in the growth of fatigue cracks, or corrosion induced weaknesses, which had then been exploited by the explosive forces. No evidence of fatigue cracking was found in the bonded joints. Inter-surface corrosion was present on most lap joints but only one very small region of corrosion had resulted in significant material thinning; this was remote from the critical region and had not played any part in the break-up.

The cracks propagating upwards as part of the petalling process did not extend beyond the window line. The wreckage evidence suggests that the vertical fractures merged, effectively closing off the fracture path to produce a relatively clean bounding edge to the upper section of the otherwise jagged hole produced by the petalling process. There are at least two probable reasons for this. Firstly the petalling fractures above the shattered zone did not diverge, as they had tended to do elsewhere. Instead, it appears that a large skin panel separated and peeled upwards very rapidly producing tears at each side which ran upwards following almost parallel paths. However, there are indications that by the time the fractures had run several feet, the velocity of fracture had slowed sufficiently to allow the free (forward) edge of the skin panel to overtake the fracture fronts, as it flexed upwards, and forcibly strike the fuselage skin above, producing clear witness marks on both items. Such a tearing process, in which an approximately rectangular flap of skin is pulled upwards away from the main skin panel, is likely to result in the fractures merging. Secondly, this merging tendency would have been reinforced in this particular instance by the stiff window belt ahead of the fractures, which would have tended to turn the fractures towards the horizontal.

It appears that the presence of this initial ('clean') hole, together with the stiff window belt above, encouraged other more slowly running tears to break into it, rather than propagating outwards away from the main hole.

2.12.1.2 Critical crack considerations

The three very large tears extending beyond the boundary of the petalled region resulted in a critical reduction of fuselage structural integrity.

Calculations were carried out at the Royal Aerospace Establishment to determine whether these fractures, growing outwards from the boundary of the petalled hole, could have occurred purely as a result of normal differential pressure loading of the fuselage, or whether explosive forces were required in addition to the pressurisation loads.

Preliminary calculations of critical crack dimensions for a fuselage skin punctured by a 20 by 20 inches jagged hole indicated that unstable crack growth would not have occurred unless the skin stress had been substantially greater than the stress level due to normal pressurisation loads alone. It was therefore clear that explosive overpressure must have produced the gross enlargement of the initially small shattered hole in the hull. Furthermore, it was apparent from the degree of curling and petalling of the skin panels within the star-burst region that this overpressure had been relatively long term, compared with the shock wave overpressure which had produced the shatter zone. A more refined analysis of critical crack growth parameters was therefore carried out in which it was assumed that the long term explosive overpressure was produced by the chemical conversion of solid explosive material into high temperature gas.

An outline of the fracture propagation analysis is given at Appendix D. This analysis, using theoretical fracture mechanics, showed that, after the incident shock wave had produced the shatter zone, significant explosive overpressure loads were needed to drive the star-burst fractures out to the boundary of the petalled skin zone. Thereafter, residual gas overpressure combined with fuselage pressurisation loads were sufficient to produce the two major longitudinal cracks and a single major circumferential crack, extending from the window belt down to beyond the keel centreline.

2.12.1.3 Damage to the cabin floor structure

The floor beams in the region immediately above the baggage container in which the explosive had detonated were extensively broken, displaying clear indications of overload failure due to buckling caused by localised upward loading of the floor structure.

No direct evidence of bruising was found on the top panel of the container. It therefore appears that the container did not itself impact the floor beams, but instead the floor immediately above the container was broken through as a result of explosive overpressure as gases emerged from the ruptured container and loaded the floor panels. Data on floor strengths, provided by Boeing, indicated that the cabin floor (with the CRAF modification) would fail at a uniform static differential pressure of between 3.5 and 3.9 psi (high pressure below the cabin floor), and that the floor panel to floor beam attachments would not fail before the floor beams. Whilst there is no direct evidence of the pressure loading on the floor structure immediately following detonation, there can be no doubt that in the region of station 700 it would have exceeded the ultimate failure load by a large margin.

2.12.2 Indirect explosive damage (damage at remote sites)

All of the damage considered in the foregoing analysis, and the mechanisms giving rise to that damage, resulted from the direct impact of explosive shock waves and/or the short-term explosive overpressure on structure close to the source of the explosion. However, there were several regions of skin separation at sites remote from the explosion (see para 1.12.3.2) which were much more difficult to understand. These remote sites formed islands of indirect explosive damage separated from the direct damage by a sea of more generalised structural failure characterised by the progressive aerodynamic break-up of the weakened forward fuselage. All of these remote damage sites were consistent with the impact of very localised pressure impulses on the internal surfaces of the hull -effectively high energy 'pressure blows' against the inner surfaces produced by explosive shock waves and/or high pressure gas flows travelling through the interior spaces of the hull.

The propagation of explosive shock waves and supersonic gas flows within multiple, interlinking, cavities having indeterminate energy absorption and reflection properties, and ill-defined structural response, is extremely complex. Work has been initiated in an attempt to produce a three-dimensional computer analysis of the shock wave and supersonic flow propagation inside the fuselage, but full theoretical analysis is beyond present resources.

Because of the complexity of the problem, the following analysis will be restricted to a qualitative consideration of the processes which were likely to have taken place. Whilst such an approach is necessarily limited, it has identified a number of propagation mechanisms which appear to have been of fundamental importance to the break-up of Flight PA103, and which are likely to be critical in any future incident involving the detonation of high explosive inside an aircraft hull.

2.12.2.1 Shock wave propagation through internal cavities

When Mach stem shocks are produced not only are the shock pressures very high but they propagate at very high velocity parallel to the reflecting surface. In the context of the lower fuselage structure in the region of Mach stem formation, it can readily be seen that the Mach stem will be perfectly orientated to enter the narrow cavity formed between the outer skin and the cargo liner/containers, bounded by the fuselage frames [Appendix B, Figure B-25]. This cavity enables the Mach stem shock wave to propagate, without causing damage to the walls (due to the relatively low pressure where the Mach stem sweeps their surface), and reach regions of the fuselage remote from the source of the explosion. Furthermore, energy losses in the cavity are likely to be less than would occur in the 'free' propagation case, resulting in the efficient transmission of explosive energy. The cavity would tend to act like a 'shock tube', used for high speed aerodynamic research, confining the shock wave and keeping it running along the cavity axis, with losses being limited to kinetic heating due to friction at the walls.

Paragraph 1.6.3 contains a general description of the structural arrangements in the area of the cargo hold. Before proceeding further and considering how the shock waves might have propagated through this network of cavities, it should be pointed out that the timescale associated with the propagation of the shock waves is very short compared with the timescale associated with physical movement and separation of skin and structure fractured or damaged by the shock. Therefore, for the purpose of assessing the shock propagation through the cavities, the explosive damage to the hull can be ignored and the structure regarded as being intact. A further simplification can usefully be made by considering the structure to be rigid. This assumption would, if the analysis were quantitative, result in over-estimations of the shock strengths. However, for the purposes of a purely qualitative assessment, the assumption should be valid, in that the general trends of behaviour should not be materially altered.

It has already been argued that the shock wave emerging from the container was, in part, reflected back off the inner surface of the fuselage skin, forming a Mach stem shock wave which would then have tended to travel into the semi-circular lower lobe cavity. The Mach stem waves would have propagated away through this cavity in two directions:

(i) under the belly, between the frames [Appendix B, Figure B-3, detail A], and
(ii) up the left side, expanding into the cavity formed by the longitudinal manifold chamber where it joins the lower lobe cavity.

As the shock waves travelled along the cavity, little attenuation or other change of characteristic was likely to have occurred until the shocks passed the entrances to other cavities, or impinged upon projections and other local changes in the cavity. A review of the literature dealing with propagation of blast waves within such cavities provides useful insights into some of the physical mechanisms involved.

As part of a research program carried out into the design of ventilation systems for blast hardened installations intended to survive the long duration blast waves following the detonation of nuclear weapons, the propagation of blast waves along the primary passages and into the side branches of ventilation ducts was studied. The research showed that 90¡ bends in the ducts produced very little attenuation of shock wave pressure; a series of six right angle bends produced only a 30% pressure attenuation, together with an extension of the shock duration. It is therefore evident that the attenuation of shock waves propagating through the fuselage cavities, all of which were short with hardly any right angle turns, would have been minimal.

It was also demonstrated that secondary shock waves develop within the entrance to any side branch from the main duct, produced by the interaction of the primary shock wave with the geometric changes in the duct walls at the side-branch location. These secondary shock waves interact as they propagate into the side branch, combining together within a relatively short distance (typically 7 diameters) to produce a single, plane shock wave travelling along the duct axis. In a rigid, smooth walled structure, this mechanism produces secondary shock overpressures in the side branch of between 30% and 50% of the value of the primary shock, together with a corresponding attenuation of the primary shock wave pressure by approximately 20% to 25%.

This potential for the splitting up and re-transmission of shock wave energy within the lower hull cavities is of extreme importance in the context of this accident. Though the precise form of the interactions is too complex to predict quantitatively, it is evident that the lower hull cavities will serve to convey the overpressure efficiently to other parts of the aircraft. Furthermore, the cavities are not of serial form, i.e. they do not simply branch (and branch again) in a divergent manner, but instead form a parallel network of short cavities which reconnect with each other at many different points, principally along the crease beams. Thus, considerable scope exists for: the additive recombination of blast waves at cavity junctions; for the sustaining of the shock overpressure over a greater time period; and, for the generation of multiple shocks produced by the delay in shock propagation inherent in the different shock path (i.e. cavity) lengths.

Whilst it has not been possible to find a specific mechanism to explain the regions of localised skin separation and peel-back (i.e. the 'pressure blow' regions referred to in para 2.12.2), they were almost certainly the result of high intensity shock overpressures produced locally in those regions as a result of the additive recombination of shock waves transmitted through the lower hull cavities. It is considered that the relatively close proximity of the left side region of damage just below floor level at station 500, [Appendix B, Figure B-19, region D] to the forward end of the cargo hold may be significant insofar as the reflections back from the forward end of the hold would have produced a local enhancement of the shock overpressure. Similarly, 'end blockage effects' produced by the cargo door frame might have been responsible for local enhancements in the area of the belly skin separation and curl-back at station

560 [Appendix B, Figure B-19 and B-20, region E].

The separation of the large section of upper fuselage skin [Appendix B, Figure B-19 and B-20, detail B] was almost certainly associated with a local overpressure in the side cavities between the main deck window line and the upper deck floor, where the cavity is effectively closed off. It is considered that the most probable mechanism producing this region of impulse overpressure was a reflection from the closed end of the cavity, possibly combined with further secondary reflections from the window assembly, the whole being driven by reflective overpressures at the forward end of the longitudinal manifold cavity caused by the forward end of the cargo hold. The local overpressure inside the sidewall cavity would have been backed up by a general cabin overpressure resulting from the floor breakthrough, giving rise to an increased pressure acting on the inner face of the cabin side liner panels. This would have provided pseudo mass to the panels, effectively preventing them from moving inwards and allowing them to react the impulse pressure within the cavity, producing the region of local high pressure evidenced by the region of quilting on the skin panels [Appendix B, Figure B-19, region C].

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2.12.2.2 Propagation of shock waves into the cabin

The design of the air-conditioning/depressurisation-venting systems on the Boeing 747 (and on most other commercial aircraft) is seen as a significant factor in the transmission of explosive energy, as it provides a direct connection between the main passenger cabin and the lower hull at the confluence of the lower hull cavities below the crease beam. The floor level air conditioning vents along the length of the cabin provided a series of apertures through which explosive shock waves, propagating through the sub floor cavities, would have radiated into the main cabin.

Once the shock waves entered the cabin space, the form of propagation would have been significantly different from that which occurred in the cavities in the lower hull. Again, the precise form of such radiation cannot be predicted, but it is clear that the energy would potentially have been high and there would also (potentially) have been a large number of shock waves radiating into the cabin, both from individual vents and in total, with further potential to recombine additively or to 'follow one another up' producing, in effect, sustained shock overpressures.

Within the cabin, the presence of hard, reflective, surfaces are likely to have been significant. Again, the precise way in which the shock waves interacted is vastly beyond the scope of current analytical methods and computing power, but there clearly was considerable potential for additive recombination of the many different shock waves entering at different points along the cabin and the reflected shock waves off hard surfaces in the cabin space, such as the toilet and galley compartments and overhead lockers. These recombination effects, though not understood, are known phenomena. Appendix B, Figure B-26 shows how shock waves radiating from floor level might have been reflected in such a way as produce shock loading on a localised area of the pressure hull.

2.12.2.3 Supersonic gas flows

The gas produced by the explosive would have resulted in a supersonic flow of very high pressure gas through the structural cavities, which would have followed up closely behind the shock waves. Whilst the physical mechanisms of propagation would have been different from those of the shock wave, the end result would have been similar, i.e. there would have been propagation via multiple, linked paths, with potential for additive recombination and successive pressure pulses resulting from differing path lengths. Essentially, the shock waves are likely to have delivered initial 'pressure blows' which would then have been followed up immediately by more sustained pressures resulting from the high pressure supersonic gas flows.

2.13 Potential limitation of explosive damage

Quite clearly the detonation of high explosive material anywhere on board an aircraft is potentially catastrophic and the most effective means of protecting lives is to stop such material entering the aircraft in the first place. However, it is recognised that such risks cannot be eliminated entirely and it is therefore essential that means are sought to reduce the vulnerability of commercial aircraft structures to explosive damage.

The processes which take place when an explosive detonates inside an aircraft fuselage are complex and, to a large extent, fickle in terms of the precise manner in which the processes occur. Furthermore, the potential variation in charge size, position within the hull, and the nature of the materials in the immediate vicinity of the charge (baggage etc) are such that it would be unrealistic to expect to neutralise successfully the effect of every potential explosive device likely to be placed on board an aircraft. However, whilst the problem is intractable so far as a total solution is concerned, it should be possible to limit the damage caused by an explosive device inside a baggage container on a Boeing 747 or similar aircraft to a degree which would allow the aircraft to land successfully, albeit with severe local damage and perhaps resulting in some loss of life or injuries.

In Appendix E the problem of reducing the vulnerability of commercial aircraft to explosive damage is discussed, both in general terms and in the context of aircraft of similar size and form to the Boeing 747. In that discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution.

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2.14 Summary

It was established that the detonation of an IED, loaded in a luggage container positioned on the left side of the forward cargo hold, directly caused the loss of the aircraft. The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential. The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion. The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage, allow the nose and flight deck area to detach within a period of 2 to 3 seconds, and subsequently allow most of the remaining aircraft to disintegrate while it was descending nearly vertically from 19,000 to 9,000 feet.

The investigation has enabled a better understanding to be gained of the explosive processes involved in such an event and to suggest ways in which the effects of such an explosion might be mitigated, both by changes to future design and also by retrospective modification of aircraft. It is therefore recommended that Regulatory Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft structure and systems to explosive damage.

3. CONCLUSIONS

(a) Findings

(i) The crew were properly licenced and medically fit to conduct the flight.

(ii) The aircraft had a valid Certificate of Airworthiness and had been maintained in compliance with the regulations.

(iii) There was no evidence of any defect or malfunction in the aircraft that could have caused or contributed to the accident.

(iv) The structure was in good condition and the minimal areas of corrosion did not contribute to the in-flight disintegration.

(v) One minor fatigue crack approximately 3 inches long was found in the fuselage skin but this had not been exploited during the disintegration.

(vi) An improvised explosive device detonated in luggage container serial number AVE 4041 PA which had been loaded at position 14L in the forward hold. This placed the device approximately 25 inches inboard from the skin on the lower left side of the fuselage at station 700.

(vii) The analysis of the flight recorders, using currently accepted techniques, did not reveal positive evidence of an explosive event.

(viii) The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential.

(ix) The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion.

(x) The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage.

(xi) Containers and items of cargo ejected from the fuselage aperture in the forward hold, together with pieces of detached structure, collided with the empennage severing most of the left tailplane, disrupting the outer half of the right tailplane, and damaging the fin leading edge structure.

(xii) The forward fuselage and flight deck area separated from the remaining structure within a period of 2 to 3 seconds.

(xiii) The No 3 engine detached when it was hit by the separating forward fuselage.

(xiv) Most of the remaining aircraft disintegrated while it was descending nearly vertically from 19,000 to 9,000 feet.

(xv) The wing impacted in the town of Lockerbie producing a large crater and creating a fireball.

(b) Cause

The in-flight disintegration of the aircraft was caused by the detonation of an improvised explosive device located in a baggage container positioned on the left side of the forward cargo hold at aircraft station 700.

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4. SAFETY RECOMMENDATIONS

The following Safety Recommendations were made during the course of the investigation :

4.1 That manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and the data recoverable after power loss.

4.2 That Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

4.3 That Airworthiness Authorities consider requiring the CVR system to contain a short duration, i.e. no greater than 1 minute, back-up power supply to enable the CVR to respond to events that result in the almost immediate loss of the aircraft's electrical power supply.

4.4 That the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

4.5 That Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of aircraft structure and systems to explosive damage.

M M Charles
Inspector of Accidents
Department of Transport

July 1990

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APPENDIX A

PERSONNEL CONDUCTING THE INVESTIGATION

The following Inspectors of the Air Accidents Investigation Branch conducted the investigation:

Mr M M Charles	Investigator-in-Charge
Mr D F King	Principal Inspector (Engineering)
Mr P F Sheppard	Assistant Principal Inspector (Engineering)
Mr A N Cable	Senior Inspector (Engineering)
Mr R G Carter	Senior Inspector (Engineering)
Mr P T Claiden	Senior Inspector (Engineering)
Mr P R Coombs	Senior Inspector (Engineering)
Mr S R Culling	Senior Inspector (Engineering)
Miss A Evans	Senior Inspector (Engineering)
Mr B M E Forward	Senior Inspector (Operations)
Mr P N Giles	Senior Inspector (Operations)
Mr S W Moss	Senior Inspector (Engineering)
Mr R Parkinson	Senior Inspector (Engineering)
Mr J D Payling	Senior Inspector (Operations)
Mr C G Pollard	Senior Inspector (Engineering)
Mr C A Protheroe	Senior Inspector (Engineering)
Mr A H Robinson	Senior Inspector (Engineering)
Mr A P Simmons	Senior Inspector (Engineering)
Mr R G Vance	Senior Inspector (Engineering)
Mr R StJ Whidborne	Senior Inspector (Operations)

The Air Accidents Investigation Branch would like to thank the following organisations from the United Kingdom, United States of America, France, and Canada who participated in the investigation:

Air Line Pilot's Association International

Boeing Commercial Airplane Company

British Airways

British Army

British Geological Survey

Bureau Enquete Accidents

Canadian Aviation Safety Bureau

Civil Aviation Authority

Cranfield Institute of Technology

Federal Aviation Administration

Federal Bureau of Investigation

Independent Union of Flight Attendants

National Transportation Safety Board

Pan American World Airways

Police Service

Royal Aerospace Establishment

Royal Air Force

Royal Armaments Research and Development Establishment

Royal Navy

Royal Ordnance

Royal Signals and Radar Establishment

United Technologies International Operations (Pratt and Whitney)

The Air Accidents Investigation Branch would also like to acknowledge the excellent work of the Dumfries & Galloway Regional Council and to thank all the many voluntary organisations who gave such unstinting support to the investigation.

APPENDIX C

ANALYSIS OF RECORDED DATA

1. Introduction

This appendix describes and analyses the different types of recorded data which were examined during the investigation of the accident to Boeing 747 registration N739PA at Lockerbie on 21 December 1988.
The recorded data consists of that from the Cockpit Voice Recorder (CVR), the Digital Flight Data Recorder (DFDR), Air Traffic Control (ATC) radio telephony (RTF), ATC radar, and British Geological Survey seismic records. The time correlation of the records is also discussed.

2. Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 analogue parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

2.1 DFDR strip and examination

Internal inspection of the DFDR showed that there was considerable disruption to the control electronics circuits. The crash protection was removed and the plastic recording tape was found detached from its various guide rollers and tangled in the tape spools. There was no tension in the negator springs. This indicated that the tape had probably moved since electrical power was removed from the recorder. The position of the tape in relation to the record/replay heads was marked with a piece of splicing tape in order to quantify the movement. To ensure that no additional damage was caused to the tape it was necessary to cut the negator springs to separate the upper and lower tape reels.

The crinkling and stretching of the tape and the damage to the control electronics meant that the tape had to be replayed outside the recorder. AAIB experience has shown that the most efficient method of replaying stretched Lockheed recorder tapes is to re-spool the tape into a known serviceable recorder, in this case a Plessey 1584G.

2.2 DFDR replay

The 25 hour duration of the DFDR was satisfactorily replayed. Data relating to the accident flight was recorded on track 2. The only significant defect in the recording system was that normal acceleration was inoperative. There was one area on the tape, 2 minutes from the end, where data synchronisation was lost for 1 second.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded. The recorded data simply stopped. Figure C-1 is a graphical representation of the main flight parameters.

2.3 DFDR analysis

In order to ensure that all recorded data from the accident flight had been decoded and to examine the quality of the data at the end of the recording, a section of tape, including both the most recently recorded data and the oldest data (data from 25 hours past), was replayed through an ultra-violet (UV) strip recorder. The data was also digitised and the resulting samples used to reconstruct the tape signal on a VDU.

Both methods of signal representation were used to determine the manner by which the recorder stopped. There was no gap between the most recently recorded data and the 25 hour old data. This showed that the recorder stopped while there was an incoming data stream from the FDAU. The recorder, therefore, stopped because its electrical supply was disconnected. The tape signal was examined for any transients or noise signals that would have indicated the presence of electrical disturbances prior to the recorder stopping. None was found and this indicated that there had been a quick clean break of the electrical supply.

The last seconds of data were decoded independently using both the UV record and the digitised signal. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or if it was old data from a previous recording.

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to ? second.
These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when tha aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

3. Cockpit voice recorder (CVR)

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1	Flight Engineer's RTF.
Channel 2	Co-Pilot's RTF.
Channel 3	Pilot's RTF.
Channel 4	Cockpit Area Microphone.

3.1 CVR strip and examination

To gain access to the recording tape it was necessary to cut away the the outer case and saw through part of the crash protected enclosure. No damage to the tape transport or the recording tape was found. The endless loop of tape was cut and the tape transferred to the replay equipment. The electronic modules in the CVR were crushed and there was evidence of long term overheating of the dropper resistors on the power supply module. The CAM had been crushed breaking internal wiring and damaging components on the printed circuit board.

3.2 CVR replay

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings was audible on the RTF channels. The CAM channel was particularly noisy, this was probably due to the combination of the inherently noisy cockpit of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high cockpit noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified as of either acoustic or electrical in origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual in crew behaviour. The tape record ended with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording. The sound occurred whilst the crew were copying their transatlantic clearance from Shanwick ATC.

3.3 Analysis of the CVR record

3.3.1 The stopping of the recorder

To determine the mechanism that stopped the recorder a bench test rig was constructed utilizing an A100 CVR and an A152 CAM. Figures C-2 to C-5 show the effect of shorting, earthing or disconnecting the CAM signal wires. Figure C-8 shows the CAM channel signal response to the event which occurred on Flight PA103. From this it can be seen that there are no characteristic transients similar to those caused by shorting or earthing the CAM signal wires. Neither does the signal stop cleanly and quickly as shown in Figure C-5, indicating that the CAM signal wires were not interrupted. The UV trace shows the recorded signal decaying in a manner similar to that shown in Figure C-6, which demonstrates the effect of disconnecting electrical power from the recorder. The tests were repeated on other CVRs with similar results and it is therefore concluded that Flight PA103's CVR stopped because its electrical power was removed.

Figures C-9A to C-9D show the recorded signals for the Air India B747 (AI 182) accident in the North Atlantic on 23 June 1985. These show that there is a large transient on the CAM track indicating earthing or shorting of the CAM signal wires and that recorder power-down is more prolonged, indicating attempts to restore the electrical power supply either by bus switching or healing of the fault. The Flight PA103 CVR shows no attempts at power restoration with the break being clean and final.

In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

3.3.2 Information concerning the event

Figure C-8 is an expanded UV trace of the final milliseconds of the CVR record. Three tracks have been used, the flight engineer's RTF channel which contained similar information to the P2's channel has been replaced with a timing signal. Individual sections of interest are identified by number. On the bottom trace, the P1 RTF track, section 1 is part of the Shanwick transatlantic clearance. During this section the loud sound on the CAM channel is evident.

Examination of the DFDR event recordings shows that the Shanwick oceanic clearance was being received on VHF2, the aerial for which is on the underside of the fuselage close to the seat of the explosion.
Section 2 identifies a transient, on the P1 channel, typical of an end of ATC transmission transient for this CVR. The start and finish of most of the recorded ATC transmissions were analysed and they produce a similar signature to the three shown in Figure C-10. The signature on the P1 channel more closely resembles the end of transmission signature and it is open to conjecture that this transient was caused by the explosion damaging the aerial feeder and/or its supporting structure.

Section 3 shows what is considered to be a high speed power supply transient which is evident on all the RTF channels and is probably on the CAM channel, but cannot be identified because of the automatic gain control (AGC), limiting the audio event. This transient is considered to coincide with the loss of electrical power to the CVR. Section 5 identifies the period to the end of recording and this agrees well with tests carried out by AAIB and independently by Fairchild as part of the AI 182 investigation. The typical time from removal of the electrical supply until end of recording is 110 milliseconds.

During the period identified as section 4 it is considered that the disturbances on the RTF channels are electrical transients probably channelled through the communications equipment. Section 6 identifies the 170 millisecond period from the point when the sound was first heard on the CAM until the recording stopped.

The CAM unit is of the old type which has a frequency response of 350 to 3500 Hz. The useable duration of the signal is probably confined to the first 60 milliseconds of the final 170 milliseconds and even during this period the AGC is limiting the signal. In the remaining time the sound is being distorted because power to the recorder has been disconnected. The ambient cockpit noise may have been high enough to have caused the AGC to have been active prior to the event and in this event the full volume of the sound would not be audible. Distortion from the incomplete erasure of the last recording may form part of the recorded signal.

It is not clear if the recorded sound is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case.

Additionally some of the frequencies present on the recording were not present in the original sound, but are the result of the rise in total harmonic distortion caused by the increased amplitude of the incoming signal. Outputs from a frequency analysis of the recorded signal for the same frequency of input to the CVR, but at two input amplitudes, are shown in Figures C-11 and C-12. These illustrate the effects on harmonic distortion as the signal level is increased. Finally the recorded signal does not lend itself to analysis by a digital spectrum analyser as it is, in a large measure, aperiodic and most digital signal analysis algorithms are unable to deal with a short duration signal of this type, however, it is hoped that techniques being developed in Canada will enable more information to be deduced from the end of the recording.

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985 the Royal Armaments Research and Development Establishment (RARDE) were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

Preliminary results from these trials indicates that if a suitable sensor can be developed its output will need to be recorded in real time and therefore it may require wiring into the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

4. Flight recorder electrical system

4.1 CVR/DFDR electrical wiring.

The flight recorders were located in the left rear fuselage just forward of the rear pressure bulkhead. Audio information to the CVR ran along the left hand side of the aircraft, at stringer 11. Electrical power to the CVR followed a similar route on the right hand side of the aircraft crossing to the left side above the rear passenger toilets. DFDR electrical power and signal information followed the same route as the CVR audio information.

4.2 Flight recorder power supply

The DFDR, CVR and the transponders were all powered from the essential alternating current (AC) bus. This bus was capable of being powered by any generator, however, in normal operation the selector switch on the flight engineers panel is selected to "normal" connecting the essential bus to number 4 generator. When the cockpit of Flight PA103 was examined the selector switch was found in the normal position.

4.3 Aircraft alternating current power supplies

AC electrical power to the aircraft was provided by 4 engine driven generators, see Figure C-13. Each generator was driven at constant speed through a constant speed drive (CSD) and connected to a separate bus-bar through a generator control breaker (GCB). The 4 generators were connected to a parallel bus-bar (sync bus) by individual bus tie breakers (BTBs). Control and monitoring of the AC electrical system was achieved through the flight engineer's instrument panel. In normal operation the generators operated in parallel, i.e with the BTBs closed.

4.4 Fault conditions

Analysis of the CVR CAM channel signal indicated that approximately 60 milliseconds after the sound on the CAM channel an electrical transient was recorded on all 4 channels and that approximately 110 milliseconds later the CVR had ceased recording. Within the accuracy of the available timing information it is believed that the incoming VHF was lost at the same time, indicating an AC power supply fault.

The AC electrical system was protected from faults in individual systems or equipment by fuses or circuit breakers. Faults in the generators or in the distribution bus-bars and feeders were dealt with automatically by opening of the GCBs and opening or closing of the BTBs. In the event of fault conditions causing the disconnection of all 4 generators electrical power for essential services, including VHF radio, was provided by a battery located in the cockpit.

The short time interval of 55 milliseconds after which the AC supply to the flight recorders was lost limits the basis on which a fault path analysis of the AC electrical system can be undertaken. On the available information only a differential (feeder) fault could have isolated the bus-bar this quickly, with the generator field control relay taking 20 milliseconds to trip. However, in normal operation, the generators would have been operating in parallel and the essential AC bus-bar would have been supplied via the number 4 BTB from the sync bus. If the fault conditions had continued, a further 40 to 100 milliseconds would have elapsed before the BTB opened. If the BTB was open prior to the fault it would have attempted to close and restore the supply to the essential bus. Any automatic switching causes electrical transients to appear on the CVR and data losses on the FDR. Both the CVR and the FDR indicate that a clean break of the AC supply occurred with no electrical transients associated with BTBs open or closing in an attempt to restore power. In the absence of any additional information only two possibilities are apparent:

i) That all 4 generators were simultaneously affected causing a total loss of AC electrical power. The feeders for the left and right side generators run on opposite sides of the aircraft under the passenger cabin floor. The only situation envisaged that could cause simultaneous loss of all 4 generators is the disruption of the passenger cabin floor across its entire width.

ii) That disruption of the main equipment centre, housing the control units for the AC electrical system, caused the loss of all AC power. However, again it would have to affect both the left and right sides of the aircraft as the control equipment is located at left and right extremes of the main equipment centre.

The nature of the event may also produce effects that are not understood. It is also to be noted that a sudden loss of electrical power to the flight recorders has been reported in other B747 accidents, e.g. Air India, AI 182.

5. Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event caused by the wing section crashing on Lockerbie. The seismic monitors are time correlated with the British Telecom Rugby standard. Using this and calculating the time for the various waves to reach the recording stations it was possible for the British Geological Survey to conclude that the event occurred at 19.03:36.5 hrs ± 1 second.

Attempts were made to correlate various smaller seismic events with other wreckage impacts. However, this was not conclusive because the nearest recording station was above ground and due to the high winds at the time of the accident had considerable noise on the trace. In addition, little of the other wreckage had the mass or impact velocity to stimulate the sensors.

6. Time correlation

6.1 Introduction

The sources of each time encoded recording were asked to provide details of their time standard and any known errors in the timings on their recordings. Although the resolution of the recorded time sources is high it was not possible to attach an accuracy of better than ±1 second due to possible errors in synchronising the recorded time with the associated standard. The following time sources were available and used in determining the significant events in the investigation:-

i) ATC

ATC communications were recorded along with a time signal. The time source for the ATC tape was the British Telecom "Tim" signal. Any error in setting the time when individual tapes are mounted was logged.

ii) Recorded rada data

A time signal derived from the British Telecom "Rugby" standard was included on radar recordings. The Rugby and Tim times were assumed to be of equal accuracy for timing purposes.

iii) The DFDR had UTC recorded.

The source of this time was the flight engineer's clock. This clock was set manually and therefore this time was subject to a significant fixed error as well any inaccuracy in the clock.

iv) The CVR had no time signal.

However, the CVR was correlated with the ATC time through the RTF and with the DFDR, by correlating the press to talk events on the FDR with the press to talk signature on the CVR.

v) Seismic recordings

Seismic recordings included a timing signal derived from the British Telecom Rugby standard.

6.2 Analysis and correlation of times

The Scottish and Shanwick ATC tapes were matched with each other and with the CVR tape. The CVR recording speed was adjusted by peaking its recorded 400 Hz AC power source frequency. This correlation served as a double check on any fixed errors on the ATC recordings and to fix events on the CVR to UTC. The timing of the sound on the CAM channel of the CVR was made simpler because Shanwick was transmitting when it occurred. From this it was possible to determine that the sound on the CVR occurred at 19.02:50 hrs ±1 second.

With the CVR now tied to the Tim standard it was possible to match the RTF keying on the CVR with the RTF keying events on the FDR. These events on the FDR were sampled and recorded once per
second, it was therefore possible for a 1 second delay to be present on the FDR. This potential error was reduced by obtaining the best fit between a number of RTF keyings and a time correlation between the
FDR and CVR of ±? second was achieved. From this it was determined, within this accuracy, that electrical power was removed from the CVR and FDR at the same time.

From the recorded radar data it was possible to determine that the last recorded SSR return was at 19.02:46.9 hrs and that by the next rotation of the radar head a number of primary returns, some left and right
of track, were evident. Time intervals between successive rotations of the radar head became more difficult to use as the head painted more primary returns.

The point at which aircraft wreckage impacted Lockerbie was determined using the time recorded by seismic activity detectors. A seismic event measuring 1.6 on the Richter scale was detected and, with
appropriate time corrections for times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the
information recorded by the various sensors.

7. Recorded radar information

7.1 Introduction

Recorded radar information on the aircraft was available from from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen, from this it
was clear that the flight had progressed in a normal manner until Secondary Surveillance Radar (SSR) was lost. There was a single primary return received by both Great Dun Fell and Claxby radars
approximately 16 seconds before SSR returns were lost. The Lowther Hill and St. Annes radars did not see this return. The Great Dun Fell radar recording was watched for 1 hour both before and after this
single return for any signs of other spurious returns, but none was seen. The return was only present for one paint and no explanation can be offered for its presence.

7.2 Limitations of recorded radar data

Before evaluating the recorded radar data it is important to highlight limitations in radar performance that must be taken into account when interpreting primary radar data. The radar system used for both primary and secondary radar utilised a rotating radar transmitter/receiver (Head). This means that a return was only visible whilst the radar head was pointing at the target, commonly called painting or illuminating the target. In the case of this accident the rotational speeds of the radar heads varied from approximately 10 seconds for the Lowther Hill Radar to 8 Seconds for the Great Dun Fell Radar.

Whilst it was possible to obtain accurate positional information within a resolution of 0.09¡ of bearing and ± 1/16 nautical mile range for an aircraft from SSR, incorporating mode C height encoding, primary radar provided only slant range and bearing and therefore positional information with respect to the ground was not accurate.

The structural break-up of an aircraft releases many items which were excellent radar reflectors eg. aluminium cladding, luggage containers, sections of skin and aircraft structure. These and other debris with reflective properties produce "clutter" on the radar by confusing the radar electronics in a manner similar to chaff ejected by military aircraft to avoid radar detection.

Even when the target is not masked by clutter repetitive detection of individual targets may not be possible because detection is a function of the target effective area which, for wreckage with its irregular shape, is not constant but fluctuates wildly. These factors make it impossible to follow individual returns through successive sweeps of the radar head.

7.3 Analysis of the radar data

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. This information was correlated with the CVR and ATC times to establish a time and position for the aircraft at the initial disintegration.

For the purposes of this analysis the data from Great Dun Fell Radar has been

presented. Figures C-14 to C-23 show a mosaic picture of the radar data i.e. each figure contains the information on the preceding
figure together with more recently recorded information. Figure C-14 shows the radar returns from an aircraft tracking 321¡(Grid) with a calculated ground speed of 434 kts. Reading along track (towards the
top left of Figure C-14) there are 6 SSR returns with the sixth and final SSR return shown decoded: squawk code 0357 (identifying the aircraft as N739PA); mode C indicating FL310; and the time in seconds
(68566.9 seconds from 00:00, i.e. 19.02:46.9 hrs).

At the next radar return there is no SSR data, only 4 primary returns. One return is along track close to the expected position of the aircraft if it had continued at its previous speed and heading. There are 2
returns to the left of track and 1 to the right of track. Remembering the point made earlier about clutter, it is unlikely that each of these returns are real targets. It can, however, be concluded that the aircraft is
no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items have been ejected at high speed probably to both right and left of the aircraft. Figure C-15
shows the situation after the next head rotation. There is still a return along track but it has either slowed down or the slant range has decreased due to a loss of altitude.

Each rotation of the radar head thereafter shows the number of returns increasing with those first identified across track in Figure C-14 having slowed down very quickly and followed a track along the
prevailing wind line. Figure C-20 shows clearly that there has been a further break-up of the aircraft and subsequent plots show a rapidly increasing number of returns, some following the wind direction and
forming a wreckage trail parallel to and north of the original break-up debris. Additionally it is possible that there was some break-up between these points with a short trail being formed between the north and
south trails. From the absence of any returns travelling along track it can be concluded that the main wreckage was travelling almost vertically downwards for much of the time.

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy
considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid)

for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

8. Conclusions

The almost instant destruction of Flight PA103 resulted in no direct evidence on the cause of the accident being preserved on the DFDR. The CVR CAM track contained a loud sound 170 milliseconds before recording ceased. Sixty milliseconds of this sound were while power was applied to the recorder; after this period the amplitude decreased. It cannot be determine whether the decrease was because of reducing recorder drive or if the sound itself decreased in amplitude. Analysis of both flight recorders shows that they stopped because the electrical supply was removed and that there were valid signals available to both recorders at that time.

The most important contribution to the investigation that the flight recorders could make was to pinpoint the time and position of the event. As the timescale involved was so small in relation to the resolution and accuracy of many of the recorded time sources it was necessary to analyse collectively all the available recordings. From the analysis of the CVR, DFDR, ATC tapes, radar data and the seismic records it was concluded that the loud sound on the CVR occurred at 19.02:50 hrs ±1 second and wreckage from the aircraft crashed on Lockerbie at 19.03:36.5 hrs ±1 second, giving a time interval of 46.5 ±2 seconds between these two events. When the loud sound was recorded on the CVR, the geographical position of the aircraft, based on the evidence of recorded data, was calculated to be within 525 metres of OS Grid Reference 14827826.

Eight seconds after the sound on the CVR the Great Dun Fell radar showed 4 primary radar returns. The returns indicated a spread of wreckage in the order of 1 nautical mile across track. On successive returns of the radar, two parallel wreckage trails are seen to develop with the second trail, to the north, becoming evident 30 to 40 seconds after the first.

APPENDIX D

CRITICAL CRACK CALCULATIONS

It was assumed that the fuselage rupture and associated star-burst petalling process was driven by an expanding 'bubble' of high pressure gas, produced by the conversion of solid explosive material into gas products. As the explosive gas pressures reduced due to dissipation through the structure and external venting, the service differential pressure loading would have taken over from the explosive pressures as the principal force driving the skin fractures.

The high temperature gas would initially have been confined within the container where, because of the low volume, the pressure would have been extremely high (too high for containment) and the gas bubble would have expanded violently into the cavities of the fuselage between the outer skin and the container. This gas bubble would have continued to expand, with an accompanying fall in pressure due to the increasing volume combined with a corresponding drop in temperature.

The precise nature of the gas expansion process could not be determined directly from the evidence and it was therefore necessary to make a number of assumptions about its behaviour, based on the geometry of the hull and the area of fuselage skin which the high pressure bubble would have ruptured. Essentially, it was assumed that the gas bubble would expand freely in the circumferential direction, into the cavity between the fuselage skin and the container. In contrast, the freedom for the bubble to expand longitudinally would have been restricted by the presence of the fuselage frames, which would have partially blocked the passage of gas in the fore and aft directions. However, the pressures acting on the frames would have been such that they would have buckled and failed, allowing the gas to vent into the next 'bay', producing failure of the next frame. This sequential frame-failure process would have continued until the pressure had fallen to a level which the frames could withstand. During the period of frame failure and the associated longitudinal expansion of the gas bubble, this expansion rate was assumed to be half that of the circumferential rate.

It was assumed that venting would have taken place through the ruptured skin and that the boundary of the petalled hole followed behind the expanding gas bubble, just inside its outer boundary, i.e. the expanding gas bubble would have stretched and 'unzipped' the skins as it expanded. This process would have continued until the gas bubble had expanded/vented to a level where the pressure was no longer able to drive the petalling mechanism because the skin stresses had reduced to below the natural strength of the material.

The following structural model was assumed:

(i) The pressurised hull was considered to be a cylinder of radius 128 inches, divided into regular lengths by stiff frames.

(ii) The contributions of the stringers and frames beyond the petalled region were considered to be the equivalent of a reduction of stress in the skins by 20%, corresponding to an increase in skin thickness from 0.064 inches to 0.080 inches.

(iii) Standing skin loads were assumed to be present due to the service differential pressure, i.e.. it was assumed that no significant venting of internal cabin pressure occurred within the relevant timescale.

(iv) The mechanism of bubble pressure load transfer into the skins was:

a) Hoop direction -conventional membrance reaction into hoop stresses

b) Longitudinal direction - reaction of pressures locally by the frames, restrained by the skins.

The critical crack calculations were based upon the generalised model of a plate under biaxial loading in which there was an elliptical hole with sharp cracks emanating from it. This is a good approximation of the initial condition, i.e.. the shattered hole, and an adequate representation of the subsequent phase, when the hole was enlarging in its star-burst, petalling, mode.

The analyses of critical crack dimensions in the circumferential and longitudinal directions were based on established Fracture Resistance techniques. The method utilises fracture resistance data for the material in question to establish the critical condition at which the rate of energy released by the crack just balances the rate of energy absorbed by the material in the cracking process, i.e. the instantaneous value of the parameter Kr, commonly referred to as the fracture toughness Kc. From this, the relationship between critical stress and crack length can be determined.

Using conventional Linear Elastic Fracture Mechanics (LEFM) with fracture toughness data from RAE experimental work and published geometric factors relating to cracks emanating from elliptical holes, the stress levels required to drive cracks of increasing lengths in both circumferential and longitudinal directions were calculated. The skin stresses at sequential stages of the expanding gas bubble/skin petalling process were then calculated and compared with these data.

The results of the analysis indicated that, once the large petalled hole had been produced by explosive gas overpressure, the hoop stresses generated by fuselage pressurisation loads acting alone would have been sufficient to drive cracks longitudinally for large distances beyond the boundaries of the petalled hole. Thus, with residual gas overpressure acting as well, the 43 feet (total length) longitudinal fractures observed in the wreckage are entirely understandable. The calculations also suggested that the hoop fractures, due to longitudinal stresses in the skins, would have extended beyond the boundary of the petalled hole, though the excess stress driving the fractures in this direction would have been much smaller than for the longitudinal fractures, and the level of uncertainty was greater due to the difficulty of producing an accurate model reflecting the diffusion of longitudinal loads into the skins. Nevertheless, the results suggested that the circumferential cracks would extend downwards just beyond the keel, and upwards as far as the window belt - conclusions which accord reasonably well with the wreckage evidence.

APPENDIX E

POTENTIAL REMEDIAL MEASURES

1. Introduction

In the following discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution. On the basis of the Flight PA103 investigation, damage is likely to fall into two categories: direct explosive damage, and indirect explosive damage.

2. Direct explosive damage

The most serious aspect of the direct explosive damage on the structure is the large, jagged aperture in the pressure hull, combined with frame and stringer break-up, which results from the star-burst rupture of the fuselage skin. Because of its uncontrolled size and position, and the naturally radiating cracks which form as part of the petalling process, the skin's critical crack length (under pressurisation loading) is likely to be exceeded, resulting in unstable crack propagation away from the boundary of the aperture. Such cracks can lead to a critical loss of structural integrity at a time when additional loads are likely to be imposed on the structure due to reflected blast pressure and/or aircraft aerodynamic and inertial loading.

A further complicating factor is that the size of this aperture is likely to be sufficiently large to allow complete cargo containers and other debris to be ejected into the airstream, with a high probability of causing catastrophic structural damage to the empennage.

3. Indirect explosive damage

Indirect explosive damage (channelling or ducting of explosive energy in the form of both shock waves and supersonic gas flows) is likely to occur because of the network of interlinked cavities which exist, in various forms, in all large commercial aircraft, particularly below cabin floor level. This channeling mechanism can produce critical damage at significant distances from the source of the explosion.

In addition to the structural damage, aircraft flight control and other critical systems will potentially be disrupted, both by the explosive forces and as a result of structural break-up and distortions. The discussion which follows focuses on possible means of limiting structural damage of the kind which occurred on Flight PA103. Undoubtedly, such measures will also have beneficial effects in limiting systems damage. However, system vulnerability can further be reduced by applying, wherever possible, those techniques used on military aircraft to reduce vulnerability to battle damage; multiplexed, multiply redundant systems using distributed hardware to minimise risk of a single area of damage producing major system disruption. Fly by wire flight control systems potentially offer considerable scope to achieve these goals, but the same distributed approach would also be required for the electronic and other equipment which, in current aircraft, tends to be concentrated into a small number of 'equipment centres'.

4. Remedial measures to reduce structural damage

Whilst pure containment of the explosive energy is theoretically possible, in an aviation context such a scheme would not be viable. Any unsuccessful attempt to contain the explosive will probably produce greater devastation than the original (uncontained) explosion since all the explosive energy would merely be stored until the containment finally ruptured, when the stored energy would be released together with massive fragmentation of the containment.

However, a mixed approach involving a combination of containment, venting, and energy absorption should provide useful gains provided that a systematic rather than piecemeal approach is adopted, and that the scheme also addresses blast channelling. The following scheme is put forward for discussion, primarily as means of identifying, by example, how the various elements of the problem might be approached at a conceptual level and to provide a stimulus for debate. No detailed engineering solutions are offered, but it is firmly believed that the requirements of such a scheme could be met from a technical standpoint. The proposed scheme is based on the need to counter a threat similar to that involving Flight PA103, i.e. a high explosive device placed within a baggage container, however, the principles should be applicable to other aircraft types.

Such a scheme might comprise several 'layers' of defence. The first two layers, one within the other, are essentially identical and provide partial containment of the explosive energy and the redirection of blast out from the compartment via pre-determined vent paths. Although the containment is temporary, it must provide an effective barrier to uncontrolled venting, preventing the escape of blast except via the pre-designated paths.

The third layer comprises a pre-determined area of fuselage skin, adjoining the outer end of the vent path, designed to rupture or burst in a controlled manner, providing a large vent aperture which will not tend to crack or rupture beyond the designated boundaries.

A fourth layer of protection has two elements, both intended to limit the propagation of shock waves through the internal cavities in the hull. The first element comprises the closure of any gaps between the vent apertures in the two innermost containment layers and the vent aperture in the outer skin. This effectively provides an exhaust duct connecting the inner and outer vent apertures to minimise leakage into the intervening structure and cavities around the cargo hold. The second element comprises the incorporation of an energy absorbing lining material within all the cavities in the lower hull, to absorb shock energy, limit shock reflection and limit the propagation of pressure waves which might enter the cavities, for example because of containment layer breakthrough.

5 Possible application to Boeing 747 type aircraft

5.1 Container Modification

The obvious candidates for the inner containment layer are the baggage containers themselves. Existing containers are of crude construction, typically comprising aluminium sheet sides and top attached to an aluminium frame with a fabric reinforced access curtain, or have sides and top of fibreglass laminate attached to a robust aluminium base section.

These containers are stacked in the aircraft in such a manner that on three sides (except for the endmost containers) the baggage within the adjoining containers provides an already highly effective energy absorbing barrier. If the container is modified so that loading access is via the outboard side of the container rather than at the end, i.e. the curtain is put on the faces shown in Figure E-1, then only the top and base are 'unbacked' by other containers, leaving the outboard face as a vent region.

The proposal is therefore that a modified container is developed in which the access is changed from the end to the outside face only, and which is modified to improve the resistance to internal pressures and thus encourage venting via the new access curtain only. How the container is actually modified to achieve the containment requirement is a matter of detail design, but two approaches suggest themselves, both involving the use of composite type materials. The first approach is to adopt a scheme for a rigid container which relies on a combination of energy absorption and burst strength to prevent uncontrolled breakout of explosive energy. The second approach is to use a 'flexible' container, i.e. rigid enough for normal use, but sufficiently flexible to allow gross deformation of shape without rupture. This, particularly if used with a backing blanket made from high performance material to resist fragmentation, could deform sufficiently to allow the container to bear against, and partially crush, adjoining containers. In this way, the shock energy transmission should be significantly reduced and the inherent energy absorption capability and mass of the baggage in adjoining containers could be utilised, whilst still retaining the high pressure gas for long enough to allow venting via the side face. Clearly, care would need to be taken to ensure that the container vent aperture remained as undistorted as possible, to ensure minimal leakage at the interface.

5.2 Cargo bay liner

The existing cargo bay liner is a thin fibreglass laminate which lines the roof and sidewalls of the cargo hold. There is no floor as such; instead, the containers are supported on rails running fore and aft on the tops of the fuselage frame lower segments. In a number of areas, there are zipped fabric panels let into the liner to provide access to equipment located behind. The liner 'ceiling' is suspended on plastic pillars approximately 2 centimeters below the bottom of the main cabin floor beams. The purpose of the liner is solely to act as a general barrier to protect wiring looms and systems components.

The proposal is to produce a new liner designed to provide the second level of containment, essentially at 'floor' and 'roof' level only [Figure E-1]. The dimensional constraints are such that potentially quite thick material could be incorporated (leaving aside the weight problem), permitting not only a rigid liner design, but semi-rigid or flexible linings backed by energy absorbing blanket materials.

The liner would be designed to provide an additional barrier at the base and roof of the containers, which unlike the sides, are not protected by adjoining containers. The outside ends of these barrier elements must effectively seal against the vent apertures in the containers, to minimise leakage into the fuselage cavities.

5.3 Structural blow-out regions.

The final element in the containment/venting part of the scheme is a line of blow-out regions in the fuselage skins, coinciding exactly with the positions of the vent apertures in the cargo containers and cargo bay liner. These should extend along the length of the cargo hold, zoned in such a way that rupture due to rapid overpressure will occur in a controlled manner. The primary function of the blow-out regions would be to provide immediate pressure relief by allowing the inevitable skin rupture to take place only within pre-determined zones, limiting the extent of the skin tearing by means of careful stiffness control at the boundary of the blow-out regions.

The structural requirements of such panels are perhaps the most difficult challenge to meet, particularly for existing designs. However, it is believed that by giving appropriate consideration to the directionality of fastening strengths, and the use of external tear straps, it should be possible to design the structure to carry the normal service loads whilst creating a pre-disposition to rupturing in a controlled manner in response to gross pressure impulse loading.

The implementation of such features will need carefully balanced design in order to provide local stiffening, sufficient to control and direct the tear processes, without creating stiffness discontinuities which could lead to fatigue problems during extended service. However, the degree of reinforcement needed at the blow-out aperture need only be sufficient to limit tearing and to sustain the aircraft long enough to complete the flight unpressurised.

All aircraft have pre-existing strength discontinuities, despite the efforts of the designers to eliminate them. By choosing the positions of butt joints, lap joints, anti-tear straps and similar structural features in future designs, so as to incorporate them into the boundary of the blow-out panel region, the natural "tear here" tendencies of such features could possibly be turned to advantage. In the case of current generation aircraft, the positions of existing lines of weakness at such features will determine the optimum position for structural blow-out areas, and hence the positions of the container and cargo bay liner blow-out panels. A limited amount of local structural reinforcement (e.g. in the form of external anti-tear straps), carried out as part of a modification program, could perhaps fine tune the tearing properties of existing lines of weakness, potentially producing significant improvements.

5.4 Closure of cavities

There are four main classes of cavity which will need to be addressed on the Boeing 747, and most other modern aircraft. These are:

(i) The channels formed between fuselage frames

(ii) The cross-ship cavities between cabin floor beams

(iii) Longitudinal 'manifold' cavities on each side of the cargo deck, running fore and aft in the space behind the upper sidewall areas of the cargo bay liner.

(iv) Air conditioning vents along the bottom of the cabin side-liner panels, which connect the side cavities below cabin floor level with the main passenger cabin.

If the containment barriers (i.e. modified cargo containers and cargo hold liner) can be made to prevent blast breakthrough into these cavities directly, then the only area where transfer can occur is at the interface between the container/cargo hold liner vent apertures and the fuselage skins at the blow-out region. This short distance will need to be sealed in order to form a short 'exhaust duct' between the container vent aperture and the fuselage skin. Since the shock and general explosive pressure will act mainly along the vent-duct axis, the pressure loading on the vent duct walls should not be excessive.

5.5 Attenuation of shock waves in structural cavities

To prevent the 'ducting' of any blast which does enter the fuselage cavities, either because of partial penetration of the containment barriers or leakage at the vent duct interfaces, the scheme requires the provision of lightweight energy absorbing material within the cavities to limit reflection and propagation of pressure waves within the cavities, and radiation of shock waves into the cabin from the conditioning air vents. Materials such as vermiculite, which are of low density yet have excellent explosive energy absorption properties, may have application in this area, perhaps in lieu of the existing insulation material.

Since the existing cavities often serve as part of the air conditioning outflow circuit, some consideration will need to be given to finding an alternative route. However, the flow rates are small compared with the total cross-sectional flow potential of the cavities and this function could be served by separate air conditioning ducts, or perhaps by restricting access to one or two cavities only (thus limiting the risk), or by using some form of blast valve to close off the air conditioning vents. Similarly, the requirement to vent pressure from the cabin in the event of a cargo bay decompression would also need to be addressed.

APPENDIX F

BAGGAGE CONTAINER EXAMINATION, RECONSTRUCTION AND RELATIONSHIP TO THE AIRCRAFT STRUCTURE

1. Introduction

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited blast damage. It was confirmed by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE), after detailed physical and chemical examination, that these items showed conclusive evidence of a detonating high performance plastic explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence from the effect of Improvised Explosive Device (IED). It was evident, from the main wreckage layout that the IED had been located in the forward cargo hold and, although all baggage container wreckage was examined, only items from the forward hold showing the relevant characteristics were considered for the reconstruction. This Appendix documents the reconstruction of two particular containers and, from their position within the forward fuselage, defines the location of the IED.

2 Container Arrangement

Information supplied by Pan Am showed that this aircraft had been loaded with 12 baggage containers and two cargo pallets in the forward hold located as shown in Figure F-1. Three containers were recorded as being of the glass fibre reinforced plastic type (those at positions 11L, 13L and 21L) with the remaining 9 being of metal construction.

3. Container Description

All the baggage containers installed in the forward cargo hold were of the LD3 type (lower deck container, half width - cargo) and designated with the codes AVE, for those constructed from aluminum alloy, and AVA or AVN for those constructed from fibreglass. Each container was specifically identified with a four digit serial number followed by the letters PA and this nine digit identifier was present at the top of three sides of each container in black letters/numbers approximately 5 inches tall. Detail drawings and photographs of a typical metal container are shown in Figure F-2. Each container was essentially a 5 feet cube with a 17 inch extension over its full length to the left of the access aperture. In order to fit within the section of the lower fuselage this extension had a sloping face at its base joining the edge of the container floor to the left vertical sidewall at a position some 20 inches above the floor. The access aperture on the AVE type container was covered by a blue reinforced plastic curtain, fixed to the container at its top edge, braced by two wires and central and lower edge cross bars which engaged with the aperture structure. The strength of this type of container superstructure was provided by the various extruded section edge members, attached to a robust floor panel, with a thin aluminum skin providing baggage containment and weatherproofing.

4. Container Identification

Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to the town of Lockerbie and was characteristically different from that from the forward hold, in that it was generally severely crushed and covered in mud. The forward hold debris, by comparison, was mostly recovered from the southern wreckage trail some distance from Lockerbie and had mainly been torn into relatively large sections.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this two containers, one metal and one fibreglass, were identified as exhibiting damage likely to have been caused by the IED. From the Pan Am records the metal container of these two had been positioned at position 14L, and the fibreglass at position

21L (adjacent positions, 4th and 5th from the front of the forward cargo hold on the left side). The serial numbers of these containers were respectively AVE 4041 PA and AVN 7511 PA.

5. Container Reconstruction

Those parts which could be positively identified as being from containers AVE 4041 PA and AVN 7511 PA were assembled onto one of three wooden frameworks; one each for the floor and superstructure of container 4041, and one for the superstructure of container 7511. Figures F-3 to F-9 show the reconstruction of container 4041 and Figure F-10 shows the reconstructed forward face of container 7511.
Approximately 85% of container 4041 was identified, the main missing sections being the aft half of the sloping face skin and all of the curtain. Two items were included which could not be fracture or tear matched to container 4041, however, they showed the particular type of blast damage exhibited only by items from this container.

While this work was in progress a buckled section of skin from container 4041 was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device.

Examination of all other component parts of the remaining containers from the front and rear cargo holds did not reveal any evidence of blast damage similar to that found on containers 4041 and 7511.

6. Wreckage Distribution

Those items which were positively identified as parts of container 4041 or 7511, and for which a grid reference was available, were found to have fallen close to the southern edge of the southern wreckage trail. This indicated that one of the very early events in the aircraft break-up sequence was the blast damage to, and ejection of, parts of these two containers.

7. Fuselage Reconstruction

In order to gain a better understanding of the failure sequence, that part of the aircraft's fuselage encompassing the forward cargo hold was reconstructed at

AAIB Farnborough. After all available blast damaged pieces of structure had been added, the floor of container 4041 was installed as near to its original position as the deformation of the wreckage would allow and this is shown in Figure F-11. The presence of this floor panel in the fuselage greatly assisted the three-dimensional assessment of the IED location. Witness marks between this floor and the aircraft structure, tie down rail, roller rail and relative areas of blast damage left no doubt that container 4041 had been located at position 14L at the time of detonation.

8. Analysis

The general character of damage that could be seen on the reconstructions of containers 4041 and 7511 was not of a type seen on the wreckage of any of the other containers examined. In particular, the reconstruction of the floor of container 4041 revealed an area of severe distortion, tearing and blackening localised in its aft outboard quarter which, together with the results of the forensic examination of items from this part of the container, left no doubt that the IED had detonated within this container.

Within container 4041 the lack of direct blast damage (of the type seen on the outboard floor edge member and lower portions of the aft face structural members) on most of the floor panel in the heavily distorted area suggested that this had been protected by, presumably, a piece of luggage. The downward heaving of the floor in this area was sufficient to stretch the floor material, far enough to be cut by cargo bay sub structure, and distort the adjacent fuselage frames. This supported the view that the item of baggage containing the IED had been positioned fairly close to the floor but not actually placed upon it. The installation of the floor of container 4041 into the fuselage reconstruction (Figure F-11) showed the blast to have been centered almost directly above frame 700 and that its main effects had not only been directed mostly downwards and outboard but also rearwards. The blast effects on the aircraft skin were onto stringer 39L but centered at station 710 (Figure F-12). Downwards crushing at the top, and rearwards distortion of frame 700 was apparent as well as rearwards distortion of frame 720.

With the two container reconstructions placed together it became apparent that a relatively mild blast had exited container 4041 through the rear lower face to the left of the curtain and impinged at an angle on the forward face of container 7511. This had punched a hole, Figure F-10, approximately 8 inches square some 10 inches up from its base and removed the surface of this face inboard from the hole for some 50 inches. Radiating out from the hole were areas of sooting, and other black deposits, extending to the top of the container. No signs were present of any similar damage on other external or internal faces of container 7511 or the immediately adjacent containers 14R and 21R.

The above assessment of the directions of distortion, comparison of damage to both containers, and the related airframe damage adjacent to the container position, enabled the most probable lateral and vertical location of the IED to be established as shown in Figure F-13, centered longitudinally on station 700.

9. Conclusions

Throughout the general examination of the aircraft wreckage, direct evidence of blast damage was exhibited on the airframe only in the area bounded, approximately, by stations 700 and 720 and stringers 38L and 40L. Blast damage was found only on pieces of containers 4042 and 7511, the relative location and character of which left no doubt that it was directly associated with airframe damage. Thus, these two containers had been loaded in positions 14L and 21L as recorded on the Pan Am cargo loading documents. There was also no doubt that the IED had been located within container 14L, specifically in its aft outboard quarter as indicated in Figure F-13, centered on station 700.

Blast damage to the forward face of container 7511 was as a direct result of hot gases/fragments escaping from the aft face of container 4041. No evidence was seen to suggest that more than one IED had detonated on Flight PA103.

APPENDIX G

MACH STEM SHOCK WAVE EFFECTS

1. Introduction

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity shock wave which will propagate outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant for two reasons. Firstly, it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter. This geometric limitation occurs irrespective of charge size (within the range of charge sizes considered realistic for the Flight PA103 scenario), and thus provides a means of calculating the standoff distance of the explosive charge from the fuselage skin. Secondly, the Mach stem may have been a significant factor in transmitting explosive energy through the fuselage cavities, producing damage at a number of separate sites remote from the source of the explosion.

2. Mach stem shock wave formation

A Mach stem shock is formed by the interaction between the incident and reflected shock waves, resulting in a coalescing of the two waves to produce a new, single, shock wave. If an explosive charge is detonated in a free field at some standoff distance from a reflective surface, then the incident shock wave expands spherically until the wave front contacts the reflective surface, when that element of the wave surface will be reflected back (Figure G-1). The local angle between the spherical wave front and the reflecting surface is zero at the point where the reflecting surface intersects the normal axis, resulting in wave reflection directly back towards the source and maximum reflected overpressure at the reflective surface. The angle between the wave front and the reflecting surface at other locations increases with distance from the normal axis, producing a corresponding increase in the oblique angle of reflection of the wave element, with a corresponding reduction in the reflected overpressure. (To a first order of approximation, explosive shock waves can be considered to follow similar reflection and refraction paths to light waves, ref: "Geometric Shock Initiation of Pyrotechnics and Explosives", R Weinheimer, McDonnel Douglas Aerospace Co.) Beyond some critical (conical) angle about the normal axis, typically around 40 degrees, the reflected and incident waves coalesce to form Mach stem shock waves which, effectively, bisect the angle between the incident and reflected waves, and thus travel approximately at right angles to the normal axis, i.e.parallel with the reflective surface (detail "A", figure G-1).

3. Estimation of charge standoff distance from the fuselage skin

Within the constraint of the likely charge size used on Flight PA103, calculations suggested that the initial Mach stem shock wave pressure close to the region of Mach stem formation (i.e. the shock wave face-on pressure, acting at right angles to the skin), was likely to be more than twice that of the incident shock wave, with a velocity of propagation perhaps 25% greater. However, the Mach stem out-of-plane pressure, i.e.the pressure felt by the reflecting surface where the Mach stem touches it, would have been relatively low and insufficient to shatter the skin material. Therefore, provided that the charge had sufficient energy to produce skin shatter within the conical central region where no Mach stems form, the size of the shattered region would be a function mainly of charge standoff distance, and charge weight would have had little influence. Consequently, it was possible to calculate the charge standoff distance required to produce a given size of shattered skin from geometric considerations alone. On this basis, a charge standoff distance of approximately 25 to 27 inches would have resulted in a shattered region of some 18 to 20 inches in diameter, broadly comparable to the size of the shattered region evident on the three-dimensional wreckage reconstruction.

Whilst the analytical method makes no allowance for the effect of the IED casing, or any other baggage or container structure interposed between the charge and the fuselage skin, the presence of such a barrier would have tended to absorb energy rather than re-direct the transmitted shock wave; therefore its presence would have been more critical in terms of charge size than of position. Certainly, the standoff distance predicted by this method was strikingly similar to the figure of 25 inches derived independently from the container and fuselage reconstructions.

From: John Barry Smith <barry@corazon.com>
Date: November 16, 1956 2:55:07 AM GMT-08:00
To: jeffreytcampbell@home.com
Subject: **Bail**

Dear Mr. Campbell, 15 Nov 00

Is it too early to present to the Court at the bail hearing that there is not conclusive evidence that a crime has been committed at all? The official report of the Canadian and Indian aviation authorities states that a mechanical event such as open cargo door in flight would cause the damage shown by the evidence.

"3.4.1 Aircraft Break-up
The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction."

(Note that floor panels separating in an upward direction gives same evidence as floor beams going in down direction, which is what happens to explosive decompression when floor beams, not panels, get sucked down, whereas, a bomb makes floor beams go up, which did not happen.)

The only group stating a crime was committed are law enforcement authorities, aviation authorities have left the probable cause in doubt. This is an airplane crash, not a bank robbery. The first assumption must be pilot error, weather related, or mechanical fault.

Bringing the official suggestion that it may have been a mechanical event and not sabotage may help get bail, in my humble opinion. That possibility of mechanical event will lead aviation authorities to start consideration and they will have 15 years of similar mechanical events with similar evidence to ponder. Let the aviation media do some of your legwork for you. The open cargo door suggestion is not weird, not wild, not last straw, not misdirection, but an suggested possible mechanical explanation which mean nobody, especially your client, put a bomb on board AI 182.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom
The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182.

3.4.6.14 That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a high explosive device, then the spectra should have shown large low frequency content, but this was absent.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-
"It is considered that from the CVR and ATC recordings supplied

for analysis, there is no evidence of a high explosive device having detonated on AI 182.
"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.

I urge you sir, just because the authorities have for fifteen years been crying bomb, the actual evidence is nowhere near conclusive, and in fact, much evidence supports a mechanical sudden decompression from some other source, such as open cargo door in flight.

To assume it was a bomb but your client did not plant it is to assume something not confirmed and very detrimental to a defense. If I were the judge and it were presented to me that a plane was bombed but your client, although tied to others who have bombed or been connected to bombings, did not do it, I would not grant bail fearing fleeing. But, if the entire event were in doubt as to being a crime or not, and no bomb on board, and supported by Canadian authorities in an official written report, a Canadian judge might grant bail.

Well, Mr. Campbell, just sticking my nose in where it may not belong, good luck in Court.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

From: John Barry Smith <barry@corazon.com>
Date: November 16, 1956 2:58:19 AM GMT-08:00
To: jeffreytcampbell@home.com
Subject: **AI 182 accident report**

Dear Mr. Campbell, below is the official Canadian and Indian accident report for AI 182. It is electroncially searchable and very valuable. You can search through and see how flimsy the 'bomb' evidence is and how strong the mechanical event is.

Cheers,
Barry
John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Canadian AviationBureau canadienSafety Boardde la sécurité aérienneAVIATION OCCURRENCEAIR INDIABOEING 747-237BVT-EFOCORK, IRELAND110 MILES WEST23 JUNE 1985 1.0 INTRODUCTION
Air India Flight 182, a Boeing 747-237B, registration VT-EFO, was on a flight from Mirabel to London when it disappeared from the radar scope at a position of latitude 51°O'N and longitude 12°50'W at 0714 Greenwich Mean Time (GMT), 23 June 1985, and crashed into the ocean about 110 miles west of Cork, Ireland. There were no survivors among the 329 passengers and crew members. The depth of the water at the crash site is about 6,700 feet.

At 0541 GMT, 23 June 1985, CP Air Flight 003 arrived at Narita Airport, Tokyo, Japan, from Vancouver. At 0619 GMT a bag from this flight exploded on a baggage cart in the transit area of the airport within an hour of the Air India occurence. Two persons were killed and four were injured. From the day of the occurrences, there have been questions about a possible linkage between the events.

This Submission examines the information available to the Canadian Aviation Safety Board (CASB) with respect to the circumstances surrounding the AI 182 accident. The sources of information include: information made public to the Indian Inquiry as a result of the RCMP investigation; the flight data recorder (FDR), cockpit voice recorder (CVR) and Shannon ATC tape recording analyses by Canadian, United Kingdom, and Indian authorities; the medical evidence obtained from Dr. Hill of the Accident Investigations Branch of the United Kingdom; and the evidence obtained by examination of the wreckage recovered, the wreckage distribution pattern, photographs, and videotapes of the wreckage on the ocean bottom.

2.0 EXAMINATION

2.1 Vancouver

On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight East Indian accent.* He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vancouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

On the same date at approximately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.
On 20 June 1985 at about 1210 PDT (1910 GMT), a male appearing to be of East Indian origin purchased the tickets with cash from a CP Air ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to M. Singh. The telephone contact number was also changed. The final itinerary was as follows:

a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22 June 1985

*See Appendix A for chronology of events.

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22 June 1985

b) L. Singh - CP 003 Vancouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 (local time in Tokyo), 23 June 1985

On 22 June 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy East Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that he was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he

could not check his baggage past Toronto unless his flight was confirmed.
On Saturday morning, 22 June 1985, a CP Air passenger agent worked check-in position number 26 at the CP Air ticket counter, Vancouver International Airport, and recalls dealing with a passenger booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto he could not interline his baggage. The passenger insisted and, as the line-ups were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that M. Singh checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage. The flight manifest for CP 003 shows that on the same day the person using the name of L. Singh with a ticket to Bangkok also checked in through the same counter, was assigned seat 38H, and checked one piece of baggage.
A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as M. and L. Singh did not board these respective flights.
2.2 Toronto
Air India Flight 181 from Frankfurt arrived at Toronto on 22 June 1985 at 1430 EDT (1830 GMT) and was parked at gate 107 of Terminal 2. All passengers and baggage were removed from the aircraft and processed through Canada Customs. Passengers continuing on the flight to Montreal were given transit cards, and on this flight 68 cards were handed out. These transit passengers are required to claim their luggage and proceed through Canada Customs. Prior to entering the public area, there is a belt which is designated for interline or transit baggage. Transit passengers deposit their luggage on this belt which carries it to be reloaded on the aircraft. This baggage was not subjected to X-ray

inspection as it was presumed to have been screened at the passengers' overseas departure point. When the transit passengers checked in to proceed to Montreal, their carry-on baggage was subjected to the normal security checks in place on this date. Passenger and baggage security checks were conducted by Burns International Security Services Ltd. and all passenger and baggage processing for both off-loading and on-loading was handled by Air Canada staff.

Air India Flight 181 was composed of the following:

- passengers continuing to Montreal (68)
- passengers from connecting flights

AC 102 (Saskatoon) 2
AC 106 (Edmonton) 4
AC 192 (Winnipeg) 1
AC 170 (Winnipeg) 4
AC 136 (Vancouver) 10
CP 060 (Vancouver) 1 Standby (M. Singh)

- passengers originating at Toronto
- diplomatic bags from the Vancouver India Consul General via AC 508
- produce cargo from India
- cargo in the form of 5th pod engine components loaded in the aft cargo compartment.

It should be noted that some passengers from India book flights to Montreal with their intended destination being Toronto. The reason is that the fare to Montreal is cheaper and therefore some passengers get off the flight in Toronto, claim their luggage and leave without reporting a cancellation of the trip to Montreal. It has been established that 65 of the 68 transit passengers reboarded the flight to Montreal.

Air India personnel were in charge for the overall operation at Toronto regarding the unloading and loading of both passengers and cargo. Although the actual work was performed by various

companies under contract, Air India personnel oversaw the operation. The Air India station manager was away on vacation on 22 June 1985. The evidence does not clearly establish who had been assigned to replace the station manager and assume his duties.
Air Canada had stored in a hangar an engine that had failed on a previous Air India flight from Toronto on 8 June 1985. Air Canada received a message from Air India stating that the failed engine was to be mounted as a 5th pod on Flight 181/182 on 22 June 1985. The engine was prepared for loading and component parts were crated for loading into the aft cargo compartment. On 22 June, the component parts were taken from the hangar and placed outside to be delivered to the aircraft by MEGA International Air Cargo. The component parts were placed just inside the airport fence separating the restricted and unrestricted areas. The installation began immediately upon the arrival of Flight 181 and was completed at 1530 EDT (1930 GMT). The front engine cowling was crated but would not fit through the aft cargo door. The crating was rearranged, and the door stops on the cargo door were removed to permit the loading of the crate and the remaining engine parts were loaded on pallets. Due to problems with loading the 5th pod and component parts, the departure was delayed from 1835 EDT (2235 GMT) to 2015 EDT (0015 GMT, 23 June).
CP Air Flight 060 arrived in Toronto at 1610 EDT (2010 GMT) and docked at gate 44, Terminal 1. A number of passengers on this flight were interlined to other flights including passenger M. Singh wait-listed on Air India Flight 181/182. It has been established that this passenger did not board Flight CP 060 but did check baggage onto the flight. This baggage was to be interlined to the Air India flight departing from Terminal 2. In this case, CP Air employees would have off-loaded all baggage from CP 060 and deposited the baggage at Racetrack 6 on the

ring road of Terminal 1 to be transported to the Air Canada sorting room at Terminal 2.

Consolidated Aviation Fuelling and Services (CAFAS) is a company which is contracted to pick up and deliver baggage from one terminal to the other. The CAFAS driver on duty at the time recalls picking up a bag from a CP Air flight originating in Vancouver and destined for Air India at Terminal 2. As this piece of luggage did not turn up as found luggage, it is deduced that normal practice was followed, and the luggage was interlined and loaded on AI 181/182.

MEGA International Air Cargo is a firm that handled air cargo and containers for Air India. Since the flight was carrying a 5th engine and component parts, no commercial cargo could be loaded at Toronto. MEGA delivered the engine component parts to be loaded in the cargo compartment by Air Canada employees. Later, MEGA received two diplomatic bags and delivered these to the aircraft. The bags were loaded into the valuable goods container (see Appendix B). These bags were not subjected to X-ray or any other security checks.

All checked-in baggage for AI 181/182 was to be screened by an X-ray machine which was located in Terminal 2 at the end of international belt number 4. This location would permit all baggage from the check-in counters and interline carts to be fed through the X-ray machine before being loaded. It has been established that this machine worked intermittently for a period of time and stopped working during the loading process at about 1700 EDT (2100 GMT). Rather than opening the bags and physically inspecting them, the Burns security personnel performing the X-ray screening were told by the Air India security officer to start using the hand-held PD-4 sniffer.

One Burns security officer checked the bags with the sniffer while another put stickers on the bags and forwarded them. The security officer forwarding the baggage recalls the sniffer making short beeping noises not long whistling ones. The security officer who used the sniffer claims it never went off, and the only time any sound was made was when it was turned on and off. At those times, it would emanate a short beep (refer to section 2.8 for further information regarding the PD-4 sniffer).

Burns International Security had a contract with Air India for the security of the aircraft while it was docked. The security arrangements contracted from Burns were as follows:

- security at the bridge door leading to the aircraft;
- security inside the aircraft from the time the passengers disembarked upon flight arrival until flight departure;
- security guards assigned the physical inspection of all carry-on baggage in the departure room; and
- security guards in the international baggage make-up room conducting screening of baggage using an X-ray machine and a hand-held PD-4 sniffer.

The statements taken from Burns security personnel in Toronto indicated that a significant number of personnel, including those handling passenger screening, had never had the Transport Canada passenger inspection training program or, if they had, had not undergone refresher training within 12 months of the previous training.

As a result of official requests made by Air India in early June 1985 for increased security for Air India flights, the RCMP provided additional security as follows:

- one member in a marked police motor vehicle patrolling the apron area;
- one member in a marked police motor vehicle parked under the right wing from time of arrival until push-back;
- one member on foot patrol at Air India check-in counter; and
- one member at the loading bridge during boarding.

In addition, all RCMP members working in that particular area of Terminal 2 were aware of the Air India flight and would check in with the assigned personnel during their patrols in the area of the aircraft and check-in/boarding lounges. Uniformed members are to patrol and monitor security within the airport premises as detailed in section 2.5 below.

Passenger check-in was handled for Air India by Air Canada under contract with Air India. The check-in included passengers originating in Toronto and interline passengers but did not include the transit passengers to Montreal. The check-in passengers were numbered using a security control sheet in accordance with instructions from Air India; however, the check-in and interline baggage was not numbered, and no attempt was made to correlate baggage with passengers. Hence, any unaccompanied interline baggage would not have been detected.

The flight and cabin crew had been in Toronto for the week prior to this flight and were to take the aircraft to London where they would be replaced by another crew. The crew members themselves and their carry-on baggage were not subjected to any security checks; however, their checked-in baggage was screened in the same manner as other baggage.

2.3 Montreal

Air India Flight 181 from Toronto arrived at Mirabel International Airport at about 2100 EDT (0100 GMT, 23 June) and parked in supply area number 14 at 2106 EDT (0106 GMT). The 65 passengers destined for Montreal along with three Air India personnel deplaned and were transported by bus to the terminal building. The remaining passengers remained on board as transit passengers and were not permitted to disembark at Montreal. Air Canada baggage handlers off-loaded four containers of cargo, three containers of baggage and a valuables container. Two diplomatic pouches from the Indian High Commission in Ottawa were delivered to the aircraft by MEGA International Cargo. One pouch weighing one kilogram was hand-delivered to the flight purser for storage in a valuables locker within the cabin and the other pouch was loaded into the valuables container.

During the check of the aircraft at Montreal, the second officer pointed out to an Air Canada mechanic that a rear latch on the fan cowl for the 5th engine did not appear to be properly secured. The mechanic examined the latch and found it well secured, but the handle was not flush and was hanging about five degrees. The mechanic applied high-speed tape to the latch handle for aerodynamic smoothness. This repair was examined by the second officer who was satisfied with the work. No records were completed by Air Canada in connection with this temporary repair.

At about 1730 EDT (2130 GMT), Air Canada, which is Air India's contracted agent, opened its check-in counter to passengers who would be flying on Air India Flight 182. Burns security personnel were also assigned at this time to screen the checked baggage. Passenger tickets were checked, issued a number, and copies of the tickets were removed and retained by Air Canada. Boarding passes were then issued and affixed to the numbered tickets. Also attached to the ticket booklets were numbered tickets which corresponded to each piece of checked baggage. The numbered checked baggage was sent to the baggage area by Air Canada personnel to be security-checked by Burns security personnel.

The passengers for AI 182 after checking in were free to enter the departure area. At the entrance to the departure area, Burns security staff used X-ray units and metal detectors to screen passengers and carry-on baggage. At about 2100 EDT (0100 GMT), the passengers proceeded to gate 80 where they gave their boarding passes and numbered tickets to an Air Canada agent. The agent kept the numbered flight tickets and checked the numbers against the passenger list. Also, at gate 80, a secondary security check was done on passengers by a Burns security officer using a metal detector. Hand-carried baggage was subjected to further physical and visual checks. A total of 105 passengers boarded the flight at Mirabel Airport; there were no interline passengers.

Between 1900 (2300 GMT) and 1930 EDT (2330 GMT), Burns security personnel identified a suspect suitcase using the X-ray machine. The suitcase was placed on the floor next to the machine. The Burns security supervisor told Air India personnel that a suspect suitcase had been located and was advised within 15 to 20 minutes to wait for the Air India security officer who would be arriving on the flight from Toronto. Subsequently, a second suspect suitcase was identified and a little later a third. The three suitcases were placed next to the X-ray machine. Between 1930 (2330 GMT) and 1945 (2345 GMT), all the Burns security personnel at the X-ray machine were assigned to other duties and the three suspect suitcases remained in the baggage area without supervision. At about 2140 (0140 GMT), the Air India security officer went to the baggage room and inspected the three suitcases with the X-ray machine and a sniffer that was in the possession of the security officer. The Air India security officer decided to keep the three suitcases and, if further examination proved negative, send them on a later flight. At approximately 2155 (0155 GMT), the Air Canada Operations Centre supervisor contacted the airport RCMP detachment regarding the suspect suitcases. At about 2205 (0205 GMT), an RCMP member located the suitcases in the baggage room and requested that an Air India representative be sent to the baggage room. About five minutes later, the Air India security officer contacted the baggage room by telephone and advised that he could not come to the room immediately. The Air India security officer arrived in the baggage room at about 2235 (0235 GMT) and, when asked to determine the owners of the suitcases, informed the RCMP member that the flight had already departed

[2218 (0218 GMT)]. The three suspect suitcases were later examined with negative results.

The remainder of the checked baggage which cleared the security check was identified by a green sticker. The baggage was then forwarded to Air Canada personnel who loaded the baggage in containers to be placed on board the aircraft. A later check with Canada Customs and Air Canada at Mirabel revealed no unclaimed baggage associated with AI 181/182. A similar check at Dorval Airport was conducted with negative results.

No record was kept as to the location and number of individual pieces of checked-in luggage. Records were kept as to the location of the containers according to destination, where loaded and the number of pieces of luggage in each container (see Appendix B).

The Mirabel Detachment of the RCMP provided the following security at the airport on 22 June 1985:

- one member in a police vehicle for airside security;
- one member on patrol in the arrival and departure areas;
- one member on general foot patrol throughout the terminal; and
- one member as a telecommunications operator in the detachment office.

In addition, due to the increased threat to Air India flights, the RCMP provided the following supplementary coverage to Air India Flight 181/182 on 22 June 1985:

- one member in a police vehicle escorted the aircraft to and from the runway and the terminal building and remained with the aircraft while it was stationary;
- one member in a police vehicle remained at the entrance to the ramp;
- two members patrolled the area of the ticket counter and access corridors, and one of these members also served in a liaison capacity with the airline representatives.

2.4 International Standards and Recommended Practices

International security standards and recommendations to safeguard international civil aviation against acts of unlawful interference are listed in ICAO Annex 17 to the Convention on International Civil Aviation. Suggested security measures and procedures are amplified in the ICAO Security Manual for Safeguarding Civil Aviation Against Acts of Unlawful Interference.

Annex 17 requires contracting States of which Canada is one to "take the necessary measures to prevent weapons or any other dangerous devices, the carriage or bearing of which is not authorized, from being introduced by any means whatsoever, on board an aircraft engaged in the carriage of passengers."

In addition to other recommendations, Annex 17 recommends that contracting States should establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage, cargo, mail and stores to be carried on board aircraft.

The Security Manual specifies that,

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Recently, ICAO has proposed amendments to Annex 17. These proposals arise from a decision taken by the Council in its 115th Session on 10 July 1985. The Council instructed its Committee on Unlawful Interference, as a matter of urgency, to review the entirety of Annex 17 and to report on those provisions which might be immediately introduced, upgraded to Standards, strengthened or improved. Among the proposed amendments is the following upgrading in the Standards:

- Each contracting State ensure the implementation of measures at airports to protect cargo, baggage, mail stores and operator's supplies being moved within an airport to safeguard such aircraft against an act of unlawful interference.

2.5 Canadian Law

In terms of Canadian statutory requirements, the Civil Aviation Security Measures Regulations and the Foreign Aircraft Security Measures Regulations made pursuant to the Aeronautics Act require specified owners or operators of aircraft registered in Canada or specified owners or operators who land foreign aircraft in Canada to establish, maintain, and carry out security measures at airports consisting of:

- systems of surveillance of persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- systems of searching persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas that are inaccessible to any person other than a person who has been searched and the personnel of the owner or operator;
- a system that provides, at airports where facilities are available, for check-points at which persons intending to board the aircraft of an owner or operator can be searched;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas in which cargo, goods and baggage that have been checked for loading on aircraft are inaccessible to persons other than those persons authorized by the owner or operator to have access to those areas;
- a system of identification that prevents baggage, goods and cargo from being placed on board the aircraft if it is not authorized to be placed on board by the owner or operator; and
- a system of identification of surveillance and search personnel and the personnel of the owner or operator.

Specified carriers including Air Canada, CP Air, and Air India were required to provide a description of their security measures to the Canadian Minister of Transport.

An Order-in-Council on 29 September 1960 established that the RCMP was responsible for the direction and administration of police functions at major airports operated by Transport Canada. The duties of the Police and Security Detail at these designated airports include the following:

- carry out policing and security duties to guard against unauthorized entry, sabotage, theft, fire or damage;
- enforce federal legislation;
- respond to violations of the Criminal Code of Canada, Federal, Provincial, and Territorial statutes, and perform a holding action pending arrival of the police department having primary criminal jurisdiction;
- man guard posts; and
- provide a police response in those areas of airports where pre-board screening takes place.

Section 5.1(9) of the Aeronautics Act states that "The Minister may designate as security officers for the purposes of this section any persons or classes of persons who, in his opinion, are qualified to be so designated." Pursuant to this section Transport Canada has established criteria for persons or classes of persons that are designated as security officers in a Schedule registered on 11 April 1984. The criteria also specify that a security guard company and its employees will meet Transport Canada requirements provided that the company:

- is under contract with a carrier to conduct passenger screening under the Aeronautics Act and Regulations;
- is licensed in the province or territory;
- complies with the security guard criteria as follows in that the guard must:
- be 18 years or older,
- be in good general health without physical defects or

abnormalities which would interfere with the performance of duties,

- be licensed as a security guard and in possession of the licence while on duty, and
- meet the training standards of Transport Canada consisting of successfully completing the Transport Canada passenger inspection training program, attaining an average mark of 70 per cent, and undergoing refresher training within 12 months from previous training;
- uses a comprehensive training program which has been approved by Transport Canada and is capable of being monitored and evaluated;
- keeps records showing the date each employee received initial training and/or refresher training and the mark attained; and
- provides supervision to ensure that their employees maintain competency and act responsibly in the conduct of searching passengers and carry-on baggage being carried aboard aircraft.

2.6 Canadian Security Procedures

In accordance with the Canadian Aeronautics Act and pursuant regulations, air carriers are assigned the responsibility for security. Transport Canada provides the following security services for the air carriers using major Canadian airports, including the international airports in Vancouver, Toronto and Montreal:

- security and policing staff including RCMP airport detachments;
- specific airport security plans and procedures;
- secure facilities (e.g., secure areas, pass identification systems, etc.); and
- security equipment and facilities (e.g., X-ray detection units, walk-through metal detectors, hand-held metal detectors, explosive detection dogs).

As of 22 June 1985, the following general security measures were in place at Canadian airports:

- metal detection screening of passengers; and
- X-raying of carry-on baggage.

Checked baggage was not normally subject to any security screening. A few air carriers such as Air India had extra security measures in place because of an assessed higher threat level (see section 2.7 below).

On 23 June 1985, Transport Canada required additional security measures to be implemented by all Canadian and foreign air carriers for all international flights from Canada except those to the continental United States. These measures required:

- the physical inspection or X-ray inspection of all checked baggage;
- the full screening of all passengers and carry-on baggage; and
- a 24-hour hold on cargo except perishables received from a known shipper unless a physical search or X-ray inspection is completed.

Further, on 29 June 1985, Transport Canada directed that all baggage or cargo being interlined within Canada to an Air India flight was to be physically inspected or X-rayed at the point of first departure and that matching of passengers to tickets was to be verified prior to departure.

2.7 Air India Security Program in Canada

In accordance with the Foreign Aircraft Security Measures Regulations, Air India had provided the Minister of Transport with a copy of its security program. It included measures to:

- establish sterile areas;
- physically inspect all carry-on baggage by means of hand-held devices or X-ray equipment;
- control boarding passes;
- maintain aircraft security;

- ensure baggage and cargo security; and
- off-load baggage of passengers who fail to board flights.

Under these procedures established by Air India, passengers, carry-on baggage, and checked baggage destined for AI 181/182 on 22 June 1985 were subjected to extra security checks. A security officer from the Air India New York office arrived in Toronto on 22 June 1985 to oversee the security operation at Toronto and Montreal.

On 17 May 1985, the High Commission of India presented a diplomatic note to the Department of External Affairs regarding the threat to Indian diplomatic missions or Air India aircraft by extremist elements. Subsequently, in early June, Air India forwarded a request for "full and strict security coverage and any other appropriate security measures" to Transport Canada offices in Ottawa, Montreal and Toronto, and RCMP offices in Montreal and Toronto.

2.8 PD-4 Sniffer

On 18 January 1985, prior to the inaugural Air India flight out of Toronto on 19 January, a meeting on security for Air India flights (Toronto) was held with representatives from Transport Canada, RCMP and Air India. At this meeting, a PD-4 sniffer belonging to Air India was produced. It was explained that it would be used to screen checked baggage as the X-ray machine had not yet arrived. At that time, an RCMP member tested its effectiveness. The test revealed that it could not detect a small container of gunpowder until the head of the sniffer was moved to less than an inch from the gunpowder. Also, the next day the sniffer was tried on a piece of C4 plastic explosives and it did not function even when it came directly in contact with the explosive substance. It is not known if this was the same sniffer used on 22 June 1985.

2.9 Medical Evidence

Medical examination was conducted on the 131 bodies recovered after the accident. This comprises about 40 per cent of the 329 persons on board. It should be noted that assigned seating is based on preliminary information. Also, the exact position of passengers is not certain because it is not known if passengers changed their seats after lift-off. On the information available, the passengers were seated as follows:

Passengers:*

	Seats Available	Occupied	Bodies Identified
Zone A	16	1	0
Zone B	22	0	0
Upper Deck	18	7	0
Zone C	112	104 + 2	29
Zone D	86	84 + 1	38
Zone E	123	105 + 3	50
SUB-TOTAL	377	301 (+6 infants)	117
Crew:			
Flight Deck	3	3	0
Cabin	19	19	5
TOTAL	399	329	122

There were 30 children recovered and they showed less overall injury. The average severity of injury increases from Zone C to E and is significantly less in C than in Zones D and E.

Flail pattern injuries were exhibited by eight bodies. Five of these were in Zone E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evenly

*See Appendix C for interior seating arrangement.

distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).
Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 in Zone D, 11 in Zone E, 2 crew and 1 unknown), and 16 had little or no clothing.
Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).
There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).
There is a general absence of signs indicating the wearing of lap belts.
Pathological examination failed to reveal any injuries indicative of a fire or explosion.

2.10 Flight Recorders and Shannon Air Traffic Control (ATC) Tape Analyses

VT-EFO was equipped with a Fairchild A100 Cockpit Voice Recorder (CVR) and a Lockheed 209E Digital Flight Data Recorder (DFDR). These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the aft pressure bulkhead. The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor.
The Shannon Air Traffic Control Centre was in contact with VT-EFO and recorded radio communications with the aircraft. At the time of the accident, 5.4 seconds of noise was recorded, and the transponder signal seen on the radar scope was lost from the aircraft. This signal which displays aircraft altitude showed no deviation before disappearing from the radar scope.

2.10.1 Analysis by National Research Council, Canada

From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder. The initial waveform of the cockpit area microphone signal is not consistent with the sharp pressure rise expected with detonation of an explosive device close to the flight deck, but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, the possibility that it originated from such a device elsewhere in the aircraft cannot be excluded.
By correlating the oscillograph records of the CVR and the Shannon ATC VHF recording, it was estimated that the unusual sounds recorded on the ATC tape started 1.4 ± 0.5 seconds after the start of the sudden sound detected by the cockpit area microphone and lasted intermittently for 5.4 seconds. It was felt the closeness in time of the two noises indicated the 5.4 seconds recorded on the ATC tapes originated from AI 182. The ATC recording that followed the cockpit area microphone sounds appeared at first to contain a series of short intermittent sounds. Listening to the sounds, it also appeared that a human cry occurred near the end of the recording. Spectral analysis of these sounds and comparison with voice imitations revealed that the recorded sounds do not contain all the pitch harmonic frequencies normally associated with voice sounds. The origin of these sounds has not been determined.
An examination of the DFDR showed no abnormal variations before the accident. With the spare engine, this aircraft was restricted to altitudes below 35,200 feet and indicated airspeeds less than 290 knots. During the last 27 minutes of the flight, the

computed airspeed did gradually increase to nine knots above this limit in the first part of this period and the power was readjusted several times. The speed fell below the 290 knot limit at about 07h:09m GMT as recorded by the DFDR; power was increased again at about 07h:10m causing the aircraft to accelerate to six knots above the limit by the time the accident occurred at 07h:13m:59s. The observed excursions outside the specified limits are not considered significant.

The aircraft was flown with 1.5-degree left-wing-down with 4.2 degrees clockwise control wheel as compared to the aircraft without the 5th engine installation. Also, 9.4 per cent of right rudder pedal was applied giving a 1.1-degree right deflection of the upper and lower rudders. Considering the carriage of the 5th engine on the left side, these figures are not considered abnormal. When synchronized with the other recordings, it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR.

Irregular signals were observed over the last 0.27 inches of the DFDR tape. Laboratory tests indicated that the irregular signals most likely occurred as a result of the recorder being subjected to sharp angular accelerations about the lateral axis of the recorder, causing rapid changes in tape speed over the record head. This equates to an angular acceleration on the recorder about the aircraft's longitudinal axis in a left-wing-down sense. Therefore, these tests indicate that the digital recorder was subjected to a sharp jolt separate from any violent motion of the aircraft.

The other possibility for the irregular signals is that the Flight Data Acquisition Unit which generated the serial digital data signal and which is located in the electronics bay under the cabin floor forward of the cargo compartment could have suffered some damage or had an intermittent power supply that caused it to generate the irregular signals.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United

Kingdom
The AIB analysis was restricted to the CVR and the Shannon ATC tape. The correlation of the CVR and ATC tapes showed that the ATC recording started after the CVR had stopped recording and 1.1 ± 0.4 seconds from the start of the sudden sound. The total duration of the signal on the ATC tape was 5.4 seconds.

An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Evidence of the presence of audio warning signals buried amongst the noise was investigated with negative results. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.

The analysis of the ATC tape audio determined three or four words could be heard at the beginning of the transmission, but extensive filtering did not allow the sounds to be transcribed. Two bursts of tone occurred during the first second. The spectrum of the tone does not coincide with any B747 audio warning. The transmission is chopped until at about 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound is similar to that heard in other accidents where there has been a rapid increase in airspeed. Toward the end of the transmission a crying sound was heard; however, a study of the noise indicates a human cry would contain more harmonics. The origin of this sound was not determined. Knocking sounds were also heard during the transmission. These were initially thought to be due to hand-held microphone vibration, but this was discounted because of the frequency of the sounds. Almost identical sounds were heard on the DC-10 CVR after the explosive decompression had occurred. Their source was not identified. On the DC-10, the pressurization audio warning sounded 2.2 seconds after the decompression. No such warning was identified on the ATC tape.

*Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization. A loud noise is associated with this event but not necessarily an explosion.

Every aircraft provides a different signature when the press-to-transmit button is released. These signatures were compared with transients which occurred during the open microphone transmission. There is a close match with the previous AI 182 signatures. Therefore, it is almost certain that the ATC tape recording originated from AI 182.

The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182. It further states there is strong evidence to suggest a sudden explosive decompression of undetermined origin occurred. Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. However, the AIB report is of the opinion that the device would have to be small not to be detected as it is considered that a large high-explosive device could not fail to be detected on the CVR.

2.10.3 Analysis by Bhabha Atomic Research Centre (BARC), India

The BARC analysis was restricted to the CVR and the Shannon ATC tape.

Channel 3 of the recording which corresponded to the cockpit area microphone showed the first indication of a rising audio signal. The signal level rises from the ambient level in the cockpit by about 18.5 decibels in approximately 45 milliseconds. The signal starts falling and stabilizes at a level about 10 decibels higher than ambient for about 375 milliseconds. The total duration of the signal is about 460 milliseconds.

The timings of the CVR and the Shannon ATC tape were correlated, and it was determined that the explosive sound on the CVR coincided with the beginning of the series of audio bursts on the ATC tape. The report concluded that the sounds recorded on the ATC tape emanated from AI 182 at the time of the occurrence.

The noise on the CVR was compared with an explosion which caused the crash of an Indian Airlines B737. In this occurrence, the explosive sound recorded on the cockpit area microphone showed a rise time of about 8 milliseconds. It was also determined that the explosion occurred 8 feet from the microphone. The report concluded that the rise time is a measure of the distance from the cockpit area microphone to the source of an explosion. Hence, the exact location in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the cockpit judging from the rise time of 45 milliseconds.

The report concluded that the series of audio bursts on the ATC tape were most probably generated by the break-up of AI 182 in mid-air.

2.11 Aircraft Structures Examination

The examination of aircraft structures consisted of the following areas: floating wreckage, wreckage mapping and surveying, wreckage distribution, photographic and video interpretation of wreckage, wreckage recovery and initial examination, and examination of recovered wreckage.

2.11.1 Floating Wreckage

During the search, aircraft wreckage was sited and recovered by several search vessels. The wreckage was transported to Cork,

Ireland, where preliminary examination was conducted. This examination took place in June and July, 1985.
The wreckage consisted mainly of various leading edge skin panels of the left and right wings, left wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canoe fairing pieces, landing gear wheel well doors, pieces of elevator and aileron, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggage, suitcases, personal effects and a number of internal fittings. The floating wreckage constitutes about three to five percent of the aircraft structure.
The wreckage was then transported from Ireland to Bombay, India where it underwent further examination by the Floating Wreckage Structures Group which then produced a report which was submitted to the Indian Inquiry. The report concluded:

- There was no evidence of fire damage.
- There was no evidence of lightning strike damage.
- The cabin floor panels from the forward and rear sections of the aircraft separated from the support structure in an upward direction (floor to ceiling) pulling free from the attaching screws and, in some cases, breaking the vertical web of the seat track/ floor beams.
- The position of the leading edge flap rotary actuator and the damage to the flap structure indicated that the leading edge flaps were in the retracted position.
- The six spoiler actuators found were in the retracted position. The lower surface of all the spoiler panels showed signs of spanwise skin splits with the edges curled into the core of the honeycomb. The report concluded that this was possibly due to the loading of the spoilers by being deployed in flight at high speed, resulting in compression on the lower surfaces. This, in turn, caused splitting of the lower skin into the honeycomb.
- The right wing root leading edge, number 3 engine inboard

fan cowling, the right inboard midflap inboard leading edge, and the right stabilizer root leading edge all exhibited damage possibly due to objects striking the right wing and stabilizer before water impact.

In addition to the above conclusions, the following significant information regarding the floating wreckage is noted in the report:

- The aircraft was carrying a -7Q engine at the 5th pod and a -7J 5th pod kit in the aft cargo compartment. In all there were 14 engine fan cowls (four in the aft cargo compartment). Out of these 14 fan cowls, nine, including six from the working engines and three from the aft cargo compartment, and two additional pieces of fan cowls were found. Five of the fan cowls from the working engines showed folding damage lines at about the three and nine o'clock positions. The number 3 engine inboard fan cowl had severe impact damage on its leading edge and had small outward puncture holes but no penetration through the outer skin in the lower centre region. The two fan cowls of the -7J 5th pod kit stowed in the aft cargo compartment showed severe damage. One piece was cut at one corner in an arc of about 20 inches diameter and its external skin was peeled back.
- The cockpit entry door and the side bulkhead panel were found relatively intact but had come out of their attachments.
- Twelve toilet doors out of 16 were found and were relatively intact but had come out of their attachments.
- Cabin interior panels and overhead bins of the main and upper decks which were recovered exhibited only minor damage.
- The wooden boxes which contained the fan blades of the 5th pod engine were loaded in container 24L in the forward cargo compartment and were found broken apart exhibiting no burn marks.
- One passenger oxygen bottle and one portable oxygen bottle were recovered and showed no sign of damage.

Mr. V.J. Clancy, an aviation explosives expert representing Boeing Aircraft Corporation, prepared a preliminary report based on his examinations of certain items of recovered and floating wreckage. Mr. Clancy's report notes the following with respect to floating wreckage:

- A foam-backed floor panel which showed a small number of perforations was recovered. Mr. Clancy recommended that it should be X-rayed and a detailed examination completed.
- One of the lavatory doors had, into its inner surface, a number of fragments of glass mirror - presumably from breakage of a mirror normally fitted into the lavatory. Most of the fragments, buried edgeways, were oriented parallel to each other. The remainder were approximately at right angles to the others. Mr. Clancy concluded that it would be improbable that any reliance could be placed on the penetration by mirror fragments as being indicative of an explosion.
- Three steel oxygen cylinders which were stowed in the forward cargo compartment were recovered. One had been dented apparently by the impact of an object measuring about one to two centimetres. The depression had a maximum depth of about four millimetres.
- A few suitcases recovered among the floating wreckage were examined. Mr. Clancy felt that one might provide useful information. It was of red plastic material with a blue lining. Mr. Clancy reported that plastic material has been found to retain identifiable traces of explosive after long immersion in the sea. Also, the lining which was severely tattered resembled that of one found after an explosion in an aircraft in Angola.
- A wooden spares box was found on the foreshore of Wales. It was of the kind used on the aircraft. It was charred on one side and partially on the bottom. The depth of charring suggested that the burn time was three to four minutes. This box was normally stowed in the aft cargo compartment; however, on this flight it

may have been stowed in the forward compartment.

- Two pieces of the cover of an overhead locker originating above either door 2R or 4R were also found on the foreshore. They were partially damaged and blackened by fire. Mr. Clancy concluded that this indicated the presence of fire.
- Two pieces of U-section alloy channel partially filled with plastic foam were found on the foreshore. The alloy was of a kind not used in aircraft structure; however, it could have been from some fitting supplied by a sub-contractor. Also, since the pieces were found near an area where practice firings at targets are carried out off the west coast of the United Kingdom, it could have come from some other source. One piece of the alloy bore marks ("mooncraters") typical of an attack by very high velocity fragments such as produced by an explosion. X-rays showed the presence of a few small particles buried in the foam which Mr. Clancy recommended should be extracted and examined. He also felt that this provided the strongest single indication of an explosion and that it was essential to determine if these pieces came from the aircraft or any of the equipment or cargo aboard the aircraft.

The CASB in its examination of the floating wreckage noted the following:

- The fan cowls of the number 4 engine had a series of five marks in a vertical line across the centre of the Air India logo on the inboard facing side of the fan cowl. These marks had the characteristic airfoil shape of a turbine blade tip. It is possible that a portion of the turbine parted from the number 3 engine and struck the cowl of the number 4 engine.
- The upper deck storage cabinet which was located on the left side had unusual damage to its bottom. A large rounded dent in the bottom inboard edge of this stiff cabinet structure revealed smooth stretching without breakthrough. The damage did not seem to be achievable by inertia or impact forces as the cabinet

except for the bottom was undamaged. The damage was considered by a CASB investigator to be compatible with the spherical front of an explosive shock wave generated below the cabin floor and inboard from the cabinet; however, it is not known if this damage could be caused by some other means.

- The right wing root fillet which faired the leading edge of the wing to the fuselage ahead of the front spar had a vertical dent similar to that which would have resulted had the fillet run into a soft cylindrical object with significant relative velocity. The paint on the inboard chord appeared to be scorched brown in the centre areas of three honeycomb panels. It has been determined that sudden heat can turn these panels brown, but it is not known if other reasons for the discolouration exist. The fillet abutted the fuselage side at the aft end of the forward cargo compartment.
- There was blackened erosion damage to the bottoms of some seat cushions. The damage had an appearance similar to that which would have been caused by an explosive device. It is not known if marine life feeding on the cushions or some other cause could have produced the same effect.
- The charred wooden spares box contained some sand and small shellfish. The flesh from the shellfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

An electronic device was found among some floating wreckage and was forwarded to the Bhabha Atomic Research Centre for analysis. There was some concern that it could have been used to detonate an explosive device. The device was forwarded to the RCMP who in conjunction with the CASB determined it to be an item manufactured for use in radiosondes (weather balloons) and was not modified as a detonating device.

2.11.2 Wreckage Mapping and Surveying

The Canadian Coast Guard Ship (CCGS) John Cabot was given the task of mapping the wreckage on the ocean floor. On 19 July 1985, the Cabot with a SCARAB deep submersible on board departed Cork. On arrival at the site, and based on surface wreckage distribution and bottom side scan sonar plots, four transmitters were placed on the sea bed. These transmitters provided signals for the ALLNAV navigation system used to accurately plot the sea bed wreckage.

Based on all the data available, the SCARAB was launched on 24 July 1985 to begin the bottom search in position 51°01.9'N 12°41.0'W. During the mapping, stage areas were designated for search and each progressive area was determined based on the information gained during the search. The search was conducted using sonar and video. Wreckage found was recorded on video tape and on 35mm positive film.

The first object plotted on the sea bed was a torn suitcase located at lat 51°02.63'N, long 12°53.15'W and was the most westerly object located. This suitcase has not been recovered, nor has it been positively identified as having come from the accident aircraft.

As the search progressed eastward, the first positive identification of aircraft wreckage was made at lat 51°02.9'N, long 12°49.93'W. Slowly, over a period of about 90 days, a detailed bottom wreckage plot was developed.

While mapping was in progress, some of the wreckage was revisited to obtain additional data. During the transit through areas already searched, wreckage not previously plotted was found, and, in some areas, the density of wreckage physically precluded 100 per cent coverage. Components and major structural items were identified from all sections of the aircraft and when the mapping of the sea bed ended, most of the aircraft had been found and photographed. Although positive identification of each piece of wreckage could not be made, it was decided in late October 1985 that the search phase was essentially completed and wreckage recovery could begin. A bottom wreckage distribution plot is contained separately in an envelope as Appendix F.

2.11.3 Wreckage Distribution

The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling on the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled.

Although badly damaged, sections 41, 42 and 44*, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been plotted or photographed.

Sections 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the westernmost identified aircraft component located at lat 51°02.90'N and long 12°50.1'W. The wreckage extended in a line about 110 degrees True to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern.

A?? third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southeast orientation. One of the operating engines was displaced 0.5 nautical miles to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

*See Appendix D for location of aircraft sections and aircraft body stations (BS).

2.11.4 Photographic and Video Interpretation of Wreckage

2.11.4.1 Photographic Interpretation

All wreckage sighted was recorded on video tape and all major items were recorded on 35mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage patterns. For example, the sine wave bending of target 7* appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into account.

2.11.4.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

2.11.4.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gear were in the 'up' position at the time of impact.

2.11.4.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

*See Appendix E for location of targets on aircraft.

2.11.4.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

2.11.4.6 Section 42

Portions of section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers.

All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

2.11.4.7 Section 44

Section 44, containing the aircraft structure between body station (BS) 1000 and BS 1480 including that area where the fuselage and wings were mated was located in the same general area as the forward sections of the aircraft. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one-third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gear were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

2.11.4.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northernmost area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

2.11.4.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of BS 1480 and, for purposes of this Submission, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were identified (targets 35, 37, 73 and 296), and one portion of the bulkhead was never located. Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognizable as having come from a specific area of the aircraft.

Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from BS 1600 to BS 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

The tail cone and the auxiliary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure of air or water.

The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabilizer was missing and the auxiliary spar was exposed. There was localized damage to the right-hand root of the leading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

2.11.4.10 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from sections 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42, and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat-belts were not fastened.

2.11.5 Wreckage Recovery and Initial Examination

During the wreckage mapping, some small items were recovered, and an unsuccessful attempt was made to recover a portion of the forward cargo door. On completion of the sea bed survey, an offshore supply ship, Kreuztrum, chartered by the National Transportation Safety Board (NTSB), joined John Cabot for a wreckage recovery operation. Prior to the commencement of the wreckage recovery, the structures group met at the Boeing facility in Seattle, USA and reviewed the video tapes and photographs of the wreckage. Based on their findings, a list of items was identified as being most desirable for recovery. The priority list was prepared by a group in Cork, Ireland, headed by Dr. V. Ramachandran. On 8 October 1985, the John Cabot sailed, and on 9 October 1985, the Kreuztrum sailed for the accident site. The following target numbers and items were recovered during the mapping and wreckage recovery stages of the investigation: 7, 8, 35, 47, 117, 193, 223, 245, 287, 296, 299, 362/396, and 399 (as the location on the aircraft of some of the targets was not known when Appendix E was created, some are not shown in the appendix). The first officer's seat, some suitcases and small debris were also recovered using a metal frame basket. Initial examination of the wreckage was carried out in Cork and then it was transported to Bombay for detailed examination.

2.11.6 Examination of Recovered Wreckage

Although all the recovered wreckage was examined, only those items exhibiting characteristics which provided some evidence as to what may have happened to the aircraft during its final moments of flight are discussed. CASB engineering personnel and other participants examined the recovered wreckage at Cork and Bombay. The observations made during their examinations are discussed below.

2.11.6.1 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from BS 1480 to 1860 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear, and the torn edge was buckled in waves, like the trace of a sine wave. On the right side, between the one-quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at BS 1480. The skin tear located at about BS 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distorted and elongated.

The left and right trunnion vertical support fittings located at BS 1480 were examined optically using the stereomicroscope. Both trunnions were fractured through the three bolt holes. The right fracture characteristics were consistent with an overload mode of failure. Although most of the left fracture surface was also characterized by overload features, there were heavily corroded areas where the fracture mode could not be confirmed through optical examination. One lug fracture was sectioned from the left trunnion and prepared for scanning electron microscope (SEM) examination. After the corroded area was cleaned, the examination revealed some ductile characteristics on the fracture surface. There was no evidence of intergranular fracture observed to suggest a stress corrosion cracking mode of failure, nor was there any evidence of progressive failure observed. The corrosion appeared to have developed after the accident.

2.11.6.2 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from BS 1860 to 1960 and from stringer 46L to 46R. A small section from the aft end along the belly skin splice at stringer 46L was removed for examination. SEM examination revealed that the fracture was characterized by slightly elongated ductile dimples along its length, including areas adjacent to the edges of the rivet holes. On the aft edge of each rivet hole examined, a distinctive shear lip was observed. These features are consistent with an overload mode of failure along the skin splice with an apparent direction of failure from aft to forward.

2.11.6.3 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 o'clock position. The piece from 12 to 1 o'clock had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 o'clock position, the outer edge showed sinusoidal buckling, and the edge sector at 9 o'clock was partially collapsed and its edge was turned under. Samples taken for optical stereomicroscope and SEM examination revealed that the fracture characteristics were consistent with an overload mode of failure. The examination suggested a general direction of failure from the aft to the forward edge of the rear pressure bulkhead panel.

2.11.6.4 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occupied the 7 to 9 o'clock position. Optical and SEM examination were undertaken on this item.

The fracture along the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

Representative fracture samples were cut from the left-hand and right-hand edges of the fracture surfaces. Optical and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

2.11.6.5 Target 47 - Aft Cargo Compartment

This portion of the aft cargo compartment roller floor was located between BS 1600 and BS 1760. Based on the direction of cleat rotation on the skin panel (target 7) and the crossbeam displacement on this structure, target 47 moved aft in relation to the lower skin panel when it was detached from the lower skin. No other significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

2.11.6.6 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between BS 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

2.11.6.7 Target 399 - Left-Hand Side Triple Seat with Tray Arms

It would appear that this section was from row 18, seats A, B and C, the first set of triple seats aft of door 2L. The notable damage to this unit was as follows: front leg aisle side buckled and crushed in place; front leg window side buckled and crushed in place; forward edge tube to seat broken and bent downwards at joint with fore and aft tube between window and centre seats; and fore and aft tube between centre and aisle seat broken at start of T-connection to rear edge of seat tube. The damage suggests that the failures resulted from vertical loading. All the life-jackets were in place.

2.11.6.8 Target 399 - Fuselage Side and 2R Entry Door

The fuselage segment was located between BS 780 and 940. This piece was badly damaged and buckled inwards along a line through the lower door hinge. There were 12 holes or damaged areas on the skin generally with petals bending outwards. The curl on a flap around a hole had one full turn. This curl was in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.

When this target was recovered from the sea, along with it came a few hundred tiny fragments and medium-sized pieces. One of the medium-sized pieces recovered with this target was a floor stantion about 35 inches long. It was confirmed that this stantion belonged to the right side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the stantion.

Scientists from the Bhabha Atomic Research Centre, the National Aeronautical Laboratory and the Explosives Research and Development Laboratory in India conducted a metallurgical examination of certain items of wreckage. Their report on target 399 concluded that:

- the curling of the metal on the floor channel was indicative of a shock wave effect;
- the large number of tiny fragments from the disintegration of nonbrittle aluminum was a characteristic indication of explosive forces; and
- the indications of punctures, outward petalling around holes, curling of metal lips, reverse slant fracture, formation of spikes at fracture edges and certain microstructural changes all were indicative of an explosion.

2.11.6.9 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segment was located between BS 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

2.11.6.10 Target 362/396 - Lower Skin Panel - Forward Cargo Area

This section of skin panel was located between BS 720 and 860 and is just below target 399. The skin was badly crumpled and torn and had several punctures. It was pulled free from a large mass of debris which included some mangled cargo floor beams and roller trays. Some of the punctures had a feathered or spiked profile, with spikes angled at approximately 45 degrees to the edge. Other puncture holes gave clear indication of being formed by underlying stiffeners at impact. Two of these holes contained pieces of web stiffener. Most of the punctures were the result of penetrations from inside.

In the preliminary report of Mr. V.J. Clancy, representing Boeing, the following observations regarding target 362/396 were made:

- There were about 20 holes in the lower skin panel clearly resulting from penetration from inside.
- In addition to the fact that perforation was from inside, there were certain features which suggested that they were made by high velocity fragments such as those produced by an explosion.

Mr. Clancy's report describes these features as follows:

- the presence of toothed or spiked edges at some parts of the metal which has petalled out from the perforations;

(Tardif and Sterling, Canadian Aeronautics and Space Journal, 1969, 15, 1, 19-27, obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.)

- the presence of marked curling (in some cases of more than 360 degrees) of some of the petals;

(Tardif and Sterling stated that such curling was a feature of explosively produced fragments.)

- the virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal;

- the virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object, thereby suggesting that the production of at least many of the perforations were separate independent events; and
- the presence of one perforation (identified as number 14) resembling a "bullet hole" that was clearly punched out - a type of hole usually associated with a high velocity missile.
- There was evidence that the forward part of the skin panel had been folded back inward along the line of station 760 and then bent back again along a line slightly forward of this station.
- Such folding, perhaps violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces, thus producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.
- One hole (identified as number 13) was almost certainly caused by a slipping wire rope used as a sling.
- Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken of this area for further examination for evidence of fire or explosives.
- A large number (several hundred) of small fragments were recovered. These varied in size from an inch or less to a few inches. They included fragments broken out of sheet metal, and these were reported to be from the same area as T362.
- The production of a large number of small fragments is generally regarded as an indication of an explosion.
- One piece, which was isolated, was about an inch square of sheet alloy with characteristic spikes on one edge similar to those described by Tardif and Sterling.

The following is an excerpt from the report by Mr. V.J. Clancy wherein he gives his opinion and conclusions regarding target 362.

"Opinion

The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

A more detailed study, metallurgical and fractographic, is required.

The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

The single "bullet hole," No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

If the forward part of this item was forcefully and rapidly folded back to impact on the other part, it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility.

The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.

The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

Mr. Clancy concluded that:

"there is strong circumstantial evidence that an explosion occurred but neither individually nor collectively do the several pointers give the degree of confidence necessary for a firm and final conclusion, at this time."

With respect to target 362/396, in his report Mr. Clancy recommended:

"that firing trials be carried out projecting various size missiles at targets similar to the material of T362 to obtain reference samples for laboratory comparison with the perforations in T362."

The Indian report, in addition to the observations made by Mr. Clancy, noted the following with respect to the metallurgical examination:

- The microstructure in the various areas examined on target 362/396 confirmed explosive loading in this part of the aircraft.
- The holes and other features observed in targets 362/396 and 399 must have been due to shock waves and penetration by fragments resulting from an explosion inside the forward cargo hold.
- The chemical nature of the explosive material was not identified. No part of an explosive device, its detonator or timing mechanism was recovered.

2.11.6.11 Examination of Wreckage in India with CASB Participation

The examination of the targets recovered did not reveal any pre-existing defect, premature cracking or pre-impact corrosion damage associated with any of the failures.

3.0 DISCUSSION

3.1 Initial Event

From the correlation of the recordings of the DFDR, CVR and

Shannon ATC tape, the unusual sounds heard on the ATC tape started shortly after the flight recorders stopped recording. The conversations in the cockpit were normal, and there was no indication of an emergency situation prior to the loud noise heard on the CVR a fraction of a second before it stopped recording. The DFDR showed no abnormal variations in parameters recorded before it stopped functioning. The only unusual observation was the irregular signals recorded over the last 0.27 inches of the DFDR tape. Laboratory tests indicated the possibility that these signals resulted from the recorder being subjected to a sharp disturbance at the time it stopped recording. The other possibility for the irregular signals on the DFDR is that they were caused by a disturbance to the Flight Data Acquisition Unit in the main electronics bay. Since there was an almost simultaneous loss of the transponder signal, this indicates the possibility of an abrupt aircraft electrical failure. The medical evidence showed a general absence of signs indicating that seat-belts were fastened. From the video and photographic examination of the wreckage on the bottom, it was ascertained that the majority of seats located did not have the seat-belts fastened. The above evidence indicates that the initial occurrence was sudden and without warning. The abrupt cessation of the data recorder could be caused by airframe structural failure or the detonation of an explosive device as the initial event. The millisecond noise on a CVR as observed in this case is usually, as described in the available literature, the result of the shock wave from detonation of an explosive device. However, in this case, certain characteristics of the noise indicate the possibility that the noise was the result of an explosive decompression. There is some disagreement regarding the cause and location of the source of the noise heard on the CVR, that is, whether the noise resulted from an explosive device or an explosive decompression and whether the noise originated from the rear or closer to the front of the aircraft.

3.2 Passenger/Flight Deck Area

From the examination of the wreckage recovered and wreckage on the bottom, there is no indication that a fire or explosion emanated from the cabin or flight deck areas. The medical examination of the bodies also showed no fire or explosion type injuries. However, pieces of an overhead locker coming from above door 2R or 4R had been blackened by fire. There was blackened erosion damage to the bottoms of some seat cushions, showing damage possibly from an explosive device, and the upper deck storage cabinet had a large rounded dent in the bottom inboard edge which might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet. It should be noted that the pieces of the overhead locker were found on the Welsh shore some time after the accident, and it is not known if the pieces were subjected to a fire after the accident. Also, it is not known if the damage to the seat cushions and the upper deck storage cabinet could have been caused by other means. Nevertheless, the above evidence suggests that some areas of the passenger cabin may have been subjected to minor fire and explosive damage possibly emanating from below the cabin floor.

3.3 Aircraft Break-up Sequence

The medical evidence showed a proportion of the passengers with indications of hypoxia, decompression, flail injuries and loss of clothing. The incidence of hypoxia and decompression indicates that the aircraft experienced a decompression at a high altitude. The flail injuries and loss of clothing indicate a proportion of the passengers were ejected from the aircraft before water impact. The severity of injuries increased from Zones C to E and was significantly less in Zone C than in Zones D and E. The wreckage of the forward portion of the aircraft up to and including the aircraft body wheel well area and the wings was lying about 0.8 miles north of the vertical and horizontal stabilizers. Hence, it is likely that the aft portion of the aircraft separated from the forward portion before striking the water. In addition, the wreckage found west of longitude 12°48' consisted of suitcases and aft cargo compartment lower skin panels. There was also a wide scatter of sections 46 and 48 in an east-west direction, whereas the wreckage of the forward portion was mainly localized within a relatively small area.

The higher severity of injuries in the aft end of the passenger cabin appears to coincide with the break-up of the aft end, sections 46 and 48 of the aircraft. The fact that items from the aft cargo compartment were found further west than the tail section indicates that the aft cargo compartment ruptured first during the break-up sequence of the aft end. The forward portion of the aircraft was highly localized, which indicates that it struck the water in one large mass.

3.4 Aircraft Structural Integrity

As described earlier, the sudden nature of the occurrence indicates the possibility of a massive airframe structural failure or the detonation of an explosive device.

3.4.1 Aircraft Break-up

The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer before water impact. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.

The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile to the west indicating that there was some break-up of the

number 3 engine before water impact.
The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction. Also, passenger seats viewed and recovered exhibited that they had been subjected to an upward force from below. They showed that the seats to the rear in sections 46 and 48 had their back legs buckled, and the seats toward the front had both front and back legs buckled. This indicates the vertical force was greater at the front than the rear of the aircraft. It is possible that this vertical force on the floor was caused by the force of the water during impact, but the rear of the aircraft broke up before impact and therefore any vertical loading on the floor in this area is unlikely to have occurred at impact. Twenty-three passengers also showed evidence of vertical impact injuries. These could have been caused from a force from below during flight or at water impact. Sixteen of these passengers had little or no clothing indicating that some may have been ejected before water impact. Therefore, there is some indication that the upward force on the floor may have occurred in flight and was more severe toward the front.

3.4.2 Aft Pressure Bulkhead

The localized impact mark found on the leading edge of the right horizontal root leading edge is indicative of an object striking the stabilizer in flight before water impact. This suggests that the loss of the tail plane was not the first event. The horizontal and vertical stabilizers were found separated and each was intact and in good condition. Items from the aft cargo compartment were found further to the west of the tail plane. The absence of the type of damage to the tail plane as was found in the Japan Airlines (JAL) Boeing 747 accident where the aft pressure bulkhead failed and which took place shortly after this occurrence, and the rupture of the aft cargo compartment before the loss of the tail indicate that there was not an in-flight failure of the aft pressure bulkhead. In addition, examination of the recovered portions of the bulkhead shows evidence of overload failures from the rear to front only and no evidence of any pre-existing defect, premature cracking or pre-impact corrosion damage.

3.4.3 Target 7 - Lower Fuselage Skin Panel

Target 7 which extends from BS 1480 to 1860 shows a break at the joint at BS 1480. The forward keel joint splice plate is bent and the keel joint holes are distorted and elongated. Some of the fracture surface was heavily corroded. An in-flight failure in this area would cause a massive failure of the aircraft's structural integrity. Further examination showed the fractures to be overload, and there was no evidence of an intergranular type fracture to suggest a stress corrosion cracking mode of failure. The corrosion was concluded to be post-impact and, therefore, there is no evidence to suggest an in-flight failure in this area as the initial event.

3.4.4 Structural Failure

The examination of the floating and recovered wreckage and the analysis of the photos and videos of the wreckage on the bottom failed to indicate any evidence of a failure of the primary or secondary structure as a result of a pre-existing defect. The initial event has been established as sudden and without warning. The abrupt cessation of the flight recorders indicates the possibility of a massive and sudden failure of primary structure; however, there is evidence to suggest that there were ruptures in the forward and aft cargo compartments prior to any failure of the primary structure in flight. Therefore, available evidence tends to rule out a massive structural failure as the initial event.

3.4.5 Explosive Device

A violent explosion occurring within an aircraft in flight usually leads to a complicated break-up mode and sequence of failure. Fractures of metal caused by an explosion are normally different in character to those caused by overstressing or crash impact forces. Shattering of metal into very small and numerous fragments and minute deep penetration of a metal surface are not usually found in aircraft accident wreckage. The size and characteristics of these particles often accompanied by rolled edges, surface spalling, pitting or evidence of heat are indicative of an explosion.

Of the floating wreckage, there is little to indicate the possibility of an explosion:

- the lining in one suitcase was severely tattered;
- although the wooden spares box was burned, this could have happened after the occurrence;
- although pieces of an overhead locker were damaged by fire, it is not known if the burning happened at the time of the occurrence;
- although the pieces of U-section alloy clearly indicated evidence of an explosion, it is quite possible that these pieces were not associated with the aircraft;
- the bottoms of some seat cushions show indications of a possible explosion;
- the inside of the right wing root fillet appears to have been scorched; and

- the deformation of the floor of the upper deck storage cabinet might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet.

It is not known if the suitcase came from the aft or forward cargo compartment, and the location of the seats from which the cushions came is also unknown.

The scorching of the right wing root fillet and the damage to the upper deck cabinet suggest, if there was an explosion, it emanated from the forward cargo compartment.

From the examination of the recovered wreckage, the following deductions can be made:

- Target 47, which is a portion of the aft cargo compartment roller floor, shows no indications characteristic of an explosion emanating from the aft cargo compartment.
- Target 362/396, which is a lower skin panel from the forward cargo compartment is badly crumpled and torn and has about 20 punctures resulting from penetration from inside. It appears that some folding occurred on water impact which brought stringers or stiffeners from the aircraft structure into forceful contact with the internal surface of the panel producing most of the penetrations. However, there are certain punctures which indicate no evidence of impact marks on the inside surface and show evidence of being produced by high velocity fragments. Part of the inner surface of the skin panel appeared to have been blackened by soot from a fire.
- Target 399, consisting of a piece of the skin and stringers on the right side in the area of the forward cargo compartment contained holes and several hundred metal fragments. The damage to the floor stantion and the presence of the fragments are consistent with an explosion.

The examination of the recovered wreckage contains no evidence of an explosion except for targets 362/396 and 399 which contain some evidence that an explosion emanated from the forward cargo compartment.

An explosion in the forward cargo compartment would explain the loss of the DFDR, CVR and transponder signal as the electronics bay is immediately ahead of the cargo compartment.

3.5 Security Aspects

There is a considerable amount of circumstantial and other evidence that an explosive device caused the occurrence. Therefore, it is reasonable to examine the security measures in place on 22 June 1985. The evidence indicates that if there was an explosion, it most likely occurred in the forward cargo hold, not the passenger and flight deck areas or exterior to the fuselage. Although an explosive device could have been placed in a cargo hold in a number of ways, the available evidence points to the events involving the checked baggage of M. and L. Singh in Vancouver. The investigation determined that a suitcase was interlined unaccompanied from Vancouver via CP Air Flight 060 to Toronto. In Toronto, there is nothing to suggest that the suitcase was not transferred to Terminal 2 and placed on board Air India Flight 181/182 in accordance with normal practice. The aircraft departed Toronto for Mirabel and London with the suitcase unaccompanied. Similarly, a suitcase was interlined unaccompanied on CP Air Flight 003 from Vancouver to Tokyo to be placed on Air India Flight 301 to Bangkok. The explosion of a bag from CP 003 at Narita Airport, Tokyo, took place 55 minutes before the AI 182 accident. Therefore, the nature of the link between the two occurrences raises the possibility that the suitcase which was unaccompanied on AI 182 contained an explosive device.

3.5.1 Canadian Security Situation

Canadian security arrangements in place prior to 23 June 1985 met or exceeded the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand luggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

In Canada, the Department of Transport (Transport Canada) is responsible for establishing overall security standards for airports and airlines, and for the provision of certain security equipment and facilities at airports. By regulation, air carriers are responsible for applying security standards for passengers, for baggage and cargo and for ensuring security within individual aircraft. The RCMP provides airport physical security and responds to criminal incidents.

Air carriers contract for or otherwise provide the personnel who operate the security check-points through which passengers and their carry-on baggage enter the secure area of the airport terminal. These personnel also operate security equipment for the screening of cargo, passengers and checked baggage. Usually, air carriers use the service of private security firms. Transport Canada has established certain standards required for licensed security guards, such as the successful completion of the Transport Canada passenger inspection training program and annual refresher training. As stated earlier, a significant number of the security guards did not meet the criteria with respect to the completion of the training program and refresher training. In addition, the criteria do not require training for the screening of cargo and checked baggage.

ICAO Annex 17 recommends that contracting States establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage or cargo intended to be carried on board aircraft. For all Canadian airlines, Canadian regulations before 23 June 1985 required a system of identification that prevented baggage, goods and cargo from being placed on board an aircraft if it was not authorized to be placed on board by the airline operator. However, if someone were to purchase a ticket, check in baggage and not board the aircraft, the baggage would in all likelihood have been authorized by the airline to be placed on board the aircraft. Therefore, it was possible to interline baggage unaccompanied and this explains how a suitcase was interlined to AI 181/182 from CP 060. It is not the normal practice of airlines to interline baggage if there is not a confirmed reservation to the destination. In this case, the ticket agent allowed the suitcase to proceed; however, if there had been a confirmed reservation, the suitcase would have been interlined unaccompanied without question.

3.5.2 Air India Security

Air India, as required by Canadian regulation, had a security program. Because of the threat level assessed against the airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and received extra security from Transport Canada and the RCMP for the month of June 1985. For Air India Flight 181/182, Air India provided a security officer from its New York office to oversee the security arrangements at Toronto and Mirabel. The security program at each airport was under the overall supervision of the respective Air India station managers. In Toronto, it was not clear who, if anyone, was undertaking this function.

It is not known if the suitcase interlined from CP 060 was screened before or after the X-ray machine broke down in Toronto. Although baggage not examined by X-ray was screened by a PD-4 sniffer, there are indications that the sniffer could have been ineffective in detecting explosives, especially plastics. Rather than using the sniffer, it would have been more effective to open all bags and physically inspect them. Even though a number of security personnel were not adequately trained in the screening of passengers and baggage, it is not known whether more training would have prevented an explosive device from being placed on board.

Although airline procedures required baggage to be accompanied, the agents checking in passengers in Toronto used a passenger security numbering system but did not number checked-in baggage, and baggage was not correlated with passengers. Therefore, the interlined unaccompanied suitcase from CP 060 was not detected. At Mirabel, checked-in passengers and baggage were numbered so that the number of passengers checking in baggage could be correlated with the number of passengers boarding the aircraft. Had a passenger-baggage correlation been carried out in Toronto, the suitcase from CP 060 would have been detected. The airline procedures would have prevented the placement of the suitcase on the aircraft.

Once loaded on the aircraft, the suitcase would have been placed in container 11L and 12L (see Appendix B) if in the forward cargo compartment, in container 44L or 44R if in the aft cargo compartment, or in position 52 if in the bulk cargo compartment. It could not be determined in which cargo compartment the suitcase was loaded.

Therefore, although the procedures were in place to prevent an explosive device from being placed on board the aircraft in checked-in baggage, there was a breakdown in the X-ray machine used to screen baggage, and there are indications that the PD-4 sniffer was inadequate. Also, the security numbering system used in Toronto was ineffective in preventing unaccompanied interlined baggage from being placed on board the aircraft.

4.0 CONCLUSIONS

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion.

4.2 Other Findings

Even though they may not be causal or related to the accident, the following additional conclusions can be drawn from the investigation with respect to certain security arrangements and their application pertaining to this flight:

1. In compliance with the International Civil Aviation Organization Annex 17 to the Convention on International Civil Aviation, the Department of Transport of Canada has made regulations requiring foreign aircraft operators who land in Canada to establish, maintain, and carry out certain security measures at airports.
2. In accordance with these regulations, Air India submitted a security program to the Minister of Transport which included security measures with respect to aircraft, cargo, baggage, and passengers.
3. On 22 June 1985, an unaccompanied suitcase was interlined from Vancouver to Toronto on CAP Flight 060 for transfer in Toronto to Air India Flight 181/182.

4. The baggage loaded in Toronto was screened through an X-ray machine process but, during the course of this procedure, the X-ray machine broke down.
5. After the X-ray machine breakdown, an explosives detector was used to screen the baggage; the baggage was not opened and physically examined.
6. The effectiveness of the explosives detector is in doubt.
7. It is not known whether the unaccompanied suitcase interlined from Vancouver was screened before or after the X-ray machine broke down.
8. The security numbering system used in Toronto did not prevent unaccompanied interlined baggage from being placed on board the aircraft.
9. The normal procedures for interlining baggage in Toronto indicate that the unaccompanied suitcase was loaded on Air India Flight 181/182.

Appendix A

PAGE

REPORT
OF
THE COURT INVESTIGATING
ACCIDENT TO AIR INDIA
BOEING 747 AIRCRAFT VT-EFO,
"KANISHKA"
ON 23RD JUNE 1985

HON'BLE MR. JUSTICE B. N. KIRPAL
JUDGE, HIGH COURT OF DELHI

ASSESSORS

DR. V. RAMACHANDRAN   MR. J. S. GHARIA

CAPT. J. S. DHILLON   MR. J. K. MEHRA

CAPT. B. K. BHASIN

SECRETARY

MR. S. N. SHARMA

FEBRUARY 26, 1986

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INTRODUCTION

1.1.1 On the morning of 23rd June, 1985 Air India's Boeing 747 aircraft VT-EFO (Kanishka) was on a scheduled passager flight (AI-182) from Montreal and was proceeding to London enroute to Delhi and Bombay. It was being monitored at Shannon on the Radar Scope. At about 0714 GMT it suddenly disappeared from the Radar Scope and the aircraft, which has been flying at an altitude of approximately 31,000 feet, plunged into the Atlantic Ocean off the south-west coast of Ireland at position latitude 51° 3.6'N and Longitude 12° 49'W. This was one of the worst air disasters wherein all the 307 passengers plus 22 crew members perished.

1.1.2 The fact that emergency had arisen was first noticed by Shannon Upper Area Control (UAC) after the aircraft had disappeared from the Radar Scope. The control gave a number of calls to the aircraft but there was obviously no response. Thereafter various messages were transmitted and that is how the rest of the world came to know of the accident.

1.1.3 Shannon Control at 0730 hours advised the Marine Rescue Coordination Centre (MRCC) about the situation which appeared to have arisen. MRCC, in turn, explained the situation to Valencia Coast Station and requested for a Pan Broadcast. Thereafter ships started converging on the scene of the accident and they commenced search and rescue operations.

1.1.4 The aircraft in question - Kanishka, was named after the most powerful and famous king of the Kushanas who perhaps ruled in India from AD 78 to AD 103. Besides being a great conqueror, he was an ardent supporter and follower of Budhism - a religion which preaches non-violence. Emperor Kanishka, however, met a violent end. After 25 years of reign he was killed by some of his own subjects. His life was thus brought to an abrupt end.

1.1.5 It is indeed ironical that the Jumbo Jet which bore the name 'Kanishka' also met with a violent and a sudden end on that fateful morning of 23rd June, 1985.

INITIAL ACTION TAKEN BY THE
GOVERNMENT OF INDIA

1.2.1 Initial intimation of the accident was received by Air India who, in turn, communicated the same to Mr. H.S. Khola, Director of Air Safety, Civil Aviation Department, New Delhi. The Accident Investigation Branch of United Kingdom also sent information to the Director General of Civil Aviation, New Delhi to the effect that the accident had taken place on international waters and as such it was India which was the authority to investigate the accident in accordance with the provisions of ICAO Annex 13.

1.2.2 Thereupon Order No. AV.15013/8/85-AS dated 23rd June, 1985 was issued by the Director General of Civil Aviation whereby Mr. H.S.Khola was appointed Inspector of Accidents for the purpose of carrying out the investigation into the aforesaid air accident. This appointment was made under Rule 71 of the Aircraft Rules, 1937.

1.2.3 While search and rescue operations were underway at the site of the accident, a team of officials headed by Dr.S.S. Sidhu, Secretary, Ministry of Tourism & Civil Aviation rushed from India to Cork. The said team was joined by Mr. Kiran Doshi, the Indian Ambassador to Ireland, and also by two officers of the Indian Navy who were attached to the Indian High Commission at London. Subsequently two Medical Experts from India also joined the said Team.

1.2.4 The Indian Team arrived at Cork, Ireland on 24th June, 1985. Representatives of the Governments of United States of America, Canada and United Kingdom also reached there that day. They were met by the representatives of the Government of Ireland.

1.2.5 The members of the Team saw the rescue and salvage operations being conducted. They also visited the Cork Regional Hospital and had discussions with Irish and other Authorities with a view to release the bodies of the victims which were being brought to Cork.

1.2.6 For facilitating the process of investigation the Inspector of Accidents after consulting the representatives of the aforesaid Governments formed the following groups:

a. Structures, Power Plant and Systems Group.
b. Operations Weather & ATS Group.
c. Medical and Human Factor Group.
d. Search & Rescue Group.

The aforesaid groups were required to collect evidence and to submit their respective reports to the Inspector of Accidents.

1.2.7 The bodies which were being recovered were brought to the Cork Regional Hospital for identification and post-mortem. At that time it was considered proper that apart from the two medical experts from India, Wing Commandor Dr.I.R. Hill, who is an expert in aviation pathology should also be called from United Kingdom.

1.2.8 It was also being speculated that the accident may have occurred due to an explosion on board the aircraft. In order to see whether there was any evidence of an explosion which could be gathered from the floating wreckage which was being salvaged, the Government of India requisitioned the services of Mr. Eric Newton, a Specialist in the detection of explosives sabotage in aircraft wreckage.

1.2.9 In order to coordinate and guide the operations of the various ships working at the crash site, a control centre was set up at Cork Airport on 30th June, 1985.

1.2.10 The control centre was manned by representatives of the Governments of Ireland, Canada and United States. The Indian Naval Officers from the High Commission at London were overall in-charge of this centre. After the flight recorders had been recovered the centre continued to function, but the representatives of the United States departed.

1.2.11 For retrieving the Cockpit Voice Recorder (CVR) and Digital Flight Data Recorder (DFDR), a cable ship named Leon Thevenin was engaged which had on board Submersible Robot (Scarab) which was fitted with a Sonar receiver and TV Cameras. The aforesaid ship was engaged and after an intensive search CVR and the DFDR (more popularly known as 'the black boxes') were located and retrieved on 10th July and 11th July, 1985 respectively.

1.2.12 The Government of India, in exercise of the powers conferred by Rule 75 of the Aircraft Rules, 1937 vide Notification No. AV.15013/10/85-A, dated 13th July, 1985, directed that a formal investigation of the accident be carried out. Mr Justice B.N. Kirpal, Judge of the Delhi High Court, was appointed as the Court to hold the said investiation. The Central Government also appointed Dr. V. Ramachandran of National Aeronautical Laboratory, Bangalore; Mr. J.S. Gharia of Explosive Research and Development Laboratory, Pune; Captian J.S. Dhillon, retired Director of Operations, Air India, Bombay;

Mr. J.K. Mehra, retired Manager (Technical Training), Indian Airlines, Hyderabad and Captain B.K. Bhasin, Deputy Managing Director of Indian Airlines, New Delhi to act as Assessors of the said Investigation. The Court was required to make its report to the Central Government by 31st December, 1985, which date was later extended to 28th February, 1986.

1.2.13 Mr. S.N. Sharma, Director of Airworthiness, Civil Aviation Department, was appointed as Secretary to the Court vide Ministry of Tourism & Civil Aviation letter No. AV/15013/10/85-A, dated 22nd August, 1985. The appointment was to take effect from 13th July, 1985.

ACTION TAKEN BY IRELAND, INCLUDING THE CORK REGIONAL HOSPITAL

1.3.1 The accident had occurred on the Atlantic Ocean approximately 100 miles south-west of the coast of Ireland. It is the Air Traffic Control at Shannon, Ireland who first became aware of the tragic event.

1.3.2 On coming to know of the accident, various authorities in Ireland took immediate action. The Shannon ATC asked the Marine and Rescue Coordinating Centre there to take emergency action. Thereupon MRCC, Shannon asked Valantia Coast Radio Station (CRS) for a PAN broadcast requiring all the vessels in areas 51N/1250W to keep a look out for the wreckage of an aircraft. The PAN broadcast was repeated and all ships were directed to proceed to the site of accident which was determined as 5101.9N/1242.5 W.

1.3.3 Irish authorities also took great pains in rendering every possible assistance to the Indian and other authorities. Some of the wreckage which had floated in to the west coast of ireland was transported to Cork where a boat house had been hired by the Government of India. The wreckage which was placed in the said boat house was protected from any outside interference by the local Gardai (police).

1.3.4 Irish ships proceeded to the scene of accident and helped in search and rescue operations. The ATC at Shannon gave details about the accident, in so far as they were aware of it, and copies of the ATC tapes were supplied. Aer Lingus, national airline of Ireland, provided assistance by making available its local engineering facilities to the coordinating centre at Cork and also to the other authorities.

1.3.5 Cork is a city having a population of approximately 1,34,000. One of the hospitals which was opened in 1978 is the Cork Regional Hospital which had been set up to meet the needs of the people. This 600-bed hospital was designated for the purposes of the Major Accident Plan of the Southern Health Board and thus became the appropriate centre for the reception of the casualities of the Air India disaster. Since the hospital first opened, it had dealt with a number of major accidents involving road, rail and marine incidents. The Major Accident Plan of the Southern Health Board sets out formally, the strategy and procedure which the hopital is required to follow while deailing with major accidents.

1.3.6 On the morning of 23rd June, 1985 at approximately 11.20 A.M. the hospital was put on alert following the disappearance of the Air India Flight 182 off the south-west coast of Ireland. The first message which was communicated to the hospital indicated that it was unlikely that there would be any survivors. The key hospital personnel were alerted and a meeting was arranged in the hospital for the purposes of discussing and making arrangements for the receipt of the bodies on the basis of the information which was available at that time.

1.3.7 On being informed that there were no survivors in the accident and that the hospital should be prepared to receive a large number of bodies, then, in accordance with the Major Accident Plan, mortuary facilities were improvised by appropriating the gymnasium attached to the Deparatment of

Rheumatology. Subsequently it became evident that additional mortuary and postmortem facilities would be needed. In order to decide where the second mortuary was to be located, the hospital had to take into cosideration the following factors:-

(a) The number and the condition of the bodies;

(b) The period during which the bodies would be retained;

(c) The hospital would be required to provide an on-going service for in-patients, out-patients and serious accident and emergency cases;

(d) To avoid unnecessary internal transport problems, the bodies should be near the Post-Mortem and Pathology Departments; and

(e) To facilitate traffic flow in the hospital curtilage and to to aviod unduc public access.

The hospital authorities accordingly located the second mortuary in a recreational room adjoining the gymnasium.

1.3.8 Two rooms were put at the disposal of the Garda (Police) authorities for use as Garda Control Rooms in the hospital. Telecommunications lines were set up immediately for their assistance as the Gardai was responsible for the forensic and identification procedures in regard to the bodies brought to the hospital.

1.3.9 A small Co-ordinating Group was set up consisting of the Chief Executive Officer of the Southern Health Board, Medical Co-ordinating Officer, Press Liaison Officer, a Senior Registrar who knew about Indian customs and traditions and a Hospital Administrator. This small Co-ordinating Group, whose membership never changed, worked together and were capable of assessing situations, making decisions, liaising with other agencies and services and undertaking with other agencies and services and undertaking responsibility for hospital press releases. Apart from individual contact between members, the Group had a standing arrangement to meet every morning and afternoon. In the late evening, the Group, met the Garda, Hospital Pathologists and key staff members for a general review of progress and to decide the tasks and objectives for the following day.

1.3.10 Within a few hours, the Co-ordinating Group realised that the hospital was a world focal point of the international media, and was required to:

a. Accommodate 131 bodies;

b. Provide pathological and Radiological services for each body;

c. Co-operate with the Garda in their forensic work;

d. Cater for relatives of the victims;

e. eet representatives of foreign Governments; and

f. Keep press agencies informed.

Thus began an operation which demanded a quick and dedicated response from all staff working in close cooperation with the Gardai. At the same time, the hospital was required to continue functioning in the delivery of normal in-patient and out-patient services. The Major Accident Plan, apart from alerting staff, provided the framework and basis for many decisions taken as events evolved. An additional advantage in the practical implementation of the Plan was the fact that the hospital had staff experienced in dealing with previous emergency situations and could marshal the extensive manpower resources available.

1.3.11 The hospital authorities also made the following arrangements:-

a. They briefed Government Ministers and Officials and other dignitaries who visited the hospital. They were taken round the hospital and were explained the arrangements which had been made.

b. Some of the services which were being provided at the hospital were either discontinued or postponed.

c. Bodies were received at the hospital and arrangements were made on their arrival to numerically label and certify as dead all the 131 bodies which were initially received. All the bodies, at that stage, had been individually placed in special purpose body bags. Initially, bodies were placed on tables, but, it was subsequently decided that it would be much easier for all concerned to place the wrapped bodies on polythene covered floors.

d. Arrangements were made for carrying out of the post-mortem examinations. Three Pathologists from other city Hospitals were recruited to augment the existing staff. Dr. Harbison, State Pathologist, was in charge of this aspect of the operation. All the post mortem were completed by 27th June, 1985.

e. For the preservation of the bodies five refrigerated containers with a capacity to hold 140 bodies were hired. These containers were fitted with timber shelving.

f. Government Information Service was located in the Matron's Office.

g. The Army provided troops for the unloading of the bodies from the helicoplers at Cork Airport. They also supplied and erected two large tents for storing bodies after post mortem and embalming. Under Garda escort transport of all the bodies which were recovered was undertaken by the
Army and these arrangements were co-ordinated by Chief Ambulance Officer.

h. Embalming was carried out in the hospital and bodies were then coffined and the coffins with appropriate number plaques were subsequently laid out in the numerical order on the floor when all the post mortems had been completed.

I. All the embalmed bodies were x-rayed (whole body). The examination was completed on 28th June, 1985.

j. A provision was made for a 24 hour extended catering service to meet the needs of staff, Gardai, Army and other personnel involved including visiting relatives.

k. A simple plan was devised for dealing with the relatives. This was a sensitive task bearing in mind the varying religious beliefs, customs and cultures generally of the visiting relatives. Their main function was to provide moral and emotional support to the relatives.

l. As identification progressed, special arrangements were made to assist the relatives. They were met by teams of councellors from the Hospital as soon as they disembarked at Cork Airport and subsequently at the Hospital. The relatives had the same Counsellor and Garda Officer throughout the identification procedure. An interesting development noted was that each family group of relatives, their Counsellor and Garda officers formed a single family unit transcending cultural barriers. On subsequent visits, families appeared lost if their own Counsellor was not immediately available to them. Usually, the Counsellor and the Garda officers accompanied the relatives, at their own request, for visual identification.

m. When plans were being formulated to receive the relatives, it had been hoped to discourage them from coming to the Hospital until such time as progress had been reported on the identification process. Practical experience subsequently proved this strategy to be inappropriate for a number of reasons. Apart from facilitating the collection from relatives of salient information on the victims, the most fundamental reason was the underestimation of the abiding wish of the relatives to be physically and psychologically as close as possible to their deceased dear ones. Moreover, it was the express wish of almost all relatives on arriving at Cork Airport to proceed directly to Cork Regional Hospital; there, they were given an informal talk by Air India and Garda representatives on the progress of the investigation and the methods of identification. Many of the relatives visited the hospital daily and remained there throughout each day.

n. Coach trips were arranged to Bantry Bay for the relatives; Bantry Bay is the nearest landmark from the site of the crash. Relatives visited the seaside to pay their last respects to the departed souls. These were solemn occasions when each relative prayed in his/her own way. Rose petals and wreaths were immersed in the sea in keeping with Indian traditions. The visit gave them mental satisfaction and in the early days following the crash, helped in diverting their attention while the investigative procedures were being completed.

o. A small number of visiting relatives had personal medical problems and they were treated at out-patient and in-patient levels at the Hospital.

p. Cork/Kerry Tourism Organisation helped to co-ordinate the accommodation of relatives between a number of hotels. Approximately seven hotels were used within a radius of twenty miles of the city for this purpose.

g. A number of press conferences were held. The Chief Executive Officer, directed that press photography and television filming be not allowed within the hospital in deference to the privacy of patients and in respect for the relatives wishes.

r. Responsibility for the identification of bodies rested with the Garda Authorities and the conditions under which bodies were released are summarised as follows :-

(I) Satisfactory identification

(ii) Consent of the Coroner

(iii) Proper authentification of the person claiming each body

All bodies arriving at Cork Regional Hospital had already been numerically labelled by the Garda Authorities. To prevent confusion, the bodies were then given identical numbers under the hospital major accident labelling system and this proved to be very helpful later during identification, investigations and recordings. A routine was established for examining and recording information about each body. Teams consisting of a doctor, nurse, clerical officer and Garda made the necessary examination, labelling and recording each body and such details as :-

a. Sex
b. Adult or child
c. Clothing
d. Jewellery and personal effects
e. Injuries
f. Obvious scars

Death was confimed in all cases. Each body was fingerprinted and photographed by Garda Technical Bureau Staff. Each body was subjected to autopsy, forensic and dental examination. All bodies were embalmed and following embalming, were photographed and x-rayed. This procedure was completed in respect of all the bodies by the evening of the fifth day of the crash. The data from these investigations was collated on an Interpol form (pink) for each body. Similar ante-mortem information was obtained from the relatives about each victim on a separate Interpol form (yellow). When the information on the pink and yellow forms matched beyond doubt, a positive identification was made. It might be noted that the photographs originally taken by the Garda Technical Bureau Officers of each body were matched with photographs of the 131 embalmed bodies. When a positive identification was made, the relatives were shown photographs of the deceased. These photographs were available for inspection by Saturday, 29th June. As positive identification progressed,

personal effects were added to the identification process and finally, visual identification took place. For obvious forensic reasons, positive identification was necessarily slow and meticulous and, in fact, was made more difficult by reason of the fact that only 131 bodies out of the 329 passengers and crew were recovered. All 131 bodies were identified, the first positive identification was made on 27th June and the last on the 6th August. Each coffin had affixed to it a metal plaque clearly indicating the number assigned in the first instance to the body it contained. The bodies when identified were released by the Garda Authorities through the undertaker. The Coroner directed that a reasonable time would have to elapse before unidentified bodies could be disposed off an this was to be by way of burial. The final date for this purpose was fixed for 3rd August, 1985, but, this date was subsequently extended to 6th August, 1985, to coincide with the date of the Civic Commemoration Ceremony.

(s) Bodies of victims for identification were brought individually to separate viewing rooms, suitably decordated with flowers and with incense burning. Visual identification was performed in private by the relatives and moreover, it allowed them to pay their last respects in their own religious beliefs. An adjoining room was also made available where they could grieve in private. Subsequently, it was learnt that these arrangements were much appreciated by the relatives who articulated this appreciation by commenting that the arrangements provided were as near as possible to the funeral rites observed in their domestic communities. The relatives were of the opinion that the special arrangements made conveyed a deep personal and individual response to the dignity of each victim which might otherwise be lost with such a large number of bodies.

(t) Procedures were laid down which were required to be followed and observed for the purposes of preventing infection.

(u) On 6th August, 1985 an interdenominational service was held in the morning. In the evening on that day a Civic Commemoration Ceremony was held which was attended by a large number of persons.

(v) A formal inquest was held by the Coroner in the Courthouse, Cork, which commenced on 17th September, 1985 and ended on

23rd September, 1985. The Coroner's Jury returned a verdict in accordance withmedical and pathological evidence.

ACTION TAKEN BY THE COURT

1.4.1 Despite the fact that Mr. H.S. Khola had been appointed as the Inspector of Accidents under Rule 71 of the Aircraft Rules, the Government thought it proper to appoint Mr.Justice B.N. Kirpal as the Court to investigate into the circumstances of the accident.

1.4.2 The appointment of the Court was made under Rule 75 of the Aircraft Rules, which is as follows :-

"75. Formal Investigation - Where it appears to the Central Government that it is expedient to hold a formal investigation of an accident it may, whether or not an investigation or an inquiry has been made under rule 71 or 74, by order direct a formal investigation to be held and with respect to any such formal investigation the following provisions shall apply namely

(1) The Central Government shall appoint a competent person (hereinafter referred to as "the Court"), to hold the investigation, and may appoint one or more persons possessing legel, aeronautical, engineering, or other special knowledge to act as assessors, it may also direct that the Court and the assessors shall receive such remuneration as it may determine.

(2) The Court shall hold the investigation in open court in such manner and under such conditions as the Court may think fit most effectual for ascertining the causes and circumstances of the accident and for enabling the Court to make the report hereinafter mentioned.

(3) (i) The Court shall have, for the purpose of the investigation, all the powers of a Civil Court under the Code of Civil Procedure, 1908 and without prejudice to those powers the Court may :-

(a) enter and inspect, or authorise any person to enter and inspect, any place or building, the entry or inspection whereof appears to the court reguisite for the purpose of the investigation; and

(b) enforce the attendance of witness and compel the production of documents and material objects; and every person required by the Court to furnish any information shall be deemed to be legally bound to do so within the meaning of section 176 of the Indian Penal Code.

(ii) The assessors shall have the same powers of entry and inspection as the Court.

(4) The investigation shall be conducted in such manner that, if a charge is made or likely to be made against any person, that person shall have an opportunity of being present and of making any statement or giving any evidence and producing witness on his behalf.

(5)Every person attending as a witness before the Court shall be allowed such expenses as the Court may consider reasonable:

Provided that, in the case of the owner or hirer of any aircraft concerned in the accident and of any person in his employment or of any other person concerned in the accident, any such expenses may be disallowed if the Court, in its discretion, so directs.

(6)The court shall make a report to the Central Government stating its findings as to the causes of the accident and the circumstances thereof and adding any observations and recommendations which the Court thinks fit to make with a view to the preservation of life and avoidance of similar accidents in future, including, a recommendation for the cancellation, suspension or endorsement of any licence or certificate issued under the rules.

(7)The assessors (if any) shall either sign the report, with or without reservations, or state in writing their dissent therefrom and their reasons for such dissent, and such reservations or dissent and reasons (if any) shall be forwarded to the Central Government with the report. The Central Government may cause any such report and reservation or dissent and reason (if any) to be made public, wholly or in part, in such manner as it thinks fit."

1.4.3 The Court, which is appointed under Rule 75, does not act as a 'Commission of Inquiry' which is usually appointed under the Commissions of Inquiry Act to inquire into any definite matters of public importance. The role of the Court, on its appointment under Rule 75 of the Aircraft Rules, is essentially that of an Investigator. It is for this reason that no procedure has been prescribed in the Rules which the Court is required to follow. While carrying out its functions, the Court is not only required to comply with the provisions of the Aircraft Act, and the Rules framed thereunder, but it must necessarily also keep in view the provisions of ICAO Annex. 13.

1.4.4. As an Investigator, investigating into an accident, the Court had to perform multi-farious duties and functions. Before referring to them, it would be pertinent to point out that whereas an Inspector of Accidents, who is appointed under Rule 71, would normally be belonging to the Civil Aviation Department and would have all the machinery available to him for conducting the investigation, the Court, when it is appointed to hold an investigation under Rule 75, lacks the basic infrastructure to conduct the investigation of such a magnitude. Assessors are appointed to assist the Court but the actual investigation work cannot be carried out by them. Despite these handicaps, the investigation continued smoothly primarily due to the fact that whenever directions were issued by the Court to any of the participants before it or to the Civil Aviation Department or any other Organisations, the directions of the Court were readily complied with. On a few occasions it also became necessary to require the Assessors to conduct the investigation, which they did with the help of other organisations.

1.4.5 As an Investigator, the first task which was undertaken was to see that the tapes from the Cockpit Voice Recorder, which had been salvaged, were recoverd from the recorders and subsequently analysed. Requisite directions were issued and the tapes were removed from their respective recorders on 16th July, 1985. This operation was carried out at the Air India workshop at Santacruz in the presence of the accredited representatives of Lockheed (manufactures of DFDR), Fairchild (manufacturers of CVR), Boeing Airplane Co., Canadian Air Safety Board (CASB), National Transportation Safety Board, USA (N.T.S.B), Air India and Government of India. The tapes so recovered were subsequently played and analysed.

1.4.6 On an appointment being made under Rule 75 the Court would become incharge of overall investigation of the accident. In that capacity, and in order to effectively discharge its functions, it became necessary for the Court to undertake the following tasks :-

(a) For getting first hand information, the Court had to personally inspect the wreckage which had been recovered and was housed in a boat yard in Cork. While in Cork opportunity was also taken to go to the Cork Regional Hospital and to have discussions with and be briefed by the hospital staff. A trip was also made to Shannon with a view to see and understand the working of the Secondary Radar System which was in use there. On this visit the original ATC tape, which contained communication betwen Kanishka and the ATC, was also heard. As it was suspected that there may be a link between the blast which had taken place at Narita Airport on 23rd June, 1985 and the accident to Air India's flight 182, it was felt necessary to inspect the site of the bomb blast at Narita Airport.

On the aforesaid visit to Tokyo, the site where the blast had taken place was inspected which gave some, though very vague, idea of the detonating power of the blast. While in Tokyo meetings and discussions were also held with the police and Aviation Authorities. The Court also had the advantage of being able to meet members of the team investigating into the Japan Airlines Flight JL 123 accident which had occurred near Tokyo on 12th August, 1985. Similarities and dissimilarities between the two accidents were, to some extent, noticed and some information was exchanged.

Information was received, that some floating wreckage had been picked on the coast of England and it was possible that some of the places, which were so received, should be subjected to further detailed chemical and metallurgical examination. In order to decide this, it became necessary to visit RADRE, Kent, U.K. As a result of the inspection and the discussions there, it was decided by the Court that the pieces so recovered should be sent to BARC at Bombay for further analysis.

(b) Directions had to be given, from time to time, with regard to the mapping and salvaging of the wreckage which was being effected. It had to be decided as to how, and in what areas, the Scarab should continue to map the wreckage and take video films and still photographs. Based on the information received therefrom and after discussions with the experts, both Indian and foreign, a list was drawn up indicating the items which had to be salvaged. As the weather was likely to be unpredictable, with a possibility of its deteriorating rapidly, a priority list of items to be salvaged had also to be prepared, and this was done. In view of the fact that the Canadian ship John Cabot and the Scarab had a limited capacity, with regard to the size and weight of pieces which could be lifted from the bottom of the ocean, decision had also to be taken with regard to the deployment of another ship. As a consequence thereof a ship 'Kreuzturm' was also engaged in salvage operations.

(c) Directions had also to be given assigning work and duties to different teams of persons. As an Investigator, the Court was incharge of the entire work of investigation which was being carried out in different parts of the world. It not being possible for the Court itself to undertake all the tasks, decisions had to be taken as to how the investigating work was to progress and who would carry out the directions issued from time to time. For example, immediately after reaching Cork on 25th July, 1985 it was felt necessary that a team should be immediately sent to Canada in an effort to get relevant information from there in connection with the flight AI 182. Accordingly, a team of 3 persons headed by Mr. H.S. Khola was directed to proceed to Canada immediately. As a result of the efforts put in by this team, and with the considerable amount of cooperation, help and assistance rendered by the Canadian Authorities valuable information was received by the Court having direct bearing on the investigation. Yet another example in this regard was of requiring Dr. V. Ramachandran, one of the Assessors and an expert in Metallurgy, to be stationed on board the salvage ships during the recovery operations. The procedure which had to be followed by him was also determined. Information about the progress of the salvage operations was communicated on telephone to the Court at all times of day and night. On receipt of such information further instructions, when ever necessary, used to be issued.

(d) Discussions were held with the Indian experts in order to understand some of the complicated questions which had arisen during the investigation.

In an effort to be able to fully appreciate the effect of decompression, the Court visited the Institute of Aviation Medicine at Bangalore where explsoive decompression was simulated for the Court's benefit. Discussions were also held with other experts of aviation medicine who were also given copies of the post-mortem reports for their opinion. National Aeronautics Laboratory was also visited in Bangalore where meeting was held with experts in aerodynamics, structure and metallurgy. Visits to Bombay where more frequent and necessary so that the Court could get first hand information with regard to the work which was being done at BARC.

The investigation involved looking into matters concerning aviation, electronics, medicine etc. Not being familiar with these branches, the discussions which were held, were of immense help and assistance to the Court who had to understand all the evidence and information which it was gathering.

(e) The accident had attracted world wide attention. Right from the start of the investigation by the Court when the recorders were first opened in Bombay on 16th July, 1985 till the conclusion of the hearing, the Press and the TV were eager for information. It was felt that rather than the media resorting to speculation of getting wrong information, the Court itself or its representative should, as and when necessary, brief the media. In this connection interviews were given, both in India and abroad, which were broadcast over the television and printed in the Press. As a result of this, correct information was disseminated with regard to the progress of the investigation without disclosing the Court's opinion on the evidence which had been received.

(f) Finally, the Court had to conduct the formal investigation in Court. For this purpose it laid down the procedure which would be followed. Rule 75 of the Aircraft Rules required that the investigation would be in open court. It was, however, felt that in this particular case it would be advisable that some evidence should be obtained in Camera.

The Court, accordingly, recommended that necessary amendment should be made in Rule 75 so that the Court was given the power to hold certain proceedings in camera when the circumstances so warranted. The suggestion of the Court was accepted and that resulted in Rule 75(2) being amended and, as a result thereof, the Court was given the power to hold proceedings in camera if the stipulated conditions existed.

COMMENCEMENT OF FORMAL INVESTIGATION

1.5.1 The object of setting up a court to investigate into an accident is primarily to find out the causes and circumstances of the accident and thereafter to make recommendations. Such an investigation is not in the nature of an adversary litigation between the participants before the Court. As such it should be the endeavour of all the participants to assist the Court in arriving at a correct conclusion.

1.5.2 Under Rule 75 of the Aircraft Rules, the procedure which has to be followed in the investigation of an accident is to be determined by the Court itself. While laying down the procedure which is required to be followed, the endeavour of the Court has necessarily to be to adopt such procedure which would help the court in being able to complete its task satisfactorily, and in the shortest possible time. Whenever an accident takes place, it is of utmost importance that the cause of the accident must be ascertained at the earliest so that if any remedial measures are to be taken then those steps should be taken without any undue delay.

1.5.3 In the present case, there were a number of factors which had to be kept in view while determining the procedure whichshould be followed. The accident had occurred over international waters and approximately at a distance of about 5000 miles from the place where the investigation was to be conducted, namely, New Delhi. The ill fated flight itself had commenced from Canada, and this meant that most of the evidence would only be available there. Matters were not simplified by the fact that the debris itself was lying at the bottom of the ocean, 2 miles under water. It became apparent, at the very beginning, that to recover the entire debris would be a superhuman task and it will not be possible to do so within the limited time span which was available.

1.5.4 It was thought that it would be of assistance if all the participants got together so as to determine what procedure should be followed. The procedure had to be such which would give an effective opportunity of hearing to all the participants, without in any way unduly prolonging the investigation.

1.5.5 The Court decided that, in order to obtain the views, it would be necessary and advisable to have a Pre-hearing Conference.

1.5.6 The first decision which had to be taken was as to who were to be given a participants status. Keeping inview the provisions of Annex 13, participants status was given to Governments of Ireland, Canada, USA and India. Similar status was also given to Boeing Airplane Co. and Air India. As there might have been some similarities or dissimilarities between the present accident and the accident of the Japan Airlines Boeing 747-SR and also because there may have been a possibility of the present accident being linked with the explosion which had taken, place at Narita Airport, Tokyo on 23rd June, 1985, an Observer's status was given to the Government of Japan.

1.5.7 Notices for holding of the Pre-hearing Conference on 16th September, 1985 were accordingly issued on 29th August, 1985. The agenda for the Conference was to be as follows :-

a. To make suggestions to the Court for its consideration, regarding the procedure to be followed in the conduct of the formal proceedings in the Court.

b. To draw up a tentative list of witness.

c. To draw up a tentative list of exhibits.

d. To determine the areas to be inquired into

e. To fix a date for the commencement of the public hearing.

f. Any other matter with the permission of the Court.

1.5.8 Except for the Government of Japan, all the other participants were represented at the said Pre-hearing Conference. After discussions had been held between the Court and the

Participants, some decisions were arrived at regarding different items of the agenda.

1.5.9 Firstly the following points were framed, indicating the areas to be inquired into by the Court:

a. Whether the accident was caused by a structural failure?

b. Whether the accident was caused by some human effort?

c. Whether the accident was caused by some criminal act?

d. Whether the accident was caused by an external non-criminal act?

e. Based on the evidence on record, what steps should or can be taken so as to ensure greater air safety.

1.5.10 It was further decided that, as suggested by all the participants, at least critical portions of the wreckage should be recovered.

1.5.11 With regard to the recording of the evidence it was decided that evidence will, in the first instance, be taken by filling affidavits or by filling statements alongwith affidavits. Copies of the same were to be supplied to the other participants for their consideration. These affidavits were to be filed on or before 18th October, 1985 and a second Pre-hearing Conference was to take place on 30th October, 1985 at New Delhi when it was to be decided as to which of the persons should be called for cross-examination. It was determined that it is only thereafter that hearing would commence in open court.

1.5.12 A tentative list of witnesses was also drawn up and it was decided that on the next date names of more witnesses may be added and, furthermore, the participants would be free to file any affidavits which they deem fit including affidavits in rebuttal.

1.5.13 Another important decision which was taken at the Pre-hearing Confence was that a Structural Group was formed consisting of (1) Mr. H.S. Khola or his nominee (2) Representative of the Canadian Government (3) Representative of NTSB, USA (4) Representative of Boeing Airplane Co., USA

(5) Representative of Air India. This group was entrusted with the task of examining and analysing, initially in Seattle, USA, the video films and the still photographs of the wreckage. This group was also to indicate and decide the items of priorities of wreckage which had to be recovered. The report of this group was required to be submitted by 18th October, 1985. The report of the work done at Seattle was in fact submitted only on 25th October, 1985. This group was also given the liberty to associate any other experts or persons from Boeing or any other Authority. The group was also to inspect the floating wreckage which had already been salvaged and any further wreckage which would be salvaged.

1.5.14 Although the affidavits by way of evidence had to be filed by 18th October, 1985, it was only the Government of Ireland who filed an affidavit by at date. On behalf of the Government of India, an application was filed asking for more time. The reason stated was that the affidavit which had to be filed was to be of Mr. H.S. Khola but he was out of India as he was heading the structures group which was evaluating the video films and photographs at Seattle. The Court had no option but to grant further time to the Union of India to file its affidavits and this necessarily resulted in the adjournment of the Pre-hearing Conference which had been fixed for 30th October 1985.

1.5.15 As the salvage operations were reaching a critical point it became necessary for the Court to go to Cork on 27th October, 1985. Taking advantage of the presence of the Court in Cork, other participants also came there. Besides them, representatives of CP Air and Air Canada also arrived. At one of the informal meetings between the Court and the representatives of the participants, applications were filed by CP Air and the Air Canada, inter alia, praying that they should be permitted to participate in the investigation. It might be mentioned here that CP Air had interlined one of the passangers from Vancouver to

AI-182, while Air Canada was the handling agents in Canada of Air India. After hearing the participants it was decided that participant status should also be given to these two viz., CP Air and Air Canada.

1.5.16 The participant had all filed their affidavits by way of submissions. The Court indicated that formal hearings would be held for the purpose of cross-examining some of the witnesses about three weeks after the receipt of all the reports of the various groups. While in Cork, in the first week of November, 1985 some of the salvaged pieces of the wreckage were brought there. After they were inspected by all the participants and their advisers, who were present in Cork, it was decided by the Court that further detailed metallurgical and other examination of those pieces would be done at BARC, Bombay. In order that there should be no undue delay the Court decided that a Group be constituted consisting of expert representatives of all the participants and also the nominees of the Court. This group was asked to carry out metallurgical and other examination of some of the critical pieces salvaged and give its report to the Court. The group consituted as a 'Committee of Experts' was as under :-

a. Mr. A.J.W. Melson, Canadian Aviation Safety Board, Canada.

b. Mr. R.K. Phillips, Canadian Pacific Air, Canada.

c. Mr. T. Swift, Federal Aviation, Administration, USA.

d. Mr. R.Q. Taylor, Boeing Commercial Airplane Co., USA.

e. Mr. J.P. Tryzl, Boeing Commercial Airplane Co., USA.

f. Mr. J.F. Wildey II, National Transportation Safety Board USA.

g. Mr. S.N. Seshadri, Bhabha Atomic Research Centre, India (Coordinator).

1.5.17 The parties were informed in Cork that the report of Mr. H.S. Khola, Inspector of Accidents, would be available by about

8th November, 1985. It was then decided that the statements of the first batch of witnesses should be recorded from 20th November, 1985. It was also agreed that if some of the reports of the experts were not received, further examination of the witness may have to postponed.

1.5.18 After receipt of the report from Mr. Khola. on the 8th November, 1985, a notice of the holding of the Public Hearing was issued to all the participants. This notice indicated that the hearing would commence on 20th November, 1985. In the meantime, a Public Notice was also published in the daily "Times of India" in Delhi and Bombay editions on 21st October, 1985 in which it was stated as follows :-

NOTICE

AIR INDIA KANISHKA

ACCIDFNT INVESTIGATION

The Government of India, vide Notification dated 13th July, 1985, appointed Hon'ble Mr. Justice B.N. Kirpal as a Court to investigate into the accident to Air India's Boeing 747 aircraft VT-EFO (KANISHKA) near the Irish Coast on 23rd June, 1985, when the aircraft was engaged on a scheduled passenger flight from Montreal to Bombay via London and New Delhi.

Any person having direct knowledge, who may desire to make representation concerning the circumstances or causes of the accident, may do so in writing in the form of an affidavit duly attested by an Oath Commissioner or a Notary Public and address the same to the undersigned so as to reach him within 15 days of the publication of this Notice.

S.N. SHARMA
SECRETARY
COURT OF INVESTIGATION
COURT NO.10,DELHI HIGH COURT
SHERSHAH ROAD
NEW DELHI - 110 003

Pursuant to the aforesaid public notice no affidavit was received from any one.

1.5.19 The public hearing commenced on 20th November, 1985 and the first session concluded on 28th November, 1985. During this period statements of Mr. H.S. Khola, Wing Commander Dr. I.R. Hill and Sgt. Atkinson of R.C.M.P., Canada were recorded.

1.5.20 Till that date, report on the examination of the salvaged pieces had not been received. It was anticipated that the report would be available by mid December, 1985. In order to give the parties sufficient time to study the reports of all the experts it was decided that further evidence would be recorded from 22nd January, 1986.

1.5.21 After the reports were received from BARC; AIB; Farnborrough; NTSB; USA; and Mr. Bernard Caiger of CASB, Canada and the copies of the same had also been received by all the participants, recording of evidence commenced from 22nd January, 1986 and concluded on 30th January, 1986. In all statements of 13 witnesses were recorded.

1.5.22 At this stage it will be pertinent to make a few observations with regard to the procedure which was laid down for recording of evidence etc. As already indicated, most of the evidence was such which was not available in India. As a Court investigating the accident under the provisions of Aircraft Rules, it had no jurisdication to compel
attendance of any witness from abroad. The Court also had no jurisdication, either under the Rules or under the provisions of Annex 13, to require any witness to be examined in a country other than the one in which the Court is holding the investigation. The Court was informed that, if called upon, some of the persons who were outside India may not be inclined to testify before the Court.

1.5.23 Faced with the aforesaid difficulty it became necessary, therefore, to evolve a procedure which would enable the Court to get the requisite information. As long as the Court was satisfied that the information which was being received was one which had been truthfully given by a person, it was immaterial as to the manner in which the information was received. It is for this reason that it was decided that evidence will, in the first instance, be given by way of affidavits. It was also provided that the statements could also be filed along with affidavits. This latter course was permitted so as to enable some of the statements, which had been recorded by members of the Royal Canadian Mounted Police, to be placed before the Court. These statements, of course, had to be accompanied, as they were, with the affidavits of the persons who had recorded the statements.

1.5.24 At one stage, by a formal application in writing, Air India had protested against this procedure being followed. By order dated 22nd November, 1985, an objection by Air India to the filing of the statements accompanied by affidavits, was dealt with by the Court in the following words :-

"With regard to the affidavits which have been filed by the Government of Canada, I would only like to observe in the Pre-hearing Conference on 16th September, 1985, it was decided that "Evidence will, in the first instance, 1985 be taken by filing affidavits or by filling of Statements along with affidavits." It was understood that if it is not possible to file affidavits of the persons who are in a position to give information then affidavits may be filed of other persons who may have recorded the statements of the persons who are in a position to give information. This is not an adversary litigation where one of the parties may lose because of lack of proof. One of the objects of setting up a Court to investigate into an accident is to find out the causes of the accident and to make recommendations. It is necessary for this purpose to get information which may be relevant. It is true that strictly speaking the statements which are annexed to the affidavits may not be admissible as evidence in a Court of Law when there is a litigation between the parties but considering limitations which we have, namely, where a Court like the present has no jurisdication to enforce the attendance of any witness who is outside this country and furthermore, the Court has no jurisdication to compel any one to give information, the procedure which was adopted was thought to be the most practical one for obtaining information in connection with the accident. Under the circumstances, the affidavits which have been filed along with the statements which have been annexed thereto which give information with regard to the accident, have to be taken on record."

1.5.25 Another advantage of following the aforesaid procedure was that the time which would have been taken in Court in examining of the witnesses was considerably reduced. After the participants had filed affidavits, the same were to be secrutinised and it was then to be decided as to which of the deponents or persons should be called for examination in Court. Effectiveness of this procedure which was adopted is apparent from the fact that though affidavits by way of evidence were filed in Court, ultimately only 13 witnesses had to be examined in Court and sitings were held in Court only on 14 days.

1.5.26 Written arguments were filed on the forenoon of the 4th February, 1986 and oral arguments were heard in the afternoon of that day. No written arguments or oral submissions were made by the Government of Ireland, CP Air or Boeing Company.

1.5.27 Mr. I.G. Whitehall, councel for the Government of Canada took exception to some of the submissions which were contained in the written submissions filed by Air India. Mr. Whitehall contended that the Court had opined that it will not go into the question of responsibility of the unfortunate accident and therefore, there was no; justification for Air India to include in its written submissions numberous passages which tended to fix responsibilities.

1.5.28 By the order dated 4th February, 1986, it was made clear that it was not the intention of the investigation to apportion blame if any lapse had been committed and, therefore, the Court would ignore any written submissions which tended to apportion blame or responsibility for any lapse of any participants. It might here be mentioned that such a question had earlier arisen while the statement of Sgt. Atkinson was being recorded. The Court had then held that it will not go into the question as to who was responsible for the accident. It was in view of this order that no evidence was led by any of the parties on the question as to who may have been responsible for any possible lapse which could have led to this accident.

2.1 Flight Preparation

2.1.1. Air India Boeing 747 aircraft VT-EFO 'Kanishka' was operating flight AI-181 (Bombay-Delhi-Frankfurt-Toronto-Montreal) on 22nd June, 1985. From Montreal it becomes AI-182 from Mirabel to Heathrow Airport, London enroute to Delhi and Bombay. The aircraft arrived at Toronto from Frankfurt at 1830 Z and was parked at gate No. 107 Terminal 2 at L.N. Pearson International Airport. In accordance with the Canadian regulations, all the passengers and their baggage were off loaded to complete the customs and immigration checks. Transit cards were handed out to 68 transit passengers destined to Montreal who disembarked at Toronto for customs and immigration checks.

2.1.2. The flight from Toronto to Montreal was made up of the following:-

(I) Passengers originating at Toronto and their baggage.

(ii) Transit passengers, and their baggage, continuing their flight to Montreal.

(iii) Two diplomatic bags from Indian Consulate General, Vancouver via Air Canada Cargo Flight, and some Air India

Mail.
(iv) Fifth Pod engine and its associated parts.
(v) Interline passengers and their baggage from connecting flights as detailed below:-

a) Air Canada flight AC-102
from Sasktoon - 2 Passengers
b) Air Canada flight AC-106
from Edmonton - 4 Passengers
c) Air Canada flight AC-170
from Winnipeg - 1 Passenger
d) Air Canada flight AC-170
from Winnipeg - 4 Passengers
e) Air Canada flight AC-136
from Vancouver - 10 Passengers

2.1.3. One passenger by name 'M. Singh', checked in at Vancouver on Canadian Pacific flight CP-060 (Vancouver-Toronto) of 22nd June 1985, and got his one piece of baggage interlined to Air India flight AI-181
even though he had no confirmed reservation on AI-181. This passenger, however, did not board the flight CP-060 at Vancouver and also did not check-in for Air India flight AI-181/182 at Toronto.

2.1.4 The checking-in of passengers for Air India flight AI-181/182 at Toronto began at 1830 Z. The checking-in of the passengers was carried out by Air Canada personnel who are the handling agents for Air India, and was supervised by Air India personnel. The Air Canada personnel indicated the computer sequeritial numbers (security numbers) on the passenger boarding card stubs. At about 1930 Z announcement was made for the primary security check of passengers and their hand baggage. The passengers passed through the Door Frame Metal Detector and their hand baggage was checked through X-Ray machine. The passengers were also subjected to physical security check with the help of Hand Held Metal Detectors. The transit passengers to Montreal and their hand baggage were also subjected to these security checks, while their checked in baggage, after clearance by the Canadian Customers authorities was placed by the passengers themselves on the conveyor belt while they were still in sterile area. In this way there was personal identification by the passengers of all checked in baggage, except the baggage which had been interlined to this flight.

2.1.5 The flight was closed for check-in at about 2150 Z. There were 10 'NO SHOWS' and 4 'GO SHOWS'. The security checked passengers remained in the holding area gate No. 107 till boarding was announced at about 2210 Z. At the boarding gate secondary security check of the passengers and their hand baggages was carried out. The passengers were frisked with the help of Hand Held Metal Detectors and their hand baggages were opened and physically checked.

2.1.6 The security numbers on the stubs were circled on the pre-numbered Security Control Sheet to ensure that all the checked-in passengers have boarded the aircraft. Passenger boarding was completed by 2300 Z. Traffic/Sales representative of Air India verified the Security Control Sheet with the number of stubs collected and the number of passengers checked-in. He found that all the 202 passengers, who had checked-in, had boarded the aircraft.

2.1.7 As stated earlier, 68 transit passengers had disembarked at Toronto for completing the customs and immigration checks. However, only 65 of these passengers re-boarded the aircraft as per transit cards collected at the boarding gate. It is in evidence that almost every flight of Air India to Canada, two or three transit passengers do not re-board the flight at Toronto. Some Toronto passengers travelling to India buy their tickets "Montreal-India-Montreal" instead of "Toronto-India-Toronto", for which the fare is higher, and they travel by bus to Montreal to catch the Air India flight to India. On their return journey, when they get down at Toronto for customs and immigration checks, they simply do not re-board the flight even though their reservations are upto Montrteal. These passengers sometimes inform Air India personnel at Toronto about their not re-boarding the aircraft. On 22nd June, 1985, however, no such passenger informed Air India personnel.

2.1.8 There was a crew change at Toronto. The flight and cabin crew members who took over the flight AI-181/182 had been laid over in Toronto for the week prior to the accident flight and were scheduled to take the flight upto London where they were to be relieved by another set of crew. Capt H.S.Narendra was the Commander of the flight, with Capt S.S.Bhinder as co-pilot and Mr.D.D.Dumasia as the Flight Engineer. In addition there were 19 cabin crew members. All the crew members reported together at the airport at 2130 Z. As per the practice existing at that time, the flight crew and cabin crew members were not subjected to frisking checks and their hand baggage were also not security checked. Their checked-in baggage was, howevewr, security checked along with the other checked-in baggage of passengers.

2.1.9 The interline baggage was brought to the international baggage make-up area by the Air Canada staff but, as mentioned earlier, it was not personally identified and matched with the passengers.

2.1.10 The checked-in baggage of the originating passengetrs and crew members of AI-181/182 was sent on a conveyer belt to the baggage make-up area. All the checked-in baggage along with the interline baggage was required to be security checked on the X-ray machine which was located in the baggage make-up area at the end of international belt No.4.

2.1.11 It has been reported that the X-ray machine worked intermittently for some period and at about 2045Z it broke down and there was no picture on the screen. The Machine could not be repaired on that day as it was a week-end and no technician could be contacted. Air India's Security Officer then advised that the rest of the baggage be checked with a PD-4 explosive detector provided by him. He also demonstrated the use of the PD-4 detec- tor to the concerned personnel. It has been reported that about 60 to 70 baggages were checked and cleared by the PD-4 detector.

2.1.12 The security checked baggage was loaded in the containers by the Air Canada personnel. The loading of the baggage in containers was over by about 2230 Z. The ramp personnel of Air Canada carried the container and loaded them in the aircraft.

2.1.13 From March, 1985, after the introduction of Air India flight AI-181 through Toronto, diplomatic bags from Indian Consulate General at Vancouver were being sent to India by Air India flight from Toronto. Accordingly, two diplomatic bags, duly sealed and escorted, were delivered to Air Canada office at Vancouver on 21st June and they arrived at Toronto by Air Canada flight AC-580. One of the bags Sl.No. 49 contained 13 empty large diplomatic bags while the other bag Sl.No.50 contained diplomatic mail. The total weight of the bags was 13.8 Kgs.

2.1.14 In addition to the above, a few envelopes containing some flight documents addressed to Accounts Office, Air India, Bombay, and one envelope addressed to Commercial Headquarters, Air India, Bombay from Air India Town Office in Toronto, were collected by Messrs Mega International.

2.1.15 The aircraft was refueled by CAFAS with 14,602 litres of fuel.

2.1.16 On 8th June No. 1 engine of Air India Boeing 747 aircraft VT-EGC had failed during take off. The failed engine

was to be ferried to Bombay on flight AI-181/182 of 22nd June.
2.1.17 The failed engine and the associated parts were placed in Air Canada Engineering Hangar at Toronto airport since June 8,when
the aircraft was brought to the engineering hangar for engine replacement. Air India had requested Air Canada on 15th June for preparing the failed engine for installation as fifth pod mounting of the aircraft on 22nd June.
2.1.18 On 15th June Air India deputed one of their foremen to Toronto to bring back the failed engine. From 17th to 21st June, Air Canada technicians prepared the failed engine for installation as fifth pod. This preparation involved removal of cowlings, fan blades, locking of compressor rotors etc. Air Canada Engineering/Maintence personnel loaded the aircraft/engine parts on 4 pallets and one container. These pallets and container were then delivered at 0100 Z on 22nd June by Air Canada personnel to Messrs Mega International cargo warehouse at Toronto Airport within restricted airport area. (Messrs Mega International Cargo Warehouse at Toronto Airport within restricted airport area. (Messrs Mega International is the cargo handling agent of Air India at Toronto). The fifth pod engine was transported by Air Canada directly from their premises to the 'Kanishka' aircraft for mounting it on the fifth pod.
2.1.19 Installation of the engine on the fifth pod began immediately on arrival of flight AI-181 at Toronto on 22nd June and the work was completed by 1930 Z. One of the mechanics of Air Canada installed the Mach Air Speed Warning Switch in the Main Equipment Centre as part of the fifth pod engine installation.
2.1.20 The pre-loaded four pallets and one container were brought to the aircraft by M/s Mega International personnel from their warehouse in the afternoon of 22nd June for loading them into the aircraft cargo compartment at positions assigned by the

Air Canada load agent. Difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fitting from the aft cargo compartment door cut-out. After removal of the fittings, the cowl could be loaded. All the removed fittings were then reinstalled.

2.1.21. On account of the delay in loading the cowls, departure of the flight was delayed by one hour and twentyfive minutes.

2.1.22 Maintenance Manager of Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft and no snag was observed by him. The commander duly accepted the aircraft.

2.1.23 Senior Flight Despatcher, Air India, Toronto did the flight despatch of AI-181/182 for sectors Toronto-Montreal-London. He briefed the flight crew members about flight plan, weather, Air Traffic Control and fuel requirements. The flight plans for the sectors Toronto-Montreal-London were duly accepted and signed by the Commander.

2.2 Progress of the Flight

2.2.1. The Aircraft took off from Toronto Runway 24L at 0016 Z on 23rd June, 1985. The Maintenance Manager, Security Officer and Passenger Service Supervisor of Air India travelled on board the aircraft for their duties at Montreal. In all there were 270 passengers on board in addition to 22 crew members.

2.2.2. The route from Toironto to Montreal was V-98/ JHL-594/MSS/V 203/FRANX at flight level 290. The flight was uneventful and the aircraft landed at Montreal at 0110 Z. No snag was reported by the flight crew. The aircraft was parked at Cluster 1 Bay No.114.

2.2.3 Sixtyfive passengers destined to Montreal along with the three Air India personnel mentioned above deplaned at Montreal. The remaining 202 passengers, who had joined the flight at Toronto, remained on board the aircraft as transit passengers were not allowed to disembark at Montreal.

2.2.4 Baggage handlers off loaded three containers of baggage, one valuable container and four cargo containers from the aircraft.

2.2.5 Transit Check 'C' of the aircraft was carried out at Montreal. The Flight Engineer also carried out his pre-flight inspection and found that rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to an Air Canada Technician who flaired the handle and applied the high speed tape. There was no other snag observed during the inspection. The personnel of CAFAS refueled the aircraft with 96,000 litres of fuel. Total fuel on board at the time of take off from Montreal was 104,000 Kgs. which was adequate for 8 hours 40 minutes of flying. The commander accepted the aircraft and signed the 'Certificate of Acceptance' of the aircraft.

2.2.6 At approximately 2130 Z Air Canada personnel opened the passenger check-in counter for flight AI-182 (The flight AI-181 terminates at Montreal and the flight from Montreal to London-Delhi-Bombay is designated as AI-182). The checked-in baggage was sent to the baggage make-up area. Between 2300-2350 Z, a suspect suitcase was identified as the X-Ray showed what appeared to be some wires next to the suitcase opening. The suitcase was placed on the floor next to the X-Ray machine. Subsequently two more suspect suitcases were located. These suitcases were also placed next to the X-Ray machine to await the arrival of the Air India Security Officer who was to arrive on Air India flight AI-181 from Toronto. The remainder of the checked-in baggage, which cleared the security check, was loaded in containers by Air Canada personnel for loading on board the aircraft.

2.2.7 Two diplomatic pouches from the Indian High Commission, Ottawa were brought to Mirabel. After the flight arrived, one of the pouches of Category 'A' weighing 1 Kg. was given to the Flight Purser. The other Category 'B' pouch

weighing 9 Kgs. was placed in an valuable container 14R.
2.2.8 No other cargo was accepted for this flight except a small package (weighing less than 1 Kg) containing medicines for cancer treatment of a patient in New Delhi. This parcel was received at 1530 Z on 21st June and was loaded in container 14R by Messrs Mega International on 22nd June, more than 24 hours after its receipt.
2.2.9 Five baggage containers, one valuables container and two empty containers were loaded in the aircraft.
2.2.10 The checked-in passengers with their hand baggage went to the departure sterile area. At the entrance to the departure sterile area security staff used X-Ray units and metal detectors to check passengers and their hand baggages.
2.2.11. At approximately 0100 Z, 23rd June, after the primary security check was completed, the passengers proceeded to boarding gate No.80. At this lcoation the secondary security check was done on passengers using hand held metal detectors. Hand baggages were also subjected to further physical and visual check by them.
2.2.12. A total of 105 passengers boarded the flight AI-182 at Mirabel Airport. It was determined that all the passengers who had checked-in, boarded the aircraft. There was no interline passenger. At Montreal there were five 'NO SHOWS' and two 'GO SHOWS'. In all 307 passengers were on board the aircraft. The flight plan and the load and trim sheet, however, indicated 303 passengers as four of the 6 infants were not included in the passenger list.
2.2.13. The seating distribution of the passengers was as given below:-

Zone/ClassTotal number ofSeats Occupied seats Zone 'A' -First Class161Zone 'B'- Club Class22-Upper deck - Club class187Zone 'C' - Economy Class112104+ 2Zone 'D' - Economy

Class8684+ 1Zone 'E' - Economy Class123105+ 3
377301+ 6(Infants)

2.2.14 The seating distribution of the 19 cabin crew members was as follows:-

Two at door L1 and two at door R1
Two at door L2 and two at door R2
Two at door L3 and one at door R3
Two at door L4 and one at door R4
One at door L5 and one at door R5
One in crew rest area, Zone 'A'
One in jump seat upper deck
One crew rest area upper deck.

2.2.15 The three suspected suit cases were not loaded on the aircraft and were detained in the baggage make-up room. After the names of the passengers to whom the suit cases had belonged had been identified the same were transferred to the decompression chamber of E1 A1 Airline where they were examined, with the aid of a Police Explosive Dog, with negative results. The suit cases were kept overnight in the said chamber and when they were opened it was found that they contained no explosive items.

2.2.16. No unclaimed baggage pertaining to the Air India flight was recovered either at Toronto or at Mirabel or Dorval Airport in Montreal.

2.2.17. The flight plan for the sector Montreal to London was filed on telephone by the Air India Flight despatch from Toronto to Dorval ATC Centre. He requested for route SHERBROOKE-COLOR-NAT XRAYBUNTY-MERLY-EXMOR-IBLEY-SAMTN-HAZEL-OCKHAM-LONDON at flight level 290 upto COLOR and flight level 330 thereafter. The reporting points on Track XRAY on that day were COLOR, 47N/50W, 49N/40W, 50N/30W, 51N/20W, 51N/15W, 51N/08W and BUNTY.

2.2.18 The aircraft took off from Montreal at 0218 Z. Its estimated time of arrival at London was 0833 Z. The CVR and the ATC tapes show that the flight was normal and quite uneventful. Suddenly at about 0714 Z, when the flight was being monitored by the Air Traffic Controller at Shannon, with the help of secondary surveillance radar, the aircraft disappeared from the radar scope. Subsequently, the ATC at Shannon got the know that the aircraft had met with an accident and its wreckage was sighted about 110 miles west south-west of Cork, Ireland.

PERSONNEL INFORMATION

2.3.1 Pilot-in-Command (Capt. H.S. Narendra)

2.3.1.1 Cap.t H.S. Narendra (age 561/2 years, date of birth 25th November, 1928) joined Air India on 1st October, 1956. He held ALTP Licence No. 247 valid upto 29th October, 1985 and FRTO No. 478 valid upto 23rd October, 1985. He was released as a Co-pilot on Boeing 707 aircraft on 21st July, 1960 and as a Commander on Boeing 707 aircraft on 17th September, 1964.

2.3.1.2 For conversion as Pilot-in-Command on Boeing 747 aircraft, Capt. Narendra had undergone ground training at Boeing Airplane Company, USA and simulator and aircraft flying training at Bombay in 1972. He completed his route checks for Pilot-in-Command endorsement between December, 72 and January, 73. He became a Commander on Boeing 747 aircraft on 14th February, 1973.

2.3.1.3 Details of Capt. Narendra's flying experience and licence renewal checks are as given below:

a. Total flying experience : 20, 379:15 hours

b. Flying experience on B-747 as
   (i) Pilot-in-Command : 6,364.50 hours
   (ii) Co-pilot : 123:45 hours

c. Day flying experience
   on B-747 aircraft : 3,980:00 hours

d. Night flying experience
   on B-747 aircraft : 2,508:35 hours

e. Flying experience during

(i) last 6 months: 301:45 hours

(ii) last 3 months: 159:40 hours

(iii) last 30 days : 68:45 hours

(iv) last 7 days : 9:00 hours

He had last flown as Pilot-in-Command on flight AI 181 (Frankfurt to Toronto) on 15th June, 1985.

f. Date of last licence renewal and IR check : 8 May, 1985

g. Date of last route check : 24 March, 1985

h. Date of last medical examination at CME, Delhi : 29 April, 1985

i. Date of last simulator refresher course : 19 December, 1984

j. Date of ground technical refresher course : 6/7 May, 1985

k. Date of last flight safety refresher course : 25 July, 1984

l. Rest period before operating the accident flight : 1 week

2.3.1.4 Records indicate that on 29th June, 1966, Captain Narendra was declared medically unfit for 2 months to reduce his weight by 10 Lbs. In February, 1973 he was advised to wear corrective by-focal glasses while flying. In May, 1975 he was again declared medically unfit for 3 months.

2.3.1.5 Capt. Narendra was earlier involved in the following two incidents:

(a) On 25th August, 1984, while operating flight AI-1100 from

London to Delhi, there was a deviation of the aircraft by about 170 nautical miles from the track over Rahimyar Khan in Pakistan. He was given necessary INS refresher and Route checks with particular emphasis on cross checking procedure.

(b) On 6th December, 1984, while operating flight AI-124 Delhi-Bombay, the aircraft was observed approaching runway 32 at Bombay Airport when runway in use was 27. Captain Narendra was given simulator training for a series of approaches and landings and visual circuits from right hand and left hands seats for approaches and landings on runway 27 at Bombay Airport.

2.3.1.6 Captain Narendra was not involved in any accident previously.

2.3.2 Co-pilot (Capt. S.S. Bhinder)

2.3.2.1 Capt. S.S. Bhinder (age 411/2 years, date of birth 30th November, 1943) joined Air India on 12th October, 1977. He held ALTP Licence
No. 940 valid upto 25th July, 1985 and FRTO Licence No. 2290 valid upto 2nd February, 1986.

2.3.2.2 Capt. Bhinder was released as a Co-pilot on Boeing 707 aircraft on 18th November, 1978 and as a Co-pilot on Boeing 747 aircraft on 17th May, 1980.

2.3.2.3 Details of his flying experience and licence renewal checks are as given below:

a. Total flying experience : 7,489:00 hours

b. Experience on B-747
aircraft as Co-pilot : 2,469:30 hours

c. Day flying experience
on B-747 aircraft : 1,426:15 hours

d. Night flying experience
on B-747 aircraft : 1,043:15 hours

e. Flying experience during

(i) last 6 months: 157:45 hours

(ii) last 3 months: 65:00 hours
(iii) last 30 days : 20:15 hours
(iv) last 7 days : 9:00 hours

He had last flown as
Co-pilot on flight AI-181
(Frankfurt to Toronto)
on 15th June, 1985).

f. Date of last licence
renewal check : 25th March, 1985

g. Date of last IR check : 23rd November, 1984

h. Date of last route check : 9 April, 1985

i. Date of last medical
examination at CME
Delhi : 14 January, 1985

j. Date of last simulator
refresher course : 16 July, 1984

k. Date of last ground technical
refresher course : 8/9 October, 1984

l. Date of last flight
safety refresher course : 3 December, 1984

m. Rest period before operating
the accident flight: 1 week.

2.3.2.4 Records indicate that Capt. Bhinder was not involved in any accident earlier.

2.3.3 Flight Engineer (Mr. D.D. Dumasia)

2.3.3.1 Flight Engineer Mr. D.D. Dumasia (age 57 1/2 years, date of birth 10th October, 1927) joined Air India on 27th December 1954. He held flight Engineer's Licence No. 37 valid upto 6th December, 1985. Mr. Dumasia was released as a Flight Engineer on Boeing 707 airecaft on 16th December, 1963 and on Boeing 747 aircraft on 6th February, 1974. He had a total flying experience of 14,885 hours out of which 5,512:35 hours were on Boeing 747 aircraft.

2.3.3.2 Last medical examination of Mr. Dumasia was completed on 1st October, 1984 at CME Delhi. He had completed simulator refresher course on 14th February, 1985, ground technical refresher course on 14/15th January, 1985 and flight safety refresher course on 13th August, 1984.

2.3.4 Cabin Crew

2.3.4.1 A total of 19 cabin crew members were on duty on Flight AI-181/182 on 23rd June, 1985. Their brief details are as given below:

Sl.No.NamesDesignationFlight Safety coursecompleted on1.Mr. S.L. LazarInflight Supervisor1/2 April, 19852.Mr. K.M. ThakurFlight Purser18 February, 19853.Mr. Inder ThakurFlight Purser9/10 May, 19844.Mr. ShuklaFlight Purser23 January, 19855.Mr. S.P. SinghFlight Purser15 January, 19856.Mr. N. VaidAsst. Flight Purser2/3 May, 19857.Mr. B.K. SenaAsst. Flight Purser3 December, 19848.Mr. N. KashipriAsst. Flight Purser12/13 Sept., 19849.Mr. J.S. DinshawAsst. Flight Purser17/18 Dec., 198410.Mr. K.K. SethAsst. Flight Purser11/12 February, 1985

11.Miss RaghavanAirhostess13 July, 198412.Miss S. GhatgeAirhostess10/11 April, 198513.Miss R. BhasinAirhostess11/12 February, 198514.Miss L. KajAirhostess17/18 April, 198515.Miss P. DinshawAirhostess17/18 Dec., 198416.Miss S. LasaradoAirhostess15/16 April, 198517.Miss E.S. RodricksAirhostess10/11 June, 198518.Miss S. GaonkarAirhostess3/4 April, 198519.Miss R.R. PhansekarAirhostess29/30 April, 1985 AIRCRAFT INFORMATION

2.4.1 General

2.4.1.1. Boeing 747-237B 'Kanishka' aircraft VT-EFO was manufactured by Messrs Boeing Company under Sl.No. 21473.

The aircraft was acquired by Air India on 19th June, 1978. Initially, it came with the expert Certificate of Airworthiness No. E-161805. Subsequently, the Certificate of Airworthiness No. 1708 was issued by the Director General of Civil Aviation, India on 5th July, 1978. The C of A was renewed periodically and was valid upto 29th June, 1985. From the beginning of June, 1985, C of A renewal work of the aircraft was in progress. The aircraft had the Certificate of Registration No. 2179 issued by the DGCA on 5th May, 1978. The commercial flight of 'Kanishka' aircraft started on 7th July, 1978.

2.4.1.2 The aircraft was maintained by Air India following the approved maintenance schedules. It had logged 23634:49 hours and had completed 7525 cycles till the time of accident.

2.4.1.3 The aircraft was fitted with four P & W JT9D-7J engines having thrust rating of 48650 pounds. The hours and cycles logged by the engines since new till the time of accident are as given below:

Engine No.1 : P662927-7J - 29,663:26 Hrs (9422 cycles)
Engine No.2 : P695610-7J - 20,810:28 Hrs (6031 cycles)
Engine No.3 : P695602-7J - 21,992:31 Hrs (6564 cycles)
Engine No.4 : P662926-7J - 32,332:15 Hrs (11295 cycles)

2.4.1.4 All the DGCA mandatory modifications and inspections applicable to the subject aircraft had been compiled with. No major component installed on this aircraft and its engines had exceeded the stipulated life period.

2.4.1.5 The last quarter Periodic Check of the aircraft was carried out on 24th May, 1985, at 23274:53 hours and 7439 cycles. Subsequent to this check, two Check 'B' schedules were carried out. The last Check 'B' was carried out on 17th June, 1985, at 23564:14 hours and 7510 cycles and was valid for 200 flying hours.

2.4.1.6 The aircraft had flown 359:56 hours and 86 cycles since last quarter Periodic Check and 70:35 hours and 15 cycles since

last Check 'B' till the time of accident.
2.4.1.7 The last Flight Release Certificate was issued on 24th May, 1985 on completion of quarter Periodic Check and was valid for 1100 hours or 150 days elapsed time whichever occurred first. After the last departure from Bombay on 21st June, 1985, the aircraft had flown for 22:34 hours till the time of crash.
2.4.1.8 Mr. Rajendra, Maintenanace Manager, Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft at Toronto on 22nd June, 1985 and no snag was observed by him. No snag was reported by the flight crew during the flight from Toronto to Montreal. Transit Check 'C' of the aircraft for the flight AI-182 was carried out at Montreal by Mr. Rajendra and three Air Canada technicians. The flight engineer also carried out his pre-flight inspection and found that the rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to Mr. P. Bayle, Air Canada technician who faired the handle and applied high speed tape. No other snag was observed during the inspection.
2.4.2 Previous Incidents and Snags
2.4.2.1 A maintenance Group was formed with representatives from Air India and Airworthiness Directorate with Mr. R.K. Paul, Senior Air Safety Officer as the Group Leader to scrutinise the maintenance documents and various defects experienced on this aircraft. The report submitted by the Group (Attachment 'B') indicates that the aircraft was involved in six incidents since the last C of A renewal, details of which are given below
(I) On 13th July, 1984 at Dubai -- flight AI-868 The aircraft returned after aborting take off due to no rise in the EPR and N1 on No.1 engine (Sl.No. 695612). The engine front and rear were checked and found OK. Slight wetness was noticed in the bleed outlets. No external oil leak was noticed. Oil quantity was topped up. The chip detectors and oil filter were found OK. EVC Ph

filter was found
OK. EVC linkage wes exercised. The engine was run up and its operation was found satisfactory. The snag was suspected to be due to lack of pressurising air at low N1.

(ii) On 18th July, 1984 at Delhi -- flight AI-105 The right hand side fuselage skin between stations 480 and 500 in line with lower portion of forward cargo door cut-out was damaged by high lift. The same was repaired at Delhi. Permanent repair was carried out at Bombay. The repairs were accomplished using guidelines given in the Boeing Structural Repair Manual.

(iii) On 12th August, 1984, at Rome -- flight AI-135 The aircraft landed with No. 2 engine (Sl.No. 662826) shut down in flight due to oil pressure and oil quantity droping. On motoring the engine, oil leak was observed from metal line between F C O C and L O P switch at the switch end. The line was found cracked which was welded and refitted. The line was subsequently replaced at Bombay.

(iv) On 24th October, 1984, at London -- flight AI-104 There was total loss of No.1 hydraulic system fluid. The fluid leak was traced to inlet pressure adapter of flap control module in the left hand body gear wheel well. Two of the four bolts holding the adaptor on the flap control module had sheared. The hydraulic pump, seal, back-up ring and case drain filter were replaced. The flap control module was replaced when the aircraft arrived at Bombay.

(v) On 14th February, 1985, at Delhi -- flight AI-164 On arrival the leading edge honey comb of the left hand aft trailing edge flap was found damaged about 18 inches in length due foreign object damage. Necessary repair was carried out at Delhi. The aft flap was replaced at Bombay.

(vi) On 28th May, 1985, at Dubai -- flight AI-103 On arrival, the left hand wing to fuselage botton fairing forward rubber seal with strip was found turn off. Temporary repair was carried out at

Dubai. Permanent repair was carried out subsequently at Bombay.

2.4.2.2 The flight snags recorded in the flight report books of the aircraft during the 4 1/2 month period prior to the accident were scrutinised by the Maintenance Group and the only significant repetitive defect observed was "R2 door not going to manual". On ground checks by the aircraft maintenance engineers, the operation of the selector was, however, found normal.

2.4.2.3 Prior to operating the accident flight, the aircraft arrived at Toronto from Frankfurt. Capt. R.K. Spencer was the commander of the flight. The flight crew had reported the following three snags:

(I) HF system No. 2 had a lot of distortion

(ii) E P R L indicator unserviceable in 'Go around' mode

(iii) Hydraulic system No.1 pressure indication unserviceable (This snag was carried forward from Delhi).

2.4.2.4 The Auxiliary Power Unit (APU) was unserviceable ex-Bombay and had been released under M E L.

2.4.2.5 For rectification of the above stated snag No.1, Shri Rajendra, Air India's Maintenance Engineer at Totonto checked the connections of the transreceiver and reracked the unit. No snag was reported on this system on Toronto-Montreal sector.

2.4.2.6 Snag No. 2 was carried forward.

2.4.2.7 Regarding the third snag, Mr. Rajendra has stated that the indicator showed 4000 P S I pressure even with no pump running. He therefore, interchanged No.1 and No.3 indicators. The snag, however, persisted. He then replaced transmitter No.1 with a spare transmitter from the aircraft SE box and the snag was rectified. No rectification work was however, recorded by the AME in the Flight Report Book. No snag was reported on this system on Toronto-Montreal sector.

2.4.3 Installation of 5th Pod Engine

2.4.3.1 On 8th June, 1985, No.1 engine of Air India Boeing 747 aircraft VT-EGC operating flight AI-181 failed during take off at Toronto. The aircraft returned and the engine was replaced by a loaned engine from Air Canada. The removed engine was a P & W JT9D-7Q type (Sl. No. P702353-7Q).

2.4.3.2 Air India had planned to bring back the failed engine of VT-EGC aircraft to Bombay, as fifth pod on their flight AI-181/182 of 22/23 June, 1985 and had sent an Engineer along with the necessary kit to Toronto on 15th June, 1985. The engine borrowed from Air Canada on 8th June, 1985, was flown back to Toronto as a fifth pod engine on flight AI-181 of 22nd June, to return it to Air Canada.

2.4.3.3 Shri C.D. Kolhe, Controller of Airworthiness, Bombay examined the aspects relating to installation of the 5th Pod engine, loading of its components and certification of the related work. Shri Kolhe's report indicates that the failed engine and the associated parts were kept in the Air Canada engineering hanger at Toronto airport since June 8 when the aircraft was brought to the hanger for engine replacement. Air India requested Air Canada on 15th June, 1985, for prepairing the failed engine for installation as fifth pod engine on 22nd June. Accordingly, Air Canada's technicians undertook the preparatory work of removing the cowlings, fan blades, panels, locking of compressor, turbine rotors etc. on 17th June, 1985, and completed the work on 21st June, 1985. The fan blades (46 in number) from the failed engine were placed in 12 wooden shipping boxes provided by Air India. These boxes were then loaded in a container. The other components of the failed engine were loaded on 4 pallets.

2.4.3.4 Installation of the fith pod engine was carried out by Air Canada technicians and the individual items on the task card were certified by the individuals who had carried out the work.

2.4.3.5 Some difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fittings from the aft cargo compartment door cut-out. After removal of the fittings, the pallet could be loaded. All the removed fittings were then re-installed. Removal and installation of the fittings was certified by Mr. Rajendra.

2.4.3.6 A question arose whether removal of the door stop fittings could have caused some difficulty in flight. From the video films of the werckage it was found that the complete aft cargo door was intact
and in its position except that it had come adrift slightly. The door was found latched at the bottom. The door was found lying along with the wreckage of the aft portion of the aircraft. This indicates that the door remained in position and did not cause any problem in flight. In the front cargo compartment, there were 16 containers out of which four were empty. Five containers had baggage of Delhi bound passengers. Container at Position 13L had baggage of the first class and London passengers and container at position 13R had crew baggage. The entire baggage of passengers ex-Montreal was loaded in containers at positions 12R, 21R, 22R, 23R and 24R in the front cargo compartment. Container at position 24L contained fan blades in wooden boxes and the other components of the pod engine. Valuable container was at position 14R.

2.4.3.7 In the aft cargo compartment, there were four pallets containing parts of the fifth pod engine and two containers at positions 44L and 44R containing baggage of Delhi bound passengers. The bulk cargo compartment contained passenger baggage bound for Delhi and Bombay. All the baggage and engine parts in the aft and bulk cargo compartments were loaded at Toronto.

2.4.3.8 The total weight of the fifth pod engine and its items was about 9000 kgs. As a result of carriage of the fifth pod engine, the payload of the flight was considerably reduced on London-Delhi sector.

2.4.3.9 At the time of take off from Montreal the aircraft had 104,000 kgs of fuel on board which was adequate for 08:40 hours of flying as against sector flying time of 06:15 hours. The flight plan fuel was calculated taking Paris as the alternate airport for London.

2.4.3.10 The load and trim sheet from the sector Montreal London was prepared and was duly counter-signed by the commander. The take off weight of the aircraft was 317,877 kgs which was within the maximum take off weight limit of 334,500 kgs. The estimated landing weight of the aircraft was 237,177 kgs which was also within the maximum landing weight limit of 256,279 kgs. The centre of gravity of the aircraft was at 21.3 percent
of MAC at take off and the estimated C G position at the time of landing at London was 25.8 percent of MAC which was within the limits.

2.4.3.11 The load and trim sheet and the flight plan of the aircraft indicated that there was 301+2 passengers on board the aircraft whereas there were actually 301+6 passengers on board. The error occured because four of the six infants were not taken into account.

2.4.4 Corrosion Control Measures

2.4.4.1 Boeing Company have recommended various measure to control corrosion on Boeing 747 aircraft through different documents such as Maintenance Planning Data Document, Corrosion Prevention Manual and Service Bulletins. Compliance of these measures on Air India fleet is accomplished as follows:

(I) Support structure under galleys and lavatories

Boeing Company have recommended repeat inspections of under galley/toilet structure at intervals of 12000 hours. However, in order to detect corrosion at an early stage, these inspections are carried out by Air India at intervals not exceeding 9000 hours.

(ii) Fuselage Lower Bilge Area:

Boeing Company have recommended modifications to provide improved drainage systems by incorporation of various Service Bulletins. All the relevant modification have been completed by Air India on the affected aircraft. In addition to completion of these modifications, repeat inspection of lower bilge area is being carried out to meet the requirements of Boeing Service Bulletins.

(iii) Canted Pressure Deck:

In order to prevent water accomulation and consequent corrosion in the area, Boeing Company have issued SBs 51-2015, 51-2026 and 51-2032. Air India have incorporated Service Bulletins 51-2015, and 51-2032 on all their affected airplanes SB 51-2026 is being complied progressively.

(iv) Cargo Compartments:

Inspection of all the cargo compartment interior structures for corrosion and cracks is being accomplished periodically by Air India after removal of linings and insulation blankets.

(v) Aft Pressure Bulkhead:

During every equalised Periodic Check routine, the aft surface of aft pressure bulkhead is being visually inspected for corrosion condition and security of attachements. The forward surface of the pressure bulkhead, which is covered by aft toilets, is inspected after removal of toilets at intervals not exceeding 9000 hours although the recommended interval by Boeing Company is 12000 hours.

2.4.4.2 Air India has stated that in addition to the above specific measures, aircraft structure particularly the areas below toilets, galleys, cargo compartments, outflow valve area etc. which are prone to corrosion, are inspected for corrosion, cleaned and protected during every equalised Periodic Check. Air India have further stated that no serious corrosion problem has been experienced by them so far on their fleet.

2.4.5 Supplemental Structural Inspection Programme

2.4.5.1 In the case of airplanes which have completed 10,000 flight cycles as on June 30, 1983, Federal Aviation Administration (FAA) U S A and Boeing Company had recommended additional structural inspections known as Supplemental Structural Inspection Programme. In the Air India fleet, the first three 747 aircraft, namely, VT-EBE, VT-EBN and VT-EBO fell in this category and are known as 'Candidate Airplanes'. The subject aircraft (VT-EFO) had completed only 7525 flight cycles at the time of the accident on 23rd June, 1985, and therefore, the Supplemental Structural Inspection Programme was not applicable to this aircraft.

2.4.6 Special Corrosion Inspection of B-747 Aircraft Fleet of Air India

2.4.6.1 In order to examine whether corrosion to the aircraft structure of Kanishka aircraft could have contributed to the accident, a group was constituted by Mr. H.S. Khola, Inspector of Accidents to carry out special corrosion Inspection of all the Boeing 747 aircraft of Air India.

The group consisted of the following members:

(a) Senior Air Safety Officer of the D.G.C.A.

(b) Senior Airworthiness Officer of the D.G.C.A.

(c) Air India's Representative.

2.4.6.2 The inspection was carried out in the following areas:

(a) Below toilets and galleys

(b) Forward and aft cargo compartments belly areas - internally and externally

(c) The forward and aft pressure bulkheads

(d) Canted pressure web area from inside the passenger cabin.

(e) Area around outflow valves

(f) MEC area inside and outside.

2.4.6.3 The inspection reports submitted by the Group show that no corrosion was noticed on the significant primary structural members of the aircraft. Surface corrosion was, however, noticed on some of the members below the toilets and galleys. The corrosion observed during the inspection was of minor nature which is normally expected on such inspection schedule. The Kanishka aircraft was subjected to Periodic Check on 24th May, 1985 at 23,274.53 hours/7,439 cycles and no significant corrosion was observed. Among the Nine 747 aircraft inspected for corrosion, 5 aircraft had logged hours more than the Kanishka aircraft. Three of the aircraft had actually logged nearly double the flying hours. Taking into consideration that the corrosion prevention measures recommended by the Boeing Company were followed by Air India and that even the high life aircraft (45,000 hours approximately) subjected to corrosion inspection at the time when Periodic Check was due i.e. 1100 hours since previous check, had no significant corrosion, it is considered unlikely that Kanishka aircraft, which had logged only 23,275 hours since new and 360 hours since last Periodic Check, had corrosion which could have contributed to the accident.

METEOROLOGICAL INFORMATION

2.5.1 A report on the Meteorological conditions prevailing en-route near the location where the aircraft crashed was provided by the Meteorological Service, Department of Communications, Dublin, Ireland. This report covers a period of one to two hours before and after the time of accident (0714 Z).

2.5.2 From the report it is seen that the surface Synoptic Situation in the vicinity of 51°N, 12.50°W at 0715 Z on 23rd June was as given below:

Surface wind: 250/15 knots

Surface visibility : 10 Kms (occasionally 4 kms in drizzle)

Surface temperature : 13°C

Cloud conditions : Cloud cover in the area was estimated to have been layered upto about FL 100 with a base of 600 feet.

There is no evidence of cumulonimbus or thunderstorm activity.
Freezing Level : 700 feet.

2.5.3 With regard to Upper Air situation the report indicates that a mainly West or West North West airflow covered the area of FL 310 The Jet stream was centred at about 48°N. The estimated wind and temperature at FL 310 were 270/65 knots and -47°C. As per the report, at FL 310, 51°N 12.50°W and at 0715 Z any significant clear air turbulence was not expected.

2.5.4 Sunlight condition was prevailing at the time of accident. There were no sigmets valid for the area at that time.

AIDS TO NAVIGATION

2.6.1 The aircraft was equipped with Inertial Navigation System (INS) and was cruising normally at its assigned flight level 310 on track X-ray over Atlantic. It was under the control of Shannon Upper Area Control and was being monitored on the Secondary Surveillance Radar (SSR) located at Mount Gabreal. Till the time of accident, the aircraft was beyond the range of Shannon primary radar.

2.6.2 The aircraft entered Shannon airspace at the correct position and level and remained on the assigned track and flight level till it disappeared from the radar screen.

2.6.3. There is no evidence to indicate that AI-182 experienced any navigational problem during the flight.

COMMUNICATIONS

2.7.1 Two-way communication between the ill-fated aircraft and the ATS units of Canada and Ireland was maintained during the flight from Montreal till the time of crash. The communications were recorded on the ATC tapes. Transcripts of the relevant tapes were provided by the Canadian Aviation Safety Board and the Director of Air Traffic Services, Ireland.

2.7.2 From the Transcript of the conversations, it is observed that two-way communication between AI-182 and the various ATS units was normal. The last R/T contact with the aircraft was at 0709:58 Z when AI-182 informed Shannon UAC that it was squawking 2005. The tape transcript also shows that the aircraft did not transmit any information regarding the emergency on frequency 131.15 MHz on which it was last working with Shannon UAC or on distress frequency 121.5 MHz. Indecipheiable noise was, however, found recorded on the Shannon ATC tape just at the time of crash i.e. 0714:01 Z. Thereafter, repeated calls were made by Shannon UAC to AI-182, but there was no response.

SEARCH AND RESCUE

2.8.1 The report of the Search and Rescue Group gives the details of the Search and Rescue operations. From the report it is seen that at 0730 Z, Shannon UAC informed Marine Rescue Co-ordination centre (MRCC) shannon that AI-182, a Boeing 747 aircraft enroute Montreal-London had disappeared from the Secondary Surveillance Radar (SSR) at 0713 Z in position 51N/ 120W. Shannon UAC requested MRCC Shannon to take emergency section. At 0740 Z MRCC Shannon telephonically explained the situation to Valantia Coast Radio Station (CRS) and requested a PAN Broadcast urgently and to ask any vessels in area to keep sharp lookout and report to Valantia Radio. At 0746 Z Valantia Radio transmitted to all stations PAN message and above advice to ships. The transmission was repeated.

2.8.2 At 0750 Z, an Irish Naval Vessel AISLING reported on R/T to Valantia Radio that it was 54 miles from site of accident and was proceeding to the site. Valantia Radio passed on this information by Telex to MRCC Shannon. Between 0740/ 0750 Z MRCC briefed the Irish Naval Service (INS) Haulbowline, MRCC Swansea, RCC Plymouth and Irish Army Air Corps (IAAC) on the situation. At 0754 Z MRCC relayed a distress message to Shannon Aeradio via the Aeronautical Fixed Telecommunication Network (AFTN)

2.8.3 At 0803 Z Valantia Radio again transmitted the PAN message and the advice to ships. At 0840 Z Cargo vessel M W Laurentian Forest/HBWP (Registered in PANAMA and owned by Federal Commerce of Montreal, Canada) at position 51.09N/ 12.18W reported that it was 22 miles away from distress area and was proceeding there. Laurantian enquired if there were other ships in the area and was informed about position of Aisling. At 0813 Z Valantia Radio informed MRCC Shannon by telex about Laurentain Forest.

2.8.4 Between 0815/0820 Z, MRCC Shannon updated RCC plymouth and they advised that a Nimrod Rescue Aircraft would depart shortly for the area and that SEA KING helicopters were already enroute the Cork Airport initially. Edinburgh RCC advised MRCC Shannon that a Nimrod Rescue Aircraft was also being prepared at Kinloss. At 0820
Shannon Aeradio informed Valantia Radio that there was message from Shanwick Oceanic Control that aircraft were picking up ELT signal in position 51N/15W and 51N/08W and the actual position was beleived to be 51W/1250W. At 0833 Z, Valentia Radio sent message giving the above information and requesting ships in the area to report to Valentia Radio.

2.8.5 At 0842 Z, Ali Baba informed Valentia Radio that it was at position 5125.5N/0825.4W and was listening on 121.5 MHz. At 0850 Z Western Arctic informed Valentia Radio its position 5207N/1151W and that it would proceed in about 20 minutes after bringing in cable. At 0857 Z, High Seas Driller informed Valentia Radio that Vessel Kongstain could be released, ETA 51/2 to 6 hours and they would standby. At 0858 Z, Valentia Radio informed MRCC Shannon about reports from Ali Baba Western Arctic and High Seas Driller.

2.8.6 At 0905 Z, Laurentian forest reported to Valdentia Radio that it was 5 miles from SOS position 51N/12.5 W and it had not sighted anything. Between 0905/0908 Z, three more vessels viz. Atlantic Concern, MV Norman Amstel and MV

Tasman reported their positions to Valentia Radio. At 0908 Z, Swansea advised MRCC Shannon that four Seaking helicopters and two Nimrod Aircraft were enroute.

2.8.7 At 0913 Z, Laurentin Forest reported to Valentia Radio that they had sighted what looked like 2 rafts about 2 miles away. At 0914 Valentia Radio informed MRCC Shannon about the report from Laurentian Forest.

2.8.8 At 0918 Z, Laurentian Forest reported to Valentia Radio that it had sighted wreckage in water at position 5101.9N/ 1242.5W and the liferafts were not inflated. Valentia Radio passed the message to MRCC Shannon at 0920 and also sent transmission about wreckage sighting. Lifeboats Valentia and Baltimore reported to Valentia Radio that they were proceeding to the position of wreckage.

2.8.9 At 0937 Z, Laurentian Forest reported that it had sighted 3 bodies in water. Valentia Radio informed the same to MRCC Shannon at 0940 Z. At 0945 Z, MRCC Shannon and MRCC Swansea decided that for security and operational reasons Cork Airport would be the primary operational base and ATC Cork were informed of this decision.

2.8.10 At 0953 Z, S MYROLI informed Valentia Radio that it was 80 miles north of position and had a group of 10 to 20 French vessesls and desired to know if they should proceed to site. After consulting Laurentian Forest, S MYROLI was advised that it was not necessary. Valentia Radio kept on giving Mayday relay frequently.

2.8.11 At 1045 Z, a prohibited flying area was established with a radius of 40 N Miles from the datum point from sea level to 5000 feet. Falmouth Coast Guard reqested Valentia Radio the position of all ships in the distress area and those proceeding so that each vessel could be designated to search a particular area.

2.8.12 At 1126 Z, Laurentian Forest reported Valentia Radio that it had located numerous bodies in water and Seaking helicopter was hovering there. Valantia Radio Transmitted this information to all stations.

2.8.13 At 1133 Z, Valentia Radio informed Coast Guard Falmouth the position and ETA of various ships and also of the Lifeabouts Valentia and Beltimore. At 1150 Z, RRC Plymouth requested MRCC Shannon that "Le Aisling" assume duty as "On Scene Commander Surface Unit". At 1204 Z, information was received by Valentia Radio that 8 Spannish Trawlers were proceeding to distress position of AI-182 and their ETAs were between 1630/2000 Z. At 1246 Z, Star Orion informed Valentia Radio that it would be able to refuel any vessel in medium or small quantities at the accident site. Valentia Radio informed MRCC Shannon and Falmouth about the Spanish Vessels and Star Orion.

2.8.14 Falmouth requested Valentia Radio at 1303 to advise Laurentian Forest to inform Aisling that 8 Spanish trawlers would arrive in search area between 1600 Z and 2000 Z and Aisling should deploy trawlers in conjunction with lifeboats to recover bodies as it would be easier to recover than from large vessels. Valentia Radio sent the above message.

2.8.15 Laurentian Forest informed Valentia Radio at 1307 Z that 10 bodies were on Aisling, 4 on Helo, and they had some alongside and had launched lifeboats to pick them up. Valentia Radio informed the same to MRCC Shannon and Falmouth. At 1338Z, MRCC Shannon requested Valentia Radio to include the following in their broadcast:

"Vessels within 100 N Miles of datum 5101.9N/1242.5W are requested to proceed to search area and contact Aisling/EIYP. Any vessels recovering bodies or wreckage are requested to retain them on board and inform MRCC Falmouth of total number of bodies recovered."

2.8.16 Valentia Radio transmitted the above message at 1340 Z to all stations and also informed MRCC Shannon. At 1503 Z Aisling informed Valentia Radio that they had recovered 56 bodies. MRCC Shannon requested Valentia Radio to advise Aisling that if they could locate "Black Box", they should drop buoy. Valentia Radio advised Aisling accordingly. At 1530 Z, on advice from MRCC Shannon, Valentia Radio asked Baltimore, Courtmaesherry and Ballycotton lifeboats to return to base. At 1633 Aisling requested Valentia Radio to inform Falmouth that they were unable to transfer bodies to Valentia Lifeboat as latter was returning to base owing to fuel shortage. At 1659, Laurentia Forest informed Valentia Radio that 66 bodies had been picked up by then. Aisling advised Valentia Radio that Valentia lifeboat was returning with four bodies.

2.8.17 At 1721 Z Falmouth requested Valentia Radio to relay following to all surface units at scene:

1. One mimrod remaining on scene overnight.
2. All other air units will be recalled at 2200 Z. One Helo remains at 15 minutes notice at Cork
3. Air Search recommences at 240400 Z.
4. All Civil surface units will be released by 2200 and may proceed on passage. Bodies should be landed at Irish Post for transfer to receiving station at Cork Airport.
5. Warship Challenger, Emer and Aisling acknowledge".

2.8.18 At 1723 Z Aisling informed Valentia Radio that they saw 3 Spanish vessels approaching and they were using Ch.16 which Aisling was using for co-ordination with RESCUE 52 and requested that Spanish Vessels be asked to stay outside 5 miles radius. Spanish Agent was told about Aisling request.

2.8.19. Valentia lifeboat informed Valentia Radio that they were heading for home (Valientia) at reduced spead of 11 knots and they had five bodies on board. At 1822 Z, Aisling requested Valentia Radio information on 'Black Box' that might help its location. Aisling was advised of ELT signal on 121.5 MHz. At

1840 Z Cork ATC Advised MRCC Shannon that a total of 64 bodies were in Cork.

2.8.20 At 1920 Z, MRCC Shannon downgraded the 'MAYDAY' Broadcast to 'PAN' (Urgency) Broadcast, Aisling informed Valentia Radio that 79 bodies had been recovered. At 1958 Z Laurentian Forest informed Valentia Radio that they were proceeding to Dublin. Valentia Radio thanked them for assistance.

2.8.21 At 2000 Z, MRCC Swansea advised MRCC Shannon that main air search would cease at 2200 Z and would recommence at 240400 Z. The overnight search would continue with one Nimrod providing air cover for the surface search by three warships. Vessels transiting the area were requested to keep a sharp look out and to report to HMS Challenger.

2.8.22 By 0300 Z on 24th June, four Seaking helicopters had deported from Cork to resume the airborne search. At that time the search area covered a six nautical mile radius of position 5059.2 N/1225.3W and the vessels Le Emer and HMS Challenger were requested to search this area. HMS Challenger was the coordinator of the surface search and Nimrod Rescue 02 was on-Scene-Commander.

2.8.23 At 0450 Z Rescue 02 reported sighting of wreckage in position 5101 M/1245 W. Between 0505 and 0543, three USAF Chinook helicopters departed from Cork Airport to join the search. At 0556, MRCC
Swansea confirmed that there were 329 people on board the aircraft (Earlier reportes had idicated 325 people on board).

2.8.24 A continuous search was maintained throughtout the day (24th June) but only one further body and numerous pieces of wreckage were recovered. An extensive surface search was also maintained throughout the day and instructions were passed by MRCC Shannon to Valentia Radio requestiong all shipping to recover any wreckage or bodies sighted.

2.8.25 At 0900 Z, Capt. G Mc. Stay of Department of Communications advised MRCC Shannon that Aisling was bound for Cork, ETA 1300 Z and he (Capt. Mc Stay) was assuming responsibility for collection of wreckage. MRCC were also advised by Mr. Gregory of Britoil that their two vessels 'Constine' and 'Star Orion' were enroute to Foynes having picked up quantities of wreckage.

2.8.26 At 1740 Z, SRCC Plymouth advised Shannon that the Search will terminate at 242200 Z, at 1800 Z Falmouth MRCC advised MRCC Shannon to direct the Portisheal and Valentia Radios to concel Urgency Broadcast from 242000 and to release HMS Challenger and Le Aisling from the search at 242000 hours. All the aircraft were released at 24000. It was also decided that Le Emer would remain at the area. At 242003 Z, a message was transmitted to all stations on R/T and W/T that air and sea search was being terminated at 242000 Z and all the participant were thanked for their assistance.

INJURIES TO PERSONS

3.1.1 Post mortem examination was carried out by Irish Authorities at Cork. At that time Wing Commandor Dr. LR. Hill was also present. Subsequently Air Vice Marshall Kunzru also reached Cork. Both of them were members of the Medical Group which had been constituted by Mr. H.S. Khola.

3.1.2 By then 131 bodies had been recovered. None of the bodies of the flying crew were revocered. The bodies which were recovered represented 39.8 per cent of the victims. The exact seating position of passengers is not certain, because it is known if the passengers had changed their seats after the take off of the aircraft from Montreal. On the information which is available, the passengers were supposed to have been as follows:-

Passengers:SeatsOccupiedBodiesAvailableidentifiedZone A1610Zone B2200Upper Deck1870Zone D112104 + 229Zone D8684 + 138Zone E123105 + 350Sub-Total377301 +(6 infants)

117Crew:Flight Deck330Cabin19195Total399329122

3.1.3 The Post-mortem reports were examined by Wing Commander Dr. Hill. He submitted two reports being Exhibits H-1 and H-2. He was also examined in Court as Witness No. 2. Dr. Hill who had developed a system which would indicate the severity of the accident and the injuries suffered. He used a scale from 0 to 4, with naught being no injury and 4 being a fatal lesion. Though there is some amount of subjectivity involved in the system, nevertheless categorising the injuries according to the sacle does give an overall picture of what had happened to the victims. After adding up all the injury scale for a particular body, Dr. Hill in his Report Exhibit H-1 divided the injuries as under:-

No. of victimsMild injury (0-49) total34.4%45%Moderate injury (50-99)38.9%51%Severe Injury (100-149) 25.2%33%Catestrophic Injury (150 +) 1.5%2Total100.1%1313.1.4 A further break up showing the overall injury score of the recovered victims is as follows:

MinorModerateSevereZoneNo.%%No.%%No.%%TotalC86.117.896.917.743.111.421D96.9201511.529.496.925.733E1511.533.31511.529.41410.74044Unknown139.928.9129.223.586.122.933Total14534.41005139.1100%3526.8100%131

3.1.5 The reports submitted by Dr.Hill further indicted as follows

(a) There were 30 children recovered and they showed less overall injury. The average severity of injury increases from zone C to E and is significantly less in C than in Zones D and E.

(b) Flail pattern injuries were exhibited by eight bodies, five of these were in Zones E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

(c) There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evently distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

(d) Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 Zone D, 11 inZone E, 2 crew and 1 unknown), and 16 had little or no clothing.

(e) Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

(f) There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

(g) There is a general absence of signs indicating the wearing of lap belts.

(h) Pathological examination failed to reveal any injuries indicative of a fire or explosion.

3.1.6 In his testimony in Court, Wing Commander Dr. I.R. Hill further stated that the significance of flail injuries being suffered by some of the passengers was that it indicated that the aircraft had broken
in mid-air at an altitude and that the victims had come out of the aeroplane at an altitude. He further explained that if an explosion had occurred in the cargo hold, it was possible that the bodies may not show any sign of explosion. It may here be mentioned that the forensic examination of the bodies do not disclose any evidence of an explosion. Furthermore, the seating pattern also shows that none of the bodies from Zone A or B was recovered, in fact as per the seating plan Zone B was supposed to have been unoccupied. This Zone is directly above the forward cargo compartment.

3.1.7 Dr. Hill further stated that the pattern of the accident as suggested by the injuries indicated that it was a complex affair and there were at least two phases of injuries, one in the air and the other at water impact. In answer to a specific question that if there was an explosive device in the cargo hold then could the passengers who were seated have suffered such injuries, the answer of Dr. Hill was that "it is possible". According to him, the pattern of injuries indicated that if there was an explosion in the aircraft it was more likely that the explosion had occurred in the rear cargo compartment than in the front cargo compartment. This conclusion was apparently based on the fact that, according to him, in zone E of the aircraft there were larger vertical load type injuries. Dr. Hill was also asked if he had to make any suggestions which would minimise injuries to passangers in the event of an accident. In answer, the witness made his suggestion in the following words

"There are very complicated things one would have to do such as rearward facing seats; having safety belts which incorporated restraint for the upper part of the body; increasing the space between aircraft seats; incorporating shocks absorbing system within the seat and using materials which do not break easily like plastic. We would also need fuel systems which would not immediately set on fire and furnishing which would be resistant to burining, and also passengers should not carry into the aeroplanes large amount of hand bags which only get in way in the event of evacuation, and I personally feel that the carriage of large amount of alchohol both in the passengers and in the aeroplane is a hazard to flight and safety. Finally the passengers should take heed of the flight safety instructions given to them by the crew of the aeroplane".

3.1.8 Air Vice Marshal Kunzru, witness No. 10 in his report dated 14th November, 1985, Ex.A-48, gave his comments not only on the post-mortem reports but also on the statement of

Wing Commander Dr. I.R. Hill. With regard to the post-mortem examination, the comment of AVM Kunzru was as follows:
"All victims have been stated in the PM reports to have died of Multiple injuries. However two of the dead, one infant and one child, are reported to have dies of Asphyxia. There is no doubt about the asphyxial death of the infant. In the case of the other child (Body No. 93) there could be doubt because the findings could also be caused due to the child undergoing tumbling or spinning with the anchor point at the ankles. Three other victims undoubtedly died of drowning. There was no evidence of significant Lap-belt injuries.
Considering rupture of the ear-drum, without injury to skull, as a criterion to indicate rapid decompression, two cases may be considered to fall in this category.
Histological examination has been carried out only in 57 bodies out of 131. Lung examination on almost all of them showed decelerative changes. Six bodies (Nos. 6,22,70,103,121 and 131) showed presence of Bone Marrow Embolism in Lung Sections. Though not of much significance in this accident, this finding does indicate survicval after a bony injury for an undefined period of time No evidence of fire burns or explosive material, other than Kerosene burns on some bodies, which I had myself seen at Cork, could be found. Kerosene burns in such acidents is a fairly common findings and is of no significance".
AVM Kunzru generally agreed with the crash injury analysis on the victims which had been furnished by Wing Commander Dr. Hill. He, however, gave the following comments with regard to hypoxia, decompression and decelerative changes:
"Hypoxia : The main Post Mortem findings in hypoxia is generalised congestion if the hypoxia is of the type described as "hypoxic hypoxia". In other causes of hypoxia of more severe degree such as "histotoxic hypoxia", "asphyxia" or "drowning" additional histological findings such as petechial haemorrhages

and generalised congestion, and lung findings such as haemorrhage and extrusion of alvoolar phagocytos are seen.
Decompression : The term used by Dr. Hill is "Decompression". It is presumed that he means "Rapid/Explosive Decompression" which occurs within one Sec. and not "decompression sickness" which takes a minimum of 5 to 7 mnts to occur even at 31,000 ft. altitude and which in this case can positively be ruled out.
The Post-Mortem and histological signs of rapid Decompressions are :-
(a) Possibility of rupture of Ear drums without any injury to the skull.
*(b) Patchy Lung Haemorrhages
*(c) Emphysomatus changes
*(These occur more commonly in those cases where the individual was in the phase of breathing-in at the time of decompression.
3.1.9 If it is assumed that the aircraft suddenly broke up in Mid-Air at an altitude of 31,000 ft. the bodies will be at once exposed to hypoxia and rapid decompression and as a consequence will suffer body changes as mentioned above. As the aircraft/occupants start descending, they will be exposed to increasing amounts of Oxygen and as soon as ;they come down below 15,000 ft. and then below 10,000 ft. the effect of hypoxia rapidly diminishes. Finally, the aircraft/individuals come down and hit the ground/water with a very heavy impact, thus submitting the individuals to extremely severe G-loads of decelarative type.
Decelerative Changes : Decelerative impact brings about well established changes in the lungs besides many other associated injuries. It is relevant to note the decelerative lung changes which are :-
(a) Patchy haemorrhages in Lung.
(b) Marked Emphysomatus Changes.

(c) Extrusion of alvoolar Phagocytes
(d) Desqummation of bronchcolar epitherium.

"Comparative study of the PM/histological findings of hypoxia, Decompression and Decelerative Lung injuries reveal that they are more or less similar. Decelerative injury being the most severe of the three and last to occur tends to so modify the Post-Mortem and Histological findings that it becomes extremely difficult and some times impossible to isolate one from the other."

3.1.10 AVM Kunzru was, therefore, of the opinion that in this accident evidence of hypoxia/decompression (except in 2 cases) had not been confirmed or established.

3.1.11 The difference of opinion between Wing Commander Dr. hill and AVM Kunzru, with regard to evidence of hypoxia and decompression, is of no significance in the present case. What is important to note, however, is that they have agreed that the injury pattern does indicate break up of the aircraft in mid-air and that the occupants of Zone E had suffered the greatest amount of injuries as compared to the occupants of the other zones.

MAPPING, WRECKAGE DISTRIBUTION AND SALVAGE

3.2.1 Introduction

3.2.1.1 Oceanographic charts indicated that the depth of sea in the crash area was about 6700 feet and the site appeared to be a flat sea bed, without any valleys or hills. The immediate necessity after rescuing/searching crash victims, was to locate and recover the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR). The operation was unique of its kind and had never been undertaken earlier in the world at this depth of the sea. It required an equipment which could home on the transmitted signals from the underwater locater acoustic beacons fitted on DFDR/ CVR, identify the units, clear them from attachments/wreckages, grab them and bring them to the surface.

3.2.1.2 The pressure exerted by the water at 6700 feet below mean sea level is extremely high and the temperature is very low. No light penetrates to that depth and it is pitch dark. Scarab I fitted on French Ship "Leon Thevenin" which had undertaken the challenging job of locating DFDR and CVR, and recovering the same, was not designed to operate at 6700 feet depth. Its maximum design operating depth was only 6000 feet. However, it was decided to exceed the design operating depth for this emergency operation.

3.2.1.3 By using the preliminary information of probable area of location OF CVR and DFDR as indicated by ship 'Gardline Locator', the Scarab I was Lowered in the sea to locate and recover these units which it accomplished on 10.7.85 and 11.7.85 respectively.

3.2.1.4 Prior to recovery of DFDR/CVR by the ship 'Leon Thevenin', sufficient spade work was done by the ship 'Gardline Locator' (A ship provided by Accident Investigation Branch, U.K.) and 'Le Aoife' (an Irish Naval Ship). The survey of the crash area, carried out with the help of side-scan sonars fitted on these ships, had indicated a general distribution of the wreckage and a rough idea about the sizes of the parts. Each part of the wreckage was called a target. The method used for survey was triangulation with multiple passes through the crash site.

3.2.1.5 Next phase was the task of :

(a) Locating hundreds of pieces of wreckage by the combined use of sonar and video monitors.

(b) Video and still photography of the pieces of wreckage.

(c) Plotting the distribution of the wreckage.

All this was to be carried out under the directions of the Court.

3.2.2 Scarab

3.2.2.1 The means (vehicles/equipment) proposed to be used in the locating, mapping and video photography of the wreckage were the CCGS John Cabot and SCARAB II.

3.2.2.2 The John Cabot is an ice breaker of the Canadian Coast Guard. Since utilisation as an ice breaker is seasonal, the John Cabot is also equipped for submarine cable laying. In order to enlarge its capabilities in this regard, the John Cabot is equipped to have on its deck the Scarab and to operate it. Thus the John Cabot can be used for repair of submarine cables. The John Cabot has complete facilities for operation, maintenance and repair of the Scarab. This includes a Control Hut, a Test Room, Workshop, Stores etc. The John Cabot has considerable experience in work on deep sea bed.

3.2.2.3 The SCARAB II is a submersible craft assisting repair and burial of cables. As will be clear from the following details, the Scarab is not ipso facto a submarine. It is a total system for carrying out its complex functions.

3.2.2.4 The SCARAB II is a state-of-the-art system designed and built for tethered unmanned work at ocean depths of upto 6000 feet. Scarab's standard equipment are :

Two rugged manipulators.

A complete optical suite.

Six thrusters of 5 hp each.

CTFM Sonar.

Navigation System.

3.2.2.5 The manipulators have a choice of grippers/claws/ cutters etc. of any required description and size. The Scarab has three TV cameras mounted on separate pan/tilt mechanism to allow real time observation and video tape documentation. A 35 mm still camera was also installed and used in the present work. There was a choice of quartz-iodide flood lights to provide illumination.

3.2.2.6 The location and control of the Scarab is accomplished through a phased array navigation system.

3.2.2.7 The Scarab was equipped with a 360° high resolution

Sonar with a range of 1000 meters. The Sonar was also capable of interrogating and detecting 37 KHz and 27 KHz pingers. It can function independently of the ship's facilities and is equipped with power generators and semiautomatic handling equipment.

3.2.2.8 The John Cabot can salvage items, but it is not a salvage ship as it does not have the specialised high capacity cranes, derricks etc. required for salvage of large objects. Further, it does not have deck space for keeping large salvaged items like the wings, fuselage or tail surfaces of an aircraft as large as a 747. The John Cabot was, therefore, adequate and fully satisfactory for the work envisaged in this phase of the programme, as salvage of large items was not planned in this phase. The task was, as mentioned earlier, locating, mapping and photography of the hundreds of pieces of wreckage. (The salvage work was part of the next phase of the programme).

3.2.3 Control and Monitoring of Operations

3.2.3.1 It was realised that the operation proposed would pose problems of control, monitoring and logistics.

3.2.3.2 Consider : A ship operating on the high seas in international waters on the task of locating, mapping and video photographing the hundreds of pieces of wreckage. The state of art system for Sonar location and photography (Scarab) used by the ship for handling this task. The group located on shore in charge of the operations. Finally, the Court in Delhi was in overall charge of the operatins.

3.2.3.3 It was realised that a proper line of control and communication was essential if the operations were to be smooth and successful.

3.2.3.4 Therefore it was decided that the following would be the chain of command :

Court Investigating the Accident
(Mr. Justice B.N. Kripal)
Control Centre at Cork

(Court's representative)
CCGS John Cabot
(Commanding Officer)
Scarab
(Project Manager)

3.2.3.5 Because of the multiplicity of agencies involved in the operations, the need was felt for a proper delineation of power at all levels. It was, therefore, decided that :

a. Overall responsibility for the operations would rest with the Indian authority viz. the Court. This would cover the identification and definition of assignment of the overall tasks, laying down of the priorities, overall control of the coverage of the operation and, finally, the time schedule for the operation.

b. Decisions taken at the Control Centre, flowing from the above, were to be taken solely by the Court's representative. The experts from CASB, NTSB and Boeing were free to give their views and recommendations, but the final decisions were to be left to the Court's representative. Examples of such matters are : Track of the survey, areas to be covered by John Cabot, assignment of priorities for specific tasks, amount of time to be devoted to any piece of wreckage, whether any item of wreckage is to be picked up, etc.

c. Operation Control of John Cabot would be in the hands of the Canadian Coast Guard Officer in the Control Centre, who would co-ordinate with the Commanding Officer of John Cabot. This would cover decision on feasibility or otherwise of operations under adverse weather conditions, manner of covering the area, method of retrieving any wreckage, etc.

d. Decisions relating to the Scarab (i.e. whether the weather was suitable for Scarab operations, whether the size, weight etc. of an item would permit its being picked up by Scarab, etc.) would be left to the Scarab Project Manager on Board John Cabot.

3.2.3.6 It might appear at first sight that in the above system excessive power was delegated at certain levels to the detriment of overall control. Any such impression would not be correct. In actual fact, because of proper delegation of responsibility and power at different levels, the operations were carried out with extraordinary efficiency, smoothness and coordination, In this connection, it is relevant to point out that the operations were not a uni-disciplinary one. The operation (aircraft accident investigation) was totally dependent on experts from other disciplines, like naval (coast guard) operations, deep sea photograph, salvage from sea bed etc. It was therefore, decided that for smooth and efficient operations, adequate power and responsibility should be delegated at all levels, particularly to specialists engaged in the different areas of work as above.

3.2.3.7 It was also considered that adequate communication was a sine qua non for smooth operation. Therefore, the following communication facilities were established :

Control Centre at Cork Airport

Telex

Telephones (2)

3.2.3.8 The ship John Cabot had both telex and telephone facility. These links were through satellite (IN MARSAT). The Control Centre was in continuous communication contact with John Cabot through telex and telephones. In order to establish a reliable and satisfactory line of communication it was decided that instructions or communication from Control Centre to the Indian experts on John Cabot would follow the path as under :

Control Centre

Court's representative --- Canadian Coast Guard Officer

John Cabot

Indian experts --- Commanding Officer

3.2.3.9 It was felt that this would eliminate any possibility of inconsistent or contradictory orders/messages going to John Cabot.

3.2.3.10 With a view to have an ordered system of communications between the control centre and John Cabot (which is essential for proper control and monitoring of the operations), it was decided that John Cabot would sent to the Control Centre daily Situation Reports (SITREPS) at specified times viz. 0800 hrs, 1200 hrs, 1600 hrs and 2000 hrs. This however did not preclude the despatch of telexes by both Control Centre and John Cabot at any other time.

3.2.3.11 In order to inform all agencies of the above system of Control and Communication a number of meetings were held. These were on 12.8.85 and 3.9.85 on board John Cabot and on a number of occasions at the Control Centre. The purpose of these meetings was not only to inform all concerned about the specific task, the programme and the line of control and communication but also to sort out differences and to understand the technical and operational difficulties faced by the personnel on the spot and to find a way out.

3.2.4 Daily Monitoring of Progress

3.2.4.1 It may be relevant to point out here that search, location and video photography work was to be carried out round the clock. Thus a considerable volume of data would be coming into Control Centre. This required regular, almost hourly, monitoring, study and analysis for

(a) proper understanding of the data collected and (b) advising John Cabot of any changes in its programme, such as additional photography on an item etc. For this purpose (i) SITREPS were filed in the Control Centre (ii) all data (description, latitude and longitude) obtained on every target was tabulated and the cumulative list updated daily.

3.2.4.2 The location of the targets was plotted on charts every 4 hours. This was in addition to the plotting of targets carried out on John Cabot.

3.2.4.3 Every day (including holidays and week ends) all the officers posted at Control Centre assembled at about 0900 hrs. They studied the SITREPS received at 0800 hrs and any other telexes received from John Cabot in the night. The lists of targets were updated and the new targets plotted on the charts. John Cabot generally also sent brief remarks such as description, nature of failure/damage, dimensions etc. Discussions were held on the significance of the targets and their implications. Instructions if any to be telexed to John Cabot were also discussed. Similarly SITREPS received at 1200 hrs and 1600 hrs were studied.

3.2.5 Monitoring at Cork

3.2.5.1 The Scarab provided video tapes and still photographs. In the initial stages (upto 9.8.1985) the John Cabot was operating in peripheral areas and therefore few targets were found. Hence the output of videotapes was small. In fact upto 9.8.85, only about 10 targets were found and only 3 video tapes were used up. But later, when John Cabot came close to and into the crucial areas, video tapes were recorded at a fast rate. Further, still photography facility on the Scrab was activated at about this time. Therefore, arrangements were made periodically to obtain the video tapes and films from John Cabot. Video tapes and still photographs (these required to be processed) were transported from John Cabot to Cork Control Centre.

3.2.5.2 About 50 video tapes and nearly 3000 still photographs (positives and transparencies) provided the visual information on the targets.

Arrangements had to be made at Cork for such viewing and study of the video tapes and still photographs. Video equipment (TV monitor plus VCR) suitable for viewing the video tapes had to be arranged.

3.2.5.3 The still photography used special professional quality colour film (35 mm), each roll having 800 frames. The film was diapositive. These had to be developed and transparencies obtained from them. Thereafter negatives and prints had to be made. Special equipment for viewing the transparencies had to be provided for continuous work. The video tapes, transparencies and prints provided the principal means of monitoring of the results of the operation.

3.2.6 Operations

3.2.6.1 The Charts prepared by 'Gardline Locator' were on a different type of grid system, and had to be translated into LAT-LONG system, for use by John Cabot. For the convenience of search/mapping operation the search area was divided into 4 blocks viz. Block 1, Block 2, Block 3 and Block 4.

3.2.6.2 The navigation system used by John Cabot is PULSE-8 system. This system needs the transponders to be placed on the sea bed. These transponders help in getting the correct fix of a target and in obtaining relative positions of the targets on the sea bed which is highly useful for revisit for the purpose of rephotography or recovery. Initially 4 transponders were placed, and subsequently the number was increased as the search operation was continued. The strategic locations for placing the transponders was decided by considering :

(a) frequencies of relative transponders,
(b) distances required between relative transponders,
(c) wreckage distribution suggested by side scan sonar plots of Eithena and Garline Locator, and
(d) size of search area.

These transponders were calibrated to match the navigation system of the ship.

3.2.6.3 In order to obtain the maximum information from search, it was decided that the Scarab search paths should be as follows :

(a) Normally the search paths should be east to west, or west to

east within the individual blocks.
(b) The pattern of search should be a parallel search method.
(c) Distances between the parallel paths to be 1,200 feet (i.e. 2 cable widths), for effective use of sonar fitted on the Scarab.
(d) If Scarab deviates from its planned path for photography or recovery, it should return to its planned path for further search.
(e) In each block, the search was to be made, at least 1/2 mile (North or South) beyond the last target sighted, so as to ensure no target is missed out from the given block.
3.2.6.4 However, when there was a need to modify the search pattern, due to wreckage distribution in particular areas, the following changes were made:
(a) Expanding box type search pattern was used in Block 1.
(b) Some North to South and South to North passes were made in Block 3.
(c) In Block 3 northern end, the distances between the search passes was reduced to 600 feet i.e. 1 cable width.
However, these deviations were made basically to improve the reliability of search in specific areas, as demanded by peculiar distribution of aircraft wreckage.
3.2.6.5 To facilitate identification of the wreckage located by Scarab it was necessary to position aircraft maintenance personnel on board the ship. As the aircraft structure was badly torn, mutilated and distorted, serious difficulty was anticipated in identification of small pieces of structure. It was therefore essential that these maintenance personnel were provided with aircraft photographs, manufacturing drawings, parts catalogue, wiring diagram manuals and maintenance manuals. Since carriage of such voluminous literature was not praticable, 3M micro film reader printer machines with micro film cassettes of the above literature were produced and installed on the ship. In case of difficulty of locating any particular information, the engineers were advised

to contact Cork Search Centre by telex or telephone who, in turn, could seek the desired information from the manufacturers.

3.2.7 Wreckage Distribution

3.2.7.1 The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling at the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled. Although badly damaged, sections 41, 42 and 44, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been mapped or photographed. Section 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the western most identified aircraft component located at lat 51°02.90'N and long 12°50.1'N. The wreckage extended in a line about 110 degrees to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern. A third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a

northwest/southwest orientation. One of the operating engines was displaced 0.5 nautical mile to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components
and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

3.2.7.2 Details of the various targets which were identified by the Structures Group is contained in Appendix 1 of this Report.

3.2.8 The Break up Pattern

3.2.8.1 The forward fuselage section of the aircraft was found inverted and badly broken into many pieces, the major pieces being :

(I) Section of fuselage right side below cockpit windows containing part of the name 'Kanishka' (in Hindi) and 3 passenger windows (Target No. 192)

(ii) Portion of upper skin between B S 360 and B S 520 below window belt right side, up and over crown. This portion includes the crew door and last letter of the "Air India" (in Hindi) logo (Target No. 192).

(iii) Section of fuselage between B S 510 to B S 700, including the passenger window belt right side, up and over crown to include upper deck windows left side (Target No. 218).

(iv) Section of fuselage between B S 720 to B S 840 including left side passenger window belt, up and over crown to right side passenger window belt. Forward and upper edges of L H No.2 door cutout can be seen (Target No. 193).

(v) Large section of fuselage between B S 1000 to B S 1460 including left side passenger window belt, up and over crown to right side passenger window belt. This section was found lying on its right side (Target No. 137).

(vi) The lower portion of the fuselage skin/frame between the nose and B S 1000 was damaged past recognition except for a small portion with the forwarded cargo door (Target No.204) and another portion containing the aft access door cutout at B S 810 (Target No. 362).

3.2.8.2 The aft fuselage was found in the following major pieces :

(I) Section of RH fuselage skin between B S 1640 and B S 1940 below the window belt up to the crown (Target No. 321).

(ii) The RH fuselage bottom skin between B S 1820 (forward edge of C2 door) and B S 2060 and between two stringers above the door cutout to just below stringer 46 lap joint (Target No. 40).

(iii) The lower fuselage skin with stringers between B S 1480 and B S 1846 about 100 inches wide approximately (Target No. 7).

(iv) The LH fuselage skin panel between B S 1740 and B S 1880 about 110 inches wide (Target No. 11).

(v) The LH fuselage skin between B S 1460 and B S 1800 width 80 inches including No. 4L door and passenger windows (Target No. 28).

(vi) The RH fuselage skin between B S 1660 and B S 1920, from below window belt up to the crown including the 4R door cutout (Target No. 321).

(vii) A fuselage lower skin panel (containing out flow valve) between B S 2120 and B S 2240 and 120 inches wide (Target No. 320).

(viii) A fuselage LH skin panel (containing 5 windows with "T -" part of registration) between B S 1980and B S 2080 between stringers 19L and 24L (Target No. 369 and 26).

(ix) A fuselage LH skin panel between B S 1460 and B S 1800 with 8 stringers below the bottom of the door and 3 stringers above the top of the door (Target No. 28).

3.2.8.3 The tail portion of the fuselage was found in the

following pieces:
(I) The lower fuselage skin between B S 2412 and B S 2598 about 20 stringers wide (Target No. 371).
(ii) The vertical fin with rudders attached was lying on the ground by itself with a portion of B S 2517 frame. This includes a small portion of the aft pressure bulkhead (Target No.37).
(iii) The horizontal tail with elevators attached was lying on ocean floor with the jack screw and drive motor attached (Target No. 31).
(iv) The fuselage tail cone aft of B S 2669 was found basically intact and lying separately (Target No. 27).

3.2.9 Extent of Damage

Photographic and Video Interpretation of Wreckage

Photographic Interpretation

3.2.9.1 All wreckage sighted was recorded on video tapes and all major items were recorded on 35 mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage pattern. For example, the sine wave bending of target 7 appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into acount.

3.2.9.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

3.2.9.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gears were in the 'up' position at the time of impact.

3.2.9.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

3.2.9.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

3.2.9.6 Section 42

Portions of Section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers. All cargo doors were found intact and attached to the fuselage structure, except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different from that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back on to the sea bed. An attempt to relocate the door was unsuccessful.

3.2.9.7 Section 44

Section 44 containing the aircraft structure between B S 1000 and B S 1480 including that area where the fuselage and wings were mated
was located and identified. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gears were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

3.2.9.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northern most area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

3.2.9.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of B S 1480 and, for purposes of this report, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

3.2.9.10 The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were positively identified (targets 35, 37, 73 and 296). Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognisable as having come from a specific area of the aircraft.

3.2.9.11 Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from B S 1600 to B S 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

3.2.9.12 The tail cone and the auxillary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

3.2.9.13 A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure.

3.2.9.14 The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure

bulkhead was leaning on the lower section of the tail.
3.2.9.15 The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates° to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabiliser was missing and the auxilliary spar was exposed. There was localized damage to the right-hand root of the loading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.
3.2.9.16 Passenger Seats
Many of the passenger seats located among the wreckage pattern and identified as having come from section 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42 and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat belts were not fastened.
3.2.10 Salvage Operations
3.2.10.1 During recovery operation the video tapes as well as photographs of the wreckage to be recovered, were supplied to

the personnel on board the ship for facilitating identification and recovery of correct targets.

3.2.10.2 Whenever any component/part of the aircraft wreckage was salvaged it was essential to immediately subject the same to inspection and to identify the damage sustained during recovery operation. In order to oversee this critical operation, the Court deputed one of its Assessors, Dr. V. Ramachandran, to be on board the ships. Under his supervision, the components/parts were thoroughly washed with fresh water, dried and treated with corrosion inhibiting compounds. A detailed inspection was thereafter carried out, observations recorded and the targets were appropriately labelled and their numbers were painted thereon. A laboratory microscope was taken on board by Dr Ramachandran. With that, fragments of significance were segregated for further investigation. Indeed some of these fragments did give important clues.

3.2.10.3 All the investigating personnel on board the ship were provided with leather gloves, fisherman's shoes, raincoat, life floating suits, writing and labelling material, camera with coloured films, etc. Sufficient number of "body bags" were positioned on each ship to cater for the eventuality of recovery of bodies with the wreckage. This precaution helped when a body did come along with wreckage on 25.10.1985.

3.2.10.4 The ship John Cabot completed the operation of locating, mapping and photography of the wreckage and returned to Cork on 1.10.85 at 2020 hours. The next phase of operation was to recover the significant wreckage parts which would be useful for deciding the cause of the crash.

3.2.10.5 Subsequent to the accident to Japan Airlines Boeing 747 aircraft, suspected to have been caused by failure of the repair to the rear pressure bulkhead, NTSB and FAA decided to fund the U.S. Navy for a two week operation over the seas for recovery of significant pieces of wreckage. For this purpose, U.S. Navy appointed Commander J.R. Buckingham, a deep sea salvage expert, to head the recovery operation. An offshore supply vessel M.V. Kreuzturm, of Canada was hired by U.S. Navy to recover the wreckage with the help of Scarab on John Cabot. One nylon lift line together with winch and ram were installed on the ship prior to its sailing to Cork where it arrived on 4th October, 1985. One crane was installed on the ship Kreuzturm in Cork.

3.2.10.6 One inch dia Kevlar lines coated with black plastic for abrasion resistance and braided with Dacron lining were used by John Cabot as primary lift lines.

3.2.10.7 The structure group after studying the photographic data, had formulated a list of 32 targets for recovery on 3.10.85. A systemwise priority list proposed by the Court of Inquiry was received through Dr V. Ramachandran on 4.10.85. Using these two lists, and taking into account the operating restrictions imposed by two ship operation, a final list of targets was prepared for recovery by the ships, assigning a priority number to each target. However, as the recovery operation progressed, changes in priority list were made to achieve optimum utilisation of the ships.

3.2.10.8 A meeting was held at 1400 hrs. on 4.10.85 on board CCGS John Cabot to establish/clarify the priorities for the wreckage recovery operation and coordination between John Cabot, Kreuzturm and Cork Search Centre. All the personnel involved in the recovery operation were shown the slides and photographs of the targets which were chosen for recovery on priority basis. The method and procedure of the recovery operation was discussed in detail and finalised. Another meeting was convened on 6.10.85
to clarify the doubts and to present the picture albums containing various photographs of targets to be recovered. The mode of attaching grippers/grabbers to the targets at strong points was clarified. A serialised list of priorities was prepared based on the

mode of operation indicated by the the crew of John Cabot and Kreuzturm. Dr Ramachandran was given the authority to make on-the-spot decisions during the salvage operations.

3.2.10.9 A detail log of the activities of the ships John Cabot and Kreuzturm which started the recovery operation of 10.10.85, reveals the following :

(a) The Scarab working independently recovered the following

(1) Basket at target 192 containing copilot's chair, 2 suitcases and radar antenna (12.10.85)

(2) Target 8 - Lower fuselage skin of aft cargo compartment. (11.10.85).

(3) Target 245 - Forward belly skin just aft of radome (16.10.85).

(4) Target 350 - Economy class seats and carpet (23.10.85).

(5) Target 296 - Piece of aft pressure bulkhead.

(b) The Scarab after attaching the grippers, bridal cable and lift line to the targets buoyed off the same to Kreuzturm which recovered the following targets :

(1) Target 362/396 - Forward cargo fuselage skin from station 700 to 840 and STR 41L to 43R. (16.10.85).

(2) Target 193 - Fueselage skin from station 720 to 860 and passenger door 2L (17.10.85)

(3) Target 223 - Nose landing gear pressure deck web and stiffeners, container pieces (staion 260-340)(19.10.85).

(4) Target 181 - Wing skin with forward cargo compartment SLIPPED OFF WITH GRIPPERS (21.10.85) AND WAS LOST.

(5) Target 399/358 - Fuselage skin from station 780 to 940 and STR 7R to 35R with 2R door (25.10.85). A body entrapped in target 399/358 was recovered. Another body which came upto surface with the wreckage fell off into sea and was lost while hauling the wreckage on board. The recovered body was identified as of Dr. Mathew Alexander, a Canadian passenger and was brought to Cork by Fisherman's

vessel "Orion" at 0130 hrs. on 28.10.85 and was sent for Post Mortem etc.

(6) Target 7 - Aft cargo compartment fuselage skin from station 1480 to 1860 (26.10.85).

(7) Target 47/50 - Aft cargo floor structure with roller tracks, frames, latch etc. from station 1600 to 1760 (27.10.85).

(8) Target 117 - Three rows of coach class seats with passenger cabin floor boards, broken floor beam (28.10.85).

(9) Target 35 - Aft Pressure Bulkhead piece (30.10.85).

3.2.10.10 The Scarab experienced malfunctions with its arms, Sonar equipment, multiplex system, junction box, microprocessor unit, etc. off and on during the above period of operation. Fouling of lift line with umbilical cord was also experienced in the early stages of operation. Since the assigned recovery by Kreuzturm was over by 30.10.85, and as the Scarab became unserviceable due to breakdown of its power suppluy, the OSV MV Kreuzturm was directed to return to Cork to off-load the recovered wreckage and its operation was terminated, (Indian Government had funded the cost of operation of M.V. Kreuzturm from 21.10.85 onwards).

3.2.10.11 Since the Scrab continued to remain unserviceable, the ship John Cabot was called back to Cork. It anchored in Cork at 1100 hrs. on 5.11.85. All the wreckage on board the ship was transported to the boat yard, in the afternoon.

3.2.10.12 After detailed macro photography of the recovered wreckage, the experts group mentioned in section 1.5.16 prepared a detailed factual report after carefully inspecting each of the targets recovered. It was decided to send the wreckage to Bombay for which necessary crates were then prepared and the large pieces of wreckage were cut along the lines indicated by the experts group to facilitate their packing.

3.2.10.13 RCMP investigators carried out a close visual and microscopic examination of the fragments recovered with the wreckage, suitcases, seats and cushions, etc. For further laboratory analysis. Dr A.D. Beveridge collected a few samples.

3.2.10.14 The Scarab appeared to be serviceable on 19.11.85 and the ship John Cabot sailed for completion of recovery of left over targets, on 20.11.85. However, the serviceability of Scarab proved elusive, it became inoperable on 21.11.85 and the ship returned to Cork at 1700 hrs on 25.11.85.

3.2.10.15 Efforts were made to repair Scarab so that the ship John Cabot could sail again in order to salvage as many pieces as possible. It was fortunate that the weather had not deteriorated. Some of the important but small pieces which had to be recovered had been placed in a basket at the bottom of the ocean. The ship sailed out again after Scarab had been repared. The basket was sought to be lifted, but, unfortunately, when it reached near the surface of the sea it overturned and the contents of the basket spilled and were never traced again.

3.2.10.16 At this juncture it was decided that the salvage operations should be terminated. The ship returned and sailed for home in the first week of December 1985.

3.2.11 Examination of Wreckage

3.2.11.1 Floating Wreckage

Soon after the accident, a number of light weight parts of the aircraft were found floating over a wide area at the crash site. These were picked up by the ships engaged in rescue operations and were brought to Cork where they were kept in the boat yard. The floating wreckage recovery continued for four days i.e. upto 26th June.

3.2.11.2 Some of the wreckage items were subsequently washed to the west coast of Ireland. These were picked up by the Irish Police and were brought to Cork. Some wreckage items were taken by a ship to Halifax, Canada. These were flown to Cork by the Canadian Aviation Safety Board. With the assitance of Air India engineers, the wreckage items were identified, labelled, photographed and laid out in the boat yard hangar for examination.

3.2.11.3 The wreckage was initially examined at Cork by the Structures, Power Plant and Systems Group. It was subsequently transported to Bombay for further examination. A few wreckage items which were taken by the Spanish trawlers to Madrid were also transported to Bombay. Some wreckage items had washed to the west coast of England. These were collected by the Accident Investigation Branch of UK and were transported to Cork and then to Bombay.

3.2.11.4 The floating wreckage recovered constituted approximately 3 to 5 per cent of the aircraft structure. The major items of the wreckage recovered were :

Various leading edge skin panels of LH nd RH wing, LH wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canon fairings aft end pieces, landing gear wheel wall doors, pieces of elevator and aileron, toilet doors, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggages, suitcases etc. and three empty oxygen bottles.

3.2.11.5 The Structures Group which had been constituted by the Court examined the floating wreckage and submitted its report. From the report the following significant information about the damage to major items of the floating wreckage is noted :

(I) VT-EFO aircraft was carrying a -7Q engine on 5th pod and a -7Q 5th pod kit in the aft cargo compartment. It had therefore, in all 14 engine fan cowls (eight working engine fan cowls plus two 5th pod engine fan cowls plus two -7T engine kit fan cowls in the aft cargo compartment plus two -7Q engine fan cowls in the aft cargo compartment). Out of these 14 fan cowls, 9 cowls (6 of working engines plus 2 of -7J kit plus one of 7Q kit) and two additional pieces of fan cowls were found. Five of the fan cowls of working engines show folding damage lines at approximately 3 O'Clock and 9 O'Clock positions. The number 3 engine inboard fan cowl has severe impact damage on its leading edge and has small inward to outward puncture holes (not penetrating through outer skin) in the lower centre region. The two fan cowls of -7J 5th pod kit stowed in the aft cargo compartment exhibit severe damage. One of these cowls is broken in two pieces. One of the pieces is cut at one corner in an arc of about 20 inches diameter and its external skin is pealed back. The external surfaces of all the three pieces have considereable scratches, tears and holes from outside to inside. None of the punctures penetrates the inner skin. Some punctures are also present from inside to outside but none of these penetrates the outer skin.

(ii) Out of the 12 spoilers, seven (number 2, 3, 5, 7, 8, 9 and 12) have been retrieved. Of these, six have their actuators attached to them in fully retracted position. Six spoilers have splits in their lower skin with split edges curled into the cores of honeycomb. Number 8 spoiler (located just inboard of number 3 engine) has a concentrated local impact damage on front spar and trailing edge beam from forward to aft and up direction over a span of 2 feet starting from outboard of spoiler actuator.

(iii) The left hand wing tip assembly with a part of H F Antenna was retrieved. No burning/discolouration marks around lightning arrester of H F system were noticed. The rib inboard of the lightning arrester was found intact. There were no burn marks anywhere on the panel.

(iv) The right hand wing leading edge top panel inboard of number 3 engine with a position of kruger flap frame along with bull nose attached was recovered. The bull nose was found crushed from top in the area just below the stay rod and the lower surface of stay rod has scratch marks from front to rear.

(v) The right hand wing root leading edge (inboard of W S 268.81) shows an impact damage at the leading edge. Bottom skin and internal structure are torn away. The leading edge skin is caved in over a span of about 3 feet and shows signs of heavy body impact in air. The impact damage shows signs of downward and backward movement of the impacting body.

(vi) A 3' x 2' piece of right hand inboard trailing edge fore flap with accordian seal was recovered. The inboard 8" portion of leading edge was found damaged by impact of an object going from lower forward to upper aft.

(vii) All the floor panels recovered from upper deck and main cabin indicate that these were detached from their attachments in an upward direction from all sides.

(viii) One main deck blow out door located between B S 2040 and 2140 left hand side was available. Out of its four metal clips, one clip was broken off with 2 nylon rivet heads sheared.

(ix) The cockpit entry door and the side bulkhead panel were found fairly intact but had come out of their attachment.

(x) Twelve toilet doors, out of a total of 16, were available and were found fairly intact, but had come out of their attachments.

(xi) The available cabin interior panels and overhead bins of the main deck and upper deck have only minor damage.

(xii) The woodent boxes which contained the fan blades of 5th pod engine and were loaded in container at position 24L in the forward cargo compartment were found broken apart with no burn marks.

3.2.11.6 Wreckage Salvaged from Sea

The wreckage salvaged from the sea was visually examined at Cork by the Committee of Experts as mentioned in section 1.5.16 and the observations thereon recorded. Subsequently detailed metallurgical examination was carried out at the Bhabha Atomic Research Centre, Bombay by

Dr. M.K. Asundi and Dr. G.E. Prasad of B.A.R.C., Mr. S. Radhakrishnan and Dr. R.V. Krishnan of National Aeronautical Laboratory and Mr. B.K. Athawale of the Explosives Research and Development Laboratory, under the guidance of Dr. V. Ramachandran. During this examination, representatives of CASB, CP Air and Boeing were present in the first week. These represntatives left Bombay while the metallurgical examination was being carried out. The metallurgical examination was continued and the aforesaid group submitted the metallurgical report to the Court in December, 1985.

3.2.11.7 Although all the recovered wreckage was examined, only those items exhibiting characteristics which provide some evidence as to what may have happened to the aircraft during its final moments of flight are discussed herein below :

3.2.11.8 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from B S 1480 to 1850 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear and the torn edge was buckled in waves, like the trace of a sine wave. One the right side, between the one quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at B S 1480. The skin tear located at about B S 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distored and elongated.

3.2.11.9 This panel was examined by the committee of experts at BARC and according to their report the keel beam trunnion fitting beneath the outer chord of the station 1480 bulkhead had fractured at the aft set of bolt holes. The fracture surface of the right side of the trunnion fitting was clean. As per the report, it was typical of overload failure in tension. The fracture surface of the left side of the trunnion fitting was covered with corrosion products, especially, at one corner, due to sea water. After cleaning this area by the recommended techniques, scanning electron microscopy revealed morphology of overload fracture consisting of dimples. Away from this corner also the fracture was similar as being due to overload. There was no evidence of there having been any fatigue failure.

3.2.11.10 At B.A.R.C., a sample was cut from the corroded corner of the failed left side trunnion fitting and metallographic examination was carried out on the same. The said examination showed on a face perpendicular to the corroded fracture surface, pits due to corrosion by sea water. The basic microstructure was however free from intergranular cracking. It was thus concluded by the experts that the material in the region corroded by sea water had not suffered stress corrosion cracking which generally manifests as intergranular cracking.

3.2.11.11 A piece of the trunnion fitting was cut and the hardness and electrical conductivity values were measured by the said experts. As per their report, the electrical conductivity values were within the specified limits.

3.2.11.12 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from B S 1860 to 1960 and from stringer 46L to 46R. The forward end of target 8 matched with the aft end of Target 7. A region of fracture along the rivet holes near stringer 46L was marked for SEM examination. SEM examination after cleaning revealed that the fracture was characterised by dimples along its length, including areas adjacent to the edges of the rivet holes. These features are consistent with an overload mode of failure.

3.2.11.13 According to the metallurgical report, there was no evidence of fatigue failure on this target.

3.2.11.14 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 O'Clock position, the piece from 12 to 1 O'Clock position had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 O'Clock position the outer edge showed sinusoidal buckling, and the edge sector at 9 O'Clock position was partially collapsed and its edge was turned under. Samples taken for optical stereo microscope and SEM examination revealed that the fracture characteristics were consistent with an ovrload mode of failure.

3.2.11.15 According to the metallurgical report, there was no evidence of fatigue or any other mode of failure.

3.2.11.16 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occuped the 7 to 9 O'Clock position. Optical and SEM examination were undertaken on this item.

3.2.11.17 The fracture alont the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

3.2.11.18 Representative fracture samples were cut from the left-hand side and circumferential fracture edges of the fracture surfaces. Optial and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

3.2.11.19 Target 47 - Aft Cargo Floor Structure

This portion of the aft cargo compartment was located between B S 1600 and B S 1760. No significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

3.2.11.20 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between B S 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

3.2.11.21 In the metallurgical report it is stated that on an examination of this target it was also found that on the underside of this
floor near the forward end, a number of dents and impact marks were observed. This region appeared to have suffered shrapnel penetration. This area was radiographed but no metallic fragment was detected.

3.2.11.22 Target 193 - Fuselage Side and 2L Entry Door
The fuselage segement was located between B S 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

3.2.11.23 Target 399 - Fuselage around 2R Door
This target is shown in Fig. 399-1. A detailed description is given below :

TARGET 399 Fuselage Station 780 to 940 in the longitudinal direction and stringer 7R down
to stringer 35R circumferentially.

This piece contained five window frames, one in the 2R passenger entry door. Three of the window frames, including the door window frame, still contained window panes. Little overall deformation was found in the stringers and skin above the door. The structure did contain a significant amount of damage and fractures in the skin and stringers beneath the window level. In the area beneath the level of the windows, the original convex outward shape of the surface had been deformed into an inward concave shape. Further inward concavity was found in the skin between many of the stringers below stringer 28R. The skin at the forward edge of the piece was folded outward and back between stringers 25R and 30R. Over most of the remaining edges of the piece a relatively small amount of overall deformation was noted in the skin adjacent to the edge separations. Twelve holes or damage areas were numbered and are further described.

No.1 : Hole, 5 inches by 9 inches with two large flaps and one smaller curl, all folded outward. Reversing slant fractures, small area missing.

No.2 : Hole, 2 inches by 3/4 inch, one flap folded outward, reversing slant fractures, one curled sliver, no missing metal.

No.3 : Triangular shaped hole about 2 inches on each side. One flap, folding inward, with one area with a serrated edge. No missing metal, extensive cracking away from corners of the hole, reversing slant fracture.

No.4 : Tear area, 8 inches overall, with deformation inward in the centre of the area. Reversing slant fracture.

No.5 : Fracture area with two legs measuring 14 inches and about 24 inches. Small triangular shaped piece missing from a position slightly above stringer 27R. Inward fold noted near the joint of the legs. An area of 45° scuff marks extend onto this fold.

No.6 : Hole about 2.5 inches by 3 inches with a flap folded outward, reversing slant fracture. Approximately half the metal from the hole is missing.

No.7 : Hole about 3 inches by 1 inch, all metal from the hole is missing. Fracture edges are deformed outward.

No.8 : Forward edge of the skin is deformed into an "S" shaped flap. Three inward curls noted on an edge.

No.9 : Inwardly deformed flap of metal between stringers 11R and 12R at a frame splice separation. No evidence of an impact on the outside surface.

No.10 : Door lower sill fractured and deformed downward at the aft edge of the door.

No.11 : Frame 860 missing above stringer 14R. Upper auxilliary

frame of the door has its inner chord and web missing at station 860. A 10 inch piece of stringer 12R is missing aft of station 860.
No.12 : Attached piece of floor panel (beneath door) has one half of a seat track attached. The floor panel is perforated and the lower surface skin is torn.

3.2.11.24 Much of the damage on this target was on the skin and stringers beneath the window level, i.e., on the starboard side of the front cargo hold. The inside and outside surface of the skin in this region are shown in Fig. 399-2 and 399-3 respectively. There were 12 holes or damaged areas on the skin as described above, generally with petals bending outwards. The curl on a flap around hole no.1 shown in Figh 399-4 has one full turn.
This curl is in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.

3.2.11.25 When this target was recovered from the sea, along with it came a large number, a few hundreds, of tiny fragments and medium size pieces, All of the fragmets were recovered from the area below the passenger entry door 2R. One of the medium size pieces recovered with this target was a floor stantion, about 35 inches long, shown in Fig. 399-5. It is a square tube. It had the mark station 880 painted on its inner face, i.e. facing the centre line of the cargo hold. The part number printed on this station is 69B06115 12 and the assembly number is ASSY 65B06115-942 E3664 1/31/78*. It was confirmed that this stantion belongs to the starboard side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the station. Fig. 399-6 is a print from the radiograph of this station. The inward curling can be seen clearly in this figure. Curling of the metal in this manner is a shock wave effect.

3.2.11.26 A piece near the fracture edge of this stantion was cut, and examined metallographically. Fig. 399-7 and 399-8 show the micro-structure of this piece. Twins are seen in the grains close to the fracture edge. The normal microstructure of the stantion material is free from twins as shown in Fig. 399-9.

3.2.11.27 Fig. 399-10 shows a collection of small fragments recovered along with target 399. There were some curved fragments with small radius of curvature (A). Reverse slant fracture (B) was noticed in some of the skin pieces. A piece 3/4" x 1/2" and 3/16" thick was found to have three blunt spikes at the edge (C). This piece was metallographicaly polished on the longitudinal edge. The microstructre of the piece is shown in Fig. 399-11. It may be seen that the grains in this fragment also contain a large number of twins.

3.2.11.28 Target 362/396 Forward Cargo Skin

This piece indluded the station 815 electronic access door, portions of seven longitudinal stringers to the left of bottom centre and five longitudinal stringers to the right of bottom centre. The original shape of the piece (convex in the circumferential direction) had been deformed to a concave inward overall shape. Multiple separations were found in the skin as well as in the underlying stringers. Further inward concavity was found in the skin between most of the stringers.

3.2.11.29 The two sides of this piece are shown in Fig. 362-1 and 362-2. This piece has 25 holes or damaged areas in most of which there are multiple petals curling outwards. These holes are numbered 1 to 3, 4a, 4b, 4c and 5 to 23. These are described below. Unless otherwise noted, holes did not have any material missing :

No.1 : Hole with a large flap of skin, reversing slant fracture.

No.2 : Hole with multiple curls, reverse slant fracture.

No.3 : Hole with multiple flaps and curls, reversing slant fracture, one area of spikes (ragged sawtooth)

No.4A : One large flap, reverse slant fracture, one area of spikes.
No.4B : Hole with two flaps.
No.4C : Hole with two flaps, one area of spikes
No.5 : HOle with two flaps.
No.6 : Braching tear from the left side of the piece, reversing slant fracture.
No.7 : Hole, with one flap, one curl and one area of spikes.
No.8 : Very large tear from the left side of the piece with multiple flaps and curls, reversing slant fracture and at least two areas of spikes.
No.9 : Hole with multiple flaps, one curl.
No. 10 : 2.5 inch tear
No.11 : One flap
No. 12 : Grip hole, plus a curl with spikes on both sides of the curl.
No.13 : "U" shaped notch with gouge marks in the inboard/ outboard direction. Three curls are nearby with one are of spikes. Gouges found on a nearby stringer and on a nearby flap.
No. 14 : Nearly circular hole, 0.3 inch to 0.4 inch in diameter. Small metal lipping on outside surface of the skin. Most of the metal from the hole is missing.
No. 15 : Hole in the skin beneath the first stringer to the left of centre bottom. Small piece missing.
No. 16 : Hole in the stringer above hole No. 15. Most of the metal from this hole is missing.
No. 17 : Hole through the second stringer to the left of centre bottom, 0.4 inch in diameter. The hole encompassed a rivet which attached the stringer to the outer skin. Small pieces of metal missing.
No. 18 : Hole at the aft end of the piece between the third and fourth stringers to the left of centre bottom. The hole consisted of a circular portion (0.4 inch diameter), plus a folded lip extending away from the hole. The metal from the circular area was

missing.
No. 19 : Hole with metal folded from the outside to the inside, about 0.6 inch by 1.5 inch. Flap adjacent to the hole contained a heavy gouge mark on the outside surface of the skin.
No. 20 : Hole containing a piece of extruded angle.
No. 21 : Hole containing a piece of extruded angle.
No. 22 : Hole with one flap.
No. 23 : Hole about 0.3 inch in diameter, with tears away from the hole. Small piece missing.

3.2.11.30 Fig. 362-3 to 362-7 show a few of these holes. There were also cracks or tears around some of the holes. The curls around some of the holes had nearly one full turn. In the large tear between body stations 700 and 740 and stringers between 41L and 45L, there were many pronounced curls as shown in Fig. 362-8. On the edges of the petals around several holes, reverse slant fracture was seen at a number of places. This slant fracture is at an angle of about 45° to the skin surface, the fracture continuing in the same general direction but with the slope of the slant fracture reversing frequently.

3.2.11.31 Sharp spikes were observed at the edges of the holes or at the edges of the petals around the holes No. 3, 4A, 4C, 7, 8 (at two locations), 12, 13 and 16. Some of the spikes are shown in Fig. 362-9 to 362-12. One of the holes, No. 14, on the skin was nearly elliptical with metal completely missing, as shown in Fig. 362-13. On the inside surface of the skin, paint surrounding this hole was missing. Hole No. 16 was through the hat section stringer, as shown in Fig. 362-14. In this, most of the metal was missing. On the inside of the hat section, the fracture edge of this hole had spikes, as shown in Fig. 362-15. Hole No. 17 was through the stringer and the skin, as shown in 362-16.

3.2.11.32 Through holes No. 20 and 21, extruded angles were found stuck inside, as shown in Fig. 362-17 and 362-18 respectively. In the petal around hole No. 20, there was an impact mark by hit from the angle as seen in Fig. 362-19 photographed after removing the angle. Such a mark was not present in the petals around other holes.

3.2.11.33 On the skin adjacent to hole No. 13 gouge marks were noticed, Fig. 362-20. These marks were on the inside surface of the skin. To check whether these could be due to rubbing by the bridal cable of Scarab during the recovery operations, a sample of bridal cable was obtained from "John Cabot" and gouge marks were produced by pressing this cable against an aluminium sheet. The gouge marks thus produced, as shown in Fig. 362-21, appear to be different from those observed near hole No. 13.

3.2.11.34 A piece surrounding hole No. 14 was cut out and examined in a Jeol 840 scanning electron microscope at the Naval Chemical and Metallurgical Laboratory, Bombay. Fig. 362-22 and 362-23 are the scanning electron micrographs showing the inside surface and outside surface of the skin around this hole. Flow of metal from inside to outside can be seen from these figures. Energy dispersive x-ray analysis was carried out on the edges of this hole. Only the elements present in this alloy and sea water residue were detected.

3.2.11.35 A portion of the skin containing part of hole No. 14 was cut, polished on the thickness side of the skin and examined in a metallurgical microscope. Fig. 362-24 shows the microstructure of this region. The flow of metal along the edge of the hole can be seen from the shape of the deformed grains near the hole. This can be compared with the bulk of the grains shown in Fig. 362-25, away from the hole. In addition, in Fig. 362-24, a series of twin bands can be seen in some of the grains near the hole. Fig. 362-26 shows these bands at a higher magnification. Normal deformation rates at various temperatures do not produce such twinning in aluminium or its alloys. It may be noted that this microstructural feature is absent in the microstructure of the skin, away from hole No. 14, Fig. 362-25.

3.2.11.36 Metallography was also carried out on a petal around hole No.7 and on a curl with spikes around hole No. 12. The microstructures indicate twins, however they could not be recorded due to their poor contrast.

3.2.11.37 Small pieces containing the spikes around holes No. 12 and 16 were cut and energy dispersive x-ray chemical analysis on the region of spikes in both was carried out in the Jeol 840 SEM. Only elements present in the alloys and sea water residue were detected.

3.2.11.38 A number of small fragments were found along with the forward cargo skin in target 362. Amongst them was a piece from the web of a roller tray. This has pronounced curling of the edges towards the drive wheel, Fig. 362-27.

3.2.11.39 Another small fragment was found from the above target. This piece, identified as specimen No. 12 in box No. 1, target 362, has a number of spikes along the edge. A scanning electron micrograph of the spikes is shown in Fig. 362-28. The sides of the spikes on SEM examination revealed elongated dimples as shown in Fig. 362-29, characteristic of shear mode of fracture. Metallography was carried out on the thickness side of this specimen. Fig. 362-30 and 362-31 show the microstructure near the apex of the spike and at the root of the spike respectively. Extensive twinning can be seen in these regions of the spikes.

3.2.11.40 Another fragment recovered with target 362 and identified as specimen No. 8 in box No. 1, also showed extensive twinning. The microstructure is recorded in Fig. 362-32.

3.2.11.41 Reference has also to be made to two other reports concerning wreckage.

3.2.11.42 The floating wreckage recovered was initially examined at Cork. On 25th June, Mr. Eric Newton a retired investigator of AIB, UK, was requested to examine the floating wreckage recovered and other materials with specific reference to the possibility of explosive sabotage having taken place. Mr. Newton examined the floating wreckage, passenger clothings and the other materials recovered from the crash victims The findings of Mr. Newton on the material available at that time are summarised below:

a. Taking the scatter of the wreckage and bodies into consideration and the condition of the limited wreckage recovered indicates that the aircraft had broken up in flight before impact with the sea.

b. Detailed examination of the structural wreckage recovered did not reveal any evidence of collision with another aircraft. Nothing was found suggestive of an external missile attack.

c. There was no evidence of fire internal or external.

d. There was no evidence of lightning strike.

e. Examination of all available structural parts recovered, did not reveal any evidence of significant corrosion, metal fatigue or other material defects. All fractures and failures were consistent with overstressing material and crash impact forces

f. Examination of clothing from the bodies did not show any explosive fractures or any signs of burning. The seat cushions and head cushions also did not show any explosive characteristics.

g. The damage to the suitcases (14 large and 29 small) which were examined was due to impact crash forces. The presence of 14 large suitcases could, however, indicate that one of the baggage containers had been broken to permit these suitcases to escape.

h. A number of lavatory doors and structure also did not show any damage consistent with explosion. The flight deck door showed no explosion damage inside or outside.

i The circumstatnial evidence strongly suggests a sudden and unexpected disaster occurred in flight.

j. There was no significant fire or explosion in the flight deck, first and tourist passenger cabin including several lavatories and the rear bulk cargo hold.

3.2.11.43 The other report dated 30th November, 1985 is of Mr. V.J. Clancy. Mr. Clancey had examined the wreckage and had also taken part, though only for a few days, in the metallurgical examination which was being conducted at BARC, Bombay.

3.2.11.44 Mr. Clancey examined practically all the items of wreckage which had been brought to BARC and in his report he has dealt with all of them. His report contained a description of the recovered items and also his comments thereon.

3.2.11.45 With regard to the aforesaid target 362, he observed that there were about 20 holes in it clearly resulting from penetrations from inside.

3.2.11.46 He further stated that:

"In addition to the fact that perforation was from inside there are certain features which suggest that they were made by high velocity fragments such as are produced by an explosion. These features are:

(a) Presence of toothed or spiked edges at some parts of the metal which had petalled out from the perforations.

"Tardif and Sterling (Canadian Aeronautics and Space Journal, 1969, 16, 1, 19-27) obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.

(b) Presence of marked curling, in some cases of more than 360°, of some of the petals.

Tradif and Sterling stated that such curling was a feature of explosively produced fragments.

(c) The virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal.

(d) The virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object. This suggested that the production of at least many of the perforations were separate independent events.
(e) One perforation (identified as No. 14) resembles a "bullet hole", that is cleanly punched out - a type of hole usually associated with a high velocity missile.
"There is evidence that the forward part of this item had been folded back inwards along the line of station 760 and then bent back again along a line slightly forward of this station.
"Such folding, may be violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.
"One hole identified as No. 13, was almost certainly caused by a slipping wire rope used as a sling.
"Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken by me of this area
and are being examined by R.A.R.D.E. for evidence of fire or explosives".
3.2.11.47 There were several hundred small fragments which were recovered from the same general area as Target 362. While dealing with these Mr. Clancey observed that the production of a large number of small fragments is generally regarded as indicative of an explosion. One piece out of this was isolated, which was about one inch square of sheet alloy, and it was noted by Mr. Clancey that this piece had characteristic spikes on one edge similar to those described by Tardif and Sterling. (This piece is the same as shown in Fig. 362-28).
3.2.11.48 Mr. Clancey also examined a few suit cases which

had been recovered. One particular suit case to which reference was made by him was of red plastic material with blue lining. With regard to this he stated that the damaged lining, severely tattered, resembles that of one found after an explosion in an aircraft in Angola. In that case microscopic examination showed definite evidence of damage by an explosion.

3.2.11.49 The later part of the report of Mr. Clancey contained his opinion. With regard to Target 362 his opinion was as follows:

"The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

"Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

"A more detailed study, metallurgical and fractographic, is required.

"The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

"The single "bullet hole", No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

"If the forward part of this item was forcefully and rapidly folded back to impact on the other part it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility".

3.2.11.50 The opinion of Mr. Clancey about the small fragments was as follows:

"The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.

"The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

3.2.11.51 It appeared to the Court that the report of Mr. Clancey required certain clarifications. It was suggested to Boeing Commercial Airplane Company by the Court that Mr. Clancey should appear as a witness. The Court received a message to the effect that Mr. Clancey felt that he could not add anything useful to his report.

3.2.11.52 A close examination of the report of Mr. Clancey shows that the opinion expressed by him in the later part of the report is at considerable variance with the observations contained in the earlier part of the report. Particularly with regard to Target 362 and the small fragments, Mr. Clancey has stated in his observations that there was strong evidence of explosion. In his opinion, however, he has stated that more detailed study is required. It is interesting to note that though Mr. Clancey has referred to the opinion of Tardif and Sterling, he has not chosen to contradict the conclusions arrived by them. Mr. Clancey has also not stated as to what could possibly have caused the special features which were noted on Target 362.

3.2.11.53 We find the metallurgical report inspires more confidence. Not only is reference and reliance made in the report to other expert opinions contained in various articles written by experts all over the world, certain explosion experiments were also carried out by the experts which led them to the same conclusion.

3.2.11.54 The particulars of the experiments so carried out and the results obtained therefrom have been stated in their report as follows:

EXPLOSION EXPERIMENTS

"To determine the damage by high velocity fragments or shock waves on a structure similar to the one in aircraft cargo hold, the following experiments were conducted on November 30 and December 1, 1985 at the Explosives Research and Development Laboratory, Pune, using plastic explosive (PEKI) and different mixtures of plastic explosive and TNT. The explosive was kept in a box made of sheet metal of 6" x 6" x 6" of 1/16" thickness. This box was kept inside another box made of sheet metal 2' x 2' x 2' of .04 or .06" thickness. The boxes were made of 2024 aluminium alloy sheets used for aircraft skin. To the inner surface of the outer box, hat section stringers similar to those used in the aircraft were riveted. The quantity of explosive used in the inner box was varied from 60 g to 100 g. The explosive was detonated with an electrical detonator. After the explosions the fragments and the panels were collected and examined.

"Experiments were also conducted to produce explosive damage on skin panels, individual hat section stringers and individual stantion tubes. In the case of stantion tubes experiments were carried out placing the explosive charge both inside and outside. The quantity of explosive used was varied from 5 g to 50 g.

"Various types of damages were recorded on all the targets. These include punched holes, petaling and curling around holes, spikes at fracture edges, curved fragments with small radius of curvature and reverse slant fracture. Fig. EXP-1 shows a collection of fragments. The features mentioned above are shown in Fig. EXP-2 to EXP-7. It may be noticed that the features produced by experimental explosion were similar to the features observed largely in target 362 of the wreckage. The small fragments had features similar to those in the fragments from targets 362 and 399.

"Metallography was carried out in (a) a specimen surrounding a punched hole in the skin (b) a specimen surrounding a hole in the stringer, (c) a curl in the stantion and (d) spikes in a fragment. In all these cases, the grains adjacent to the area of explosive damage are having twins. Two typical microstructures are shown in Fig. EXP-8 and EXP-9. Away from these areas the microstructure is normal. Thus it is confirmed that twinning in the microstructure of these structural members is a unique feature of explosive fracture, not produced by any other measns known so far."

3.2.11.55 The findings in the said metallurgical report are also strengthened by the observations of Eric Newton in the article "Investigating Explosive Sabotage in Aircraft" published in the International Journal of Aviation Safety, March 1985, p. 43. Mr. Newton is an acknowledged authority in the detection of explosive sabotage in aircraft. The conclusions contained in the article are based on his review of incidents of explosion between 1946 and 1984 which were known to him. Some of the conclusions arrived at by him which were relevant in the present case are when he states "Generally speaking, the smaller the fragment, higher the velocity of the detonation. Minute fragmentation is indicative of high explosive having been used, and provides clues to the focal point or region of the explosion. The mode of break up of the aircraft itself and its sequence of failure is usually very complicated and quite without the logic dictated by normal aerodynamic overstressing".

3.2.11.56 Mr. Newton has also observed that curling, cork-screwing, and saw tooth edges may also be indicative of an explosion though such fractures by themselves may not be conclusive evidence that an explosion was involved. Firmer

evidence, according to him, was of fusing
of metal, scorching, pitting and blast effect. He further states that "Perhaps the most conclusive material evidence to be found on metal specimens is cratering, very often in groups, often minute and numerous".

3.2.11.57 Mr. Newton also refers to the positive explosive signatures which remain on a detonation in an aircraft. These positive singatures, according to him, are as follows:

"(a) The formation of distinctive surface effects such as pitting or very small craters formed in metal surfaces, caused by extremely high velocity impacts from small particles of explosive material. Such craters, when viewed under the microscope, have raised and rolled over edges and often have explosive residue in the bottom of the crater.

"(b) Small fragments of metal, some less than 1 mm in diameter, which, under the scanning electron microscope, reveal features such as rolled edges, hot gas washing (orange peel effect, surface melting and pitting and general evidence of heat; such features have been proved and observed following explosive experiments with known explosives). Supporting strong evidence would be if such fragments (normally found embedded in structures, furnishing or suitcases) were found embedded in a body where evidence of burning of tissue is present at the puncture entry and where the fragment came to rest.

"(c) As well as surface effects on metal fragments produced by explosives there are deformation mechanisms which are peculiar to high rates of strain at normal temperature. At normal rates of strain metals deform by usual mechanism associated with dislocation movement. However, because this process in an explosion is thermally activated at very high rates of strain, there is insufficient time for the normal process to occur. In some metals such as copper, iron and steel, deformation in the crystals of the metal takes place by 'twinning', that is to say by parallel

lines or cracks cutting across the crystal. Such a phenomenon can occur only if the specimen has been subjected to extreme shock wave loading at velocities in the order of 8000 m/sec. Such specimens, usually distorted must be selected with care, prepared in a metallurgical laboratory, polished, mounted
and microscopically examined. Where such twinning of the crystals is found it establishes (a) that the specimen was close to the seat of the explosion and (b) that a military type explosive had been used with a detonating velocity of 8000 m/sec or more. Twinning is rarely produced when shock impact loadings are below 8000 m/sec.

"The above features, singly or combined, are considered to be proof positive evidence of a detonation of a high explosive; they could not be produced in any other way."

3.2.11.58 The metallurgical report indicates that the microscopic examination (conducted by them) discloses such features being present which had been described as positive signatures of the detonation of an explosive device in an aircraft by Mr. Newton. Furthermore, twinning effect has also been noticed at a number of places - around holes and in fragments. These have been categorised by Mr. Newton as positive signature of an explosion.

3.2.11.59 In the primary zone of explosion, metallic structures disintegrate into numerous tiny fragments and usually these fragments contain the above mentioned distinct signatures of explosion. In the present case the explosive damage had occurred at an altitude of 31000 feet when the aircraft was flying over the ocean. The fragments that formed due to explosion must have been scattered over a wide area and it is impossible to locate and recover all of them from the ocean bed. Nevertheless, some of the fragments which were recovered along with the targets 362 and 399 do contain signatures of explosive fracture.

3.2.11.60 From the aforesaid discussion it would, therefore, be safe to conclude that the examination of targets 362 and 399 clearly reveals that there had been a detonation of an explosive device on the Kanishka aircraft and that detonation has taken place not too far away from where these targets had been located.

FIRE

3.3.1 There is no evidence that there was any fire on board the aircraft before it met with the accident.

3.3.2 Amongst the floating wreckage, however, was found, what was later on identified as, a spares equipment box belonging to this aircraft. This box was charred on one side and partially on the bottom. The depth of charring suggested that the burning time was three to four minutes. This box contained some sand and small shellfish. The flesh from the shelfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

FLIGHT RECORDERS

3.4.1 Recovery of Flight Recorders

3.4.1.1 Recovery of the flight recorders was a very difficult and challenging job. At the site of accident, depth of water is about 6700 feet. The job involved fixing the location of recorders and then retrieving them. For this purpose three ships viz. Guardline Locator (a ship provided by Accident Investigation Branch of U.K.), Le Aoife (an Irish Naval Ship) and Leon Thevenin (a French Cable laying ship, charterd by the Government of India) were utilised. Guardline Locator and Le Aoife were solely for fixing the positions of recorders and also had the capability to lift the recorders with the help of its scarab.

3.4.1.2 Both the Cockpit Voice Recorder and the Digital Flight Data Recorder were fitted with Dukane Underwater Acoustic Beacons (Pingers) which enabled establishing the location of flight recorders under water. The Beacons are designed to provide a signal at 37.5 ñ 1 Khz frequency that can be heard for approximately 2 miles in any direction for 30 days after water entry. Its high strength case permits operation in water depth to 20,000 feet. Its pulse repetition rate is not less than 0.9 pulse per second.

3.4.1.3 On 4th July, 1985, Guardline Locator reported strong possibility of two separate sound sources of frequencies between 39 KHz and 42 KHz. On 5th July, Guardline Locator gave coordinates of an area, which it believed contained the pinger. Guardline Locator later reported that using a Dukane Hand Locator, it had located pinger (2) at 5102.6N, 1248.6W. Leon Thevenin then concentrated its search in this area for retrieving the recorders.

3.4.1.4 In response to a query, Messrs Dukane Corporation advised that Pinger transducer is made of ceramic and if cracked during impact, its frequency could be elevated. The pulse rate should, however, be uneffected. Keeping this in mind, the Leon Thevenin increased its Sonar Band one upper frequency limit from 40 KHz to 45 KHz.

3.4.1.5 On 9th July at about 2300 hours the Scarab of Leon Thevenin located the Cockpit Voice Recorder at 5102.67N, 1248.93W and the recorder was brought on the deck at 0747 hrs on 10th July. The CVR was kept in a drum filled with water. The scarab was again lowered on 10th July in the same area and at about 2130 hours faint signals were picked up on Sonar. By about 2200 hours the signals became louder and the pulse rate frequency was calculated to be 72 transmissions per minute. At about 2230 hours the DFDR was also located at 5103.10N, 1249.59W and it was brought on deck at 0245 Z on 11th July.

3.4.1.6 The DFDR was also placed alongside the CVR in the drum filled with water. Leon Thevenin was then advised to return to Cork with the Flight Recorders. Leon Thevenin reached Cork on the morning of 12th July and the flight recorders were placed in two specially fabricated water tight steel containers filled with water. The recorders were then carried to Bombay on the same day by Mr. Satendra Singh, Reginal Controller of Air Safety, Bombay, accompanied by Mr. Vishwanath of Air India for preparing read-outs and transcript of the recorders. Necessary precautions were taken to ensure that the data recorded was not affected during transportation to Bombay.

3.4.1.7 Both the recorders reached Bombay on the morning of 13th July and were kept in the office of the Regional Controller of Air Safety under Armed Police Guard.

3.4.2 Description of Flight Recorders

3.4.2.1 Kanishka was equipped with a Fairchild A-100 Cockpit Voice Recorder Serial No. 5809 and a Lockheed 209E Digital Flight Data Recorder Serial No. 1282. These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the rear pressure bulkhead.

3.4.2.2 The CVR records all crew communications and sounds in the cockpit on a continuous tape loop which has a tape speed of 1-7/8 inches per second. The Recorder has two heads, one head which erases the previous recording and the second which records the current information and thus the last 30 minutes of recorded signals are retained, the previous being automatically erased. It continuously records convervations/sounds from 4 different sources on the following four separate channels:

Channel 1 : Radio channel of pilot

Channel 2 : Radio channel of flight engineer

Channel 3 : Cockpit Area Mike

Channel 4: Radio channel of co-pilot.

3.4.2.3 The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor. Adjacent to this unit was a Lockheed Model 280 Quick Access Recorder that recorded the same serial digital signals on to a 50 hour cassette.

3.4.2.4 The DFDR records 52 basic parameters on a magnetic tape. The tape preserves records of the last 25 hours. The serial digital signal has a bit rate of 768 bits per second and is recorded at a tape speed of 0.37 inches per second.

3.4.3 Examination of Flight Recorders and Tapes

3.4.3.1 General

The recorders brought to Bombay from Cork were opened on 16th July, 1985 at the Air India's Facilities in Bombay in the presence of the Court and Assessors. A team of foreign experts including one each representatives from both the Recorder Manufacturers, three from National Transportation Safety Board, one from Canadian Aviation Safety Board and one from NRC Flight Recorder Playback Centre, Canada were present when the tapes were taken out of the recorders. Apart from them, representatives of the Government of India and Air India were also present.

3.4.3.2 Cockpit Voice Recorder

When the unit was removed from its shipping and storage container, some mechanical damage was immediately evident. The top of the cover had been deformed inwards, probably due to initial external

strong attachments for the horizontally mounted Underwater Acoustic Beacon. The plate had torn away from the light structure behind it. The cause of the damage was not obvious. The light outer cover was removed by cutting it open with hand shears and pliers.

3.4.3.3 When the armoured and insulated containment was opened, the tape transport was found to be in relatively good condition and the tape physically undamaged. Eighteen inches of the tape was pulled from the centre of the tape stack and the tape cut near the stack well clear of the end of recording. The tape was then removed from the recorder, transferred to standard tape reels, laboriously cleaned several times with distilled water and dried with lint free absorbent material.

3.4.3.4 Digital Flight Data Recorder
When the recorder was removed from its shipping and storage container, it was noted that there was very little external damage. A cover on the rear section was removed and it was observed that, when viewed from the front of the recorder, the right hand edges of the four rearmost printed circuit cards were displaced towards the front of the recorder. The left hand edges were restrained by plug-in connectors to the boards. The rearmost card, that controls track selection on the tape, and the one in front of it, had bowed along the right-hand edges and popped out of their plastic guides in the top and bottom of the recorder. Deflection of the other two cards had occurred following failure of the attachments of the right hand ends of the plastic guides to the chassis. The damage could have been caused by a high lontitudinal decelaration, as would occur if the front face of the recorder impacted the water.

3.4.3.5 When the tape deck was opened, it was found that the tape was intact but had become dislodged from the last tape guide when the tape was moving in the direction of the odd-numbered tracks and had also jumped out of the adjacent end-of-tape sensor. One edge of the tape had been streteched in this area. The drive belt to the tape transport was still in its correct position. The tape was stuck to the third tape guide in the odd-numbered track direction and suffered some damage when it was finally detached from it. This was repeaired with a splicing tape.

3.4.3.6 The location of the record heads was marked on the back of the tape with a waterproof felt pen. It was noted that there was slightly more tape on the supply reel for the odd tracks than on the other reel. The tape reels and tape were removed from the recorder, keeping the tape wet with distilled water, and the tape transferred to the standard reels for meticulous cleaning. During the cleaning process, it was found that the edge of the tape had also been stretched locally 336 inches down- stream from the splice repair in the odd track direction. The tape was dried by patting it with absorbent lint-free material before loading it into a serviceable recorder as this was the only means by which it could be replayed at the Air India base.

3.4.3.7 The circuit card controlling track selection was removed from the accident recorder and the status of the latching relays checked to determine the last track on which recording was being made. It was found that the relay states indicated Track 1, but since this requires all relays to be set in the same condition, it was considered possible that they had been mechanically set on water impact. The card was subsequently inserted to another recorder and the Track 1 setting confirmed on a test bench.

3.4.3.8 When a change in track selection was attempted, it was found that the relays would not switch, probably due to the effects of salt water corrosion or high water pressure. It was decided that Track 1 would be considered as the most likely one to contain the accident data with the possibility that it could have occurred on any of the other tracks. When the data was recored, the accident information was found some distance past the mid-point of Track 1.

3.4.4. Recovery of Information

3.4.4.1 Cockpit Voice Recorder Tape

The spool was removed from the CVR and was washed with distilled water, dried and loaded on to another spool. The cleaned and dried tape was taken to the Bhabha Atomic Research Centre (BARC), and a copy

of the tape was prepared which was used for preparing transcript and carrying out further analysis. The transcript of the CVR conversation is given in Appendix 2.

3.4.4.2 Shannon Air Traffic Control Tape

A copy of this tape that contains all radio communications between the aircraft and Shannon was provided to the Indian

Authorities by the Air Traffic Control Authorities, Shannon. The recording also included the short series of unusual sounds that occurred about the time of the accident.

3.4.4.3 When the CVR and the ATC tapes were played it was found that some adjustment in speed was necessary so as to synchronize the two. This adjustment was independently carried out by different experts who analysed the CVR tapes.

3.4.4.4 Digitial Flight Data Recorder Tape

The Lockheed representative had brought a Lockheed Model 235 Copy Recorder from his plant. This unit copies all the 25 hours of data from the recorder by running it at high speed for only two passes of the tape, an operation lasting only 16 minutes. A copy tape was made by this procedure before embarking on the standard Air India recovery procedure to serve as a back-up tape in the event of physical damage to the original tape in subsequent playback.

3.4.4.5 Air India playback equipment for the DFDR required that the tape be re-installed in another DFDR in which it was driven at high speed. In the standard playback procedure, the tape was first run to the beginning of Track 1 through 6 sequentially on to a computer tape followed by a repeat of Track 1. The computer tape was then taken to Air India's main computing facility where selected information was printed out in engineering units.

3.4.4.6 The first printouts showed that the accident was recorded on Track 1, as indicated by the latching relays, and suggested a rather abrupt end to the recording. There was a loss in bit synchronization in word 26 of the last Subframe 3 of data that was followed by a normal Subframe 4. Prior to the loss in bit synchronization, all measurements appeared normal. Plans were made to borrow the high speed oscillograph recorder previously used to studythe final CVR signals from BARC to examine the end of the recorded serial digital signal in detail.

3.4.4.7 Meanwhile, the critical section of the tape and the heads of the playback recorder were re-cleaned and a second transfer of data on to the computer tape was made. Printouts from this computer tape showed no significant difference from the first one.

3.4.4.8 The recorder was then opened and the tape positioned about 1.5 inches before the final resting place of the tape that was clearly indicated by head imprints on the magnetic oxide coating side. A high speed oscillograph record of a few seconds of data was made and visually decoded. It was found that the recorded GMT was 21 hr 16 min. This time corresponded to 15 min or about 333 inches of the tape after start of the oldest recording downstream of the accident.

3.4.4.9 The tape was then re-positioned using a Lockheed analogue playback unit, that had a display of the recorded time and a stopwatch was used to locate the accident timing. Two oscillograph copies of the end of the serial digital data were made, the second one having more data preceding the end. Visual reading of the traces confirmed that recording became erratic and irrecoverable at the end of Word 26 in Subframe 3 at the recorded time of 07 h : 14m : 35s. The erratic signal continued for about 0.27 inches of the tape before switching back to the data recorded 25 hours earlier.

3.4.4.10 Examination of the printouts confirmed a suspicion that the complete Subframe 4 of data following the partial Subframe 3, was data from 32 seconds earlier that had not been cleared from the data buffer in the computer and that Word 26 of the Subframe 3 was the last normal measurement provided by the recorder.

3.4.4.11 The end of recording occurred at the point on the tape at which some damage had been observed during the cleaning process. It was apparent that, after the end of the recording, the tape had run on for 336 inches before finally coming to rest.

3.4.4.12 A copy tape of the DFDR tape was made at Bombay and taken to Ottawa. Data from the accident flight, the preceeding Toronto-to-Montreal flight and part of the cruise conditions of the earlier flight to Toronto were transcribed on to the computer tape. The tape was edited to minimize errors and converted to engineering units using standards calibration. Time histories of all parameters for periods of interest were plotted. In addition, chart records were made of all parameters in raw data form for the total duration of the last lap of the flight.

3.4.4.13 The DFDR read out shows that the aircraft was cruising at an altitude of 31,000 ft. and a computed air speed of 296 knots till it suddently stopped recording at 07:14:35 GMT recorded time.

3.4.5 Reports received by the Court

3.4.5.1 The CVR was taken to B.A.R.C. This tape was played by the CVR group a number of times and hard copies of the time information were also prepared using an ultra violet (UV) Recorder. The group consisted of Mr. Satendra Singh, Regional Controller of Air Safety of D.G.C.A., Mr. S.N. Seshadri of BARC, Mr. Paul C. Turner of NTSB, USA, Mr. John G. Young of NTSB, USA and Mr. P. dE Niverville of CASB, Canada. On 18th July, 1985 this group made the following observations after playing the aforesaid tape (UV recording of CVR is at Fig. 1) :-

"The first visible rising signal volume was observed on channel number three the CAM channel It reaches a maximum in about 50 milliseconds. At this time noticeable disturbances are observable on the other three channels. A smaller disturbance is observable on channels 2 and 4 earlier than observable on channel 1. A major disturbance is observed to begin approx. ninety milliseconds following the initial observation on channel number 3 (CAM), on channels 1,2 and 4. Following this point at 75 milliseconds the CAM signal subsides to a lower level but much higher than observed ambient (prior to disturbance) where it remains for approximately 375 milliseconds from initiation when it ceases. Channel four goes off at the same time. Channel 1 goes off twenty five milliseconds earlier. Channel two is inconclusive and had a different pattern. All four channels exhibit a disturbance at approx. 450 milliseconds. The cockpit voice recorder power then shuts off at 650 milliseconds.

The Shannon area control centre tape made the night of the accident was examined and printed. It shows a signal was received at approximately the time the aircraft disappeared from radar. It isn't conclusive at this time that the signal originated from the accident aircraft. The signal was received in pulses for approximately five seconds."

3.4.5.2 The tape was again played on 19th July, 1985 and a further report was prepared which was signed by the aforesaid persons and Mr. B. Caiger of NRC, Canada. In this report it was stated as follows:-

"The Shannon area control centre tape was again printed at .05"/ second per inch speed from approximately 22 sec. before the first broadcast from the accident aircraft at 0709.58 until Radio carrier with indecipherable modulation can be heard at 0714:01. The print contains a time encoded signal.

A similar print was made from the CVR channel 4 (Co-Pilot's) of the same audio as received on the ATC tape. Although the tape speed is different, the events when corrected for tape speed errors occur at the same time. It appears that the ATC recording contains the beginning of the aircraft breaking until power is lost to the transmitter since channel one and channel four (Capt + Co-pilot's radio) appear to contain a transmitted signal on the CVR. It is probable that the ATC signal at 0714:01 coincides with the final quarter second of CVR radio channels".

3.4.5.3 On the date i.e. 19th July, 1985, Mr. Paul Turner of NTSB also gave an additional report which is to the following effect :-

"During my observations of numerous cockpit voice recorders I have heard and observed a number of aircraft breakages due to various causes. In this case the explosive sound on the CAM channels occurs prior to any electrical disturbance observable on the selector panel signals. Electrical disturbances can generally be seen prior to audio signal when explosive sounds originate at any significant measureable distance from the microphone (15 feet) and in the area where there is significant electrical systems. It is my opinion that an explosive event occurred close to the cockpit. The CAM signal which follows the explosive event shows a very much higher noice level than cockpit ambient 85 db, indicating to me the cockpit area was penetrated and opened to the atmosphere. The selector panel signals show signatures similar to those of an aircraft breaking up and are apparantly caused by electrical systems disturbance (circuit breaker blowing, fuse switching etc.). The lack of Mayday call and apparent inadvertant signal from the cockpit crew incapacitation. The transmitter coming on due to breakup is phenomena observed previously.
This contains only my personal opinion and in no way should be considered a final determination of cause without corroborating evidence".

3.4.5.4 Copies of the tapes were also sent to some of the participants who wanted to carry out independent analysis.

3.4.5.5 With regard to DFDR the Court received reports from Dr. Caroll Roberts of NTSB and report dated 11th November of Mr. B. Caiger.

3.4.5.6 With regard to CVR the Court received reports from Mr. B. Caiger dated 11th November, 1985, report dated November, 1985 of Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K., report dated 31st August, 1985 of Mr. S.N. Seshadri of BARC, Bombay.

3.4.6 Court Observations

3.4.6.1 Digital Flight Data Recorder
The reports of Dr. Caroll Roberts and Mr. Caiger which also coincide with the report submitted by Mr. Satendra Singh disclose that the DFDR showed no evidence of abnormal values of any of the many parameters being monitored upto a point at which the recorded data signal became irregular for a fraction of a second and recording ceased. Both the DFDR and the CVR stopped at the same time.

3.4.6.2 The short period of irregular digital data that occupied only 0.27 inches of tape, most probably indicates that the recorder was subjected to a sharp angular acceleration in the left wing down sense about the aircraft longitudinal axis.

3.4.6.3 According to Mr. Caiger's report the possibility that the digital recorder was subjected to a sharp disturbance more rapid than violent motion of the aircraft lends some credence to the possibility of a detonatiaon of an explosive device in the aircraft. The other alternative, according to Mr. Caiger, which could have led to this was that the Flight Data Acquisition Unit in the main electronics bay .or its power supply were suddenly disturbed. As the Lockheed Quick Access Recorder was not recovered from the wreckage, this possibility could not be investigated further. A perusal of the DFDR print out, however, shows that whereas there was a speed limit of 290 knots (.81 Mach) of the aircraft due to carriage of the 5th pod engine, in actual fact the aircraft's speed during cruise varied from 287 to 296 knots. Mr. H.S. Khola asked the Boeing Airplane Company to examine the effect of aircraft cruising at a speed of 296 knots with a 5th pod engine installed on it. The Boeing company sent a reply, inter alia, stating as follows:

"The operating speed limit of Air India 747-237B, JT9D-7J with fifth engine pod was 290 knots indicated airspeed, with an altitude limit of 35,200 feet. Flight testing of this model airplane configuration was successfully accomplished to a dive speed of

386 knots calibrated airspeed and 0.92 Mach number, with no adverse effects.
In the event that the operating speed placard was exceeded an increase in perceptible vibration levels would be felt. As the dive Mach number (0.92) is approached the buffet vibration would increase to level that could become objectional to the flight crew, but would not he bazardous".
3.4.6.4 It would thus be clear that if no adverse effects could have been noticed with a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, there was little likelihbood of the aircraft having been subjected to any adverse effect by reason of the speed varying from 287 to 296 knots while it was cruising at a height of about 31,000 feet.
3.4.6.5 Cockpit Voice Recorder
The Court received four reports of the CVR tape analysis. These reports were of Mr. B. Caiger, Mr. R.A. Davis, Mr. S.N. Seshadri and Mr. Paul C. Turner. Whereas the first three experts appeared and deposed in Court, Mr. Paul Turner did not come.
3.4.6.6. There were certain aspects of the report of Mr. Turner which required clarification. After the Court had failed to secure his presence, it sent a questionnaire to Mr. Turner for his answers thereto. It is indeed unfortunate that till now no reply has been received. It is in this background that the report dated 13th November, 1985 of Mr. Turner and the reports of other experts have to be judged and analysed.
3.4.6.7 Mr. B. Caiger's Report and Deposition
Mr. Caiger has said in his report that the Cockpit Area Microphone signal was studied in detail. According to him, in an aircraft, sound can be transmitted by multiplicity of paths. If an explosive device was located close to the microphone then the short wave from the disturbance would cause a sharp rise in pressure which was not noticed. From more remote location, however, structurally transmitted sounds could reach the

microphone first and induce more complex signals. According to Mr. Caiger, at this time he did not have any evidence from occurrences of this nature that would permit any meaningful comparisons or conclusions.

3.4.6.8 Mr. Caiger obtained from the manufacturers details of Automatic Gain Control (AGC) on the cockpit area microphone. According to the information so provided it was indicated that the decrease in amplitude of the recorded noise over about 33 msec after the peak level was reached 40 msec from the start of the disturbance is most probably due to the AGC and that the actual envelope of the pressure levels at the microphone continued to increase until 90 msec from the start before establishing at about four times the recorded level until the 160 msec point when the recorded amplitude started to decrease rapidly. Mr. Caiger could not find any explanation for this marked reduction. Mr. Caiger further recorded that the large amplitude lower frequency signature, that immdediately followed this reduction, is similar to signatures observed by the manufacturer when there was an abrupt break in the line from the cockpit area microphone pre-amplifier output to the voice recorder. No similar signature was observed in tests on the crew audio channels when the appropriate lines to the recorder were similarly interrupted.

3.4.6.9 The observation of Mr. Caiger with regard to ATC tape was as follows :-

"The ATC recording that followed the cockpit area microphone sounds appears at first to contain a series of short intermittant sounds. Closer study reveals that the background noise only returns to its steady level for about 160 msec immediately after the first low level noise and again for about 85 msec just over halfway through the 5.4 sec duration of the recordings. At the end of all routine radio transmissions, a damped sine wave transmitter keying signature is observed with a frequency in the region of 450 Hz. In the accident recordings, only two of these are observed".

"Listening to the sounds, it also appears that a human cry occurs near the end of the recordings. Spectral analysis of these sounds and comparison with voice limitations reveals that the accident sounds do not contain all the pitch harmonic frequencies normally associated with such voice sounds. The origin of all the sounds has not been identified."

3.4.6.10 From the aforesaid investigation Mr. Caiger concluded that :-

"From the voice and data recorders, Air India Flight 182 was proceeding normally enroute from Montreal to London, England at an altitude of 31,000 feet and a computed airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound the cause of which has not yet been identified. The sound continued for about 0.35 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder".

"The initial waveform of the cockpit area microphone signal is not consistant with the sharp pressure rise expected with detonation of an explosive device close to the flight deck but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, we cannot at this time exclude the possibility that it originated from such a device elsewhere in the aircraft".

"Within 1 to 2 seconds of the first detection of the loud sound on the cockpit area microphone, a series of unidentified noises were recorded on the Shannon ATC tape. These extended over a period of 5.4 seconds and are assumed to have origniated from VT-EFO. They gave the impression of abnormal conditions on the flight deck".

3.4.6.11 In his evidence in court, Mr. Caiger explained about Automatic Gain Control. He stated that the CAM channel of the CVR had an Automatic Gain Gontrol in a pre-amplifier that is installed close to the microphone. This AGC is designed to prevent excessively loud signals from saturating the microphone and the associated electronics. He further stated that from the tests conducted by the manufacturers it could be concluded that most likely at 45 msec. point the AGC came into effect which gradually reduced the signal over the next 33 msec. before letting it stabilise at a roughly constant value. This figure of 33 msec. was taken by Mr. Caiger not by carrying out any experiment himself but it was provided to him by the manufacturers. He also stated that there was no positive indication of structural failure being evident from the flight
recorders. Mr. Caiger was asked to explain as to what was the reason for loud sound to which reference had been made in his report. In answer to the said question from the Court he said that there could be a number of reasons. The detonation of an explosive device not close to the microphone was one possibility, the occurrence of some type of structural failure was another possibility. He was further of the opinion that at the present stage of development in structural acoustics, he did not think it was possible to come up with any reasonable estimate of the location of either explosive device or some type of possible structural failure. When asked for his opinion about the sequence of events which he could determine by looking at the sound spectrum, he said as follows:

"From the study that we have made which have of course been augmented by studies done by several other groups it would appear that there was a very sharp bang that was detected by the CAM. Approximately one-third of a second after this happened the line from the CAM to the CVR was disconnected but intermitant power supply was still being sent to the voice recorder for approximately one and a half seconds. During this 1-1/2 seconds period sounds were being transmitted from the 'Kanishka' aircraft that tend to suggest that the aircraft was in some distress. Though it is difficult to be specific about the basis on which we assesss the state of the aircraft, this signal ceased after a period of 5.4 seconds and we have no more audio information concerning the aircraft from that point onwards."

3.4.6.12 Mr. R.A. Davis's Report and Deposition

Mr. R.A. Davis in his report on the analysis of CVR has stated that he did not have with him a faithful copy of the original CVR tape. The tape supplied to his contained signals which warranted investigation but any measurement could be hampered by a decreased signal to noise ratio due to the copying process. Mr. Davis however analysed the tape which admittedly according to him was not of good quality. Mr. Davis in his report states that he carried out a spectrum analysis of the different channels of the CVR. The spectra did contain the sound of a bang. He however, could not find any significant low frequency content in the spectrum which according to him, would have been expected if the sound was of a high explosive detonation.

3.4.6.13 While carrying out detailed study of the tape he also looked out for any evidence of various audio warning signals which may have been buried in the noise. One such audio warning which could have been detected was that of pressurisation warning. Mr. Davis stated that this warning possessed a very defined frequency spectrum which was not present in the signal of the CVR of Kanishka. With regard to this he, however, stated that absence of this signal was not surprising as any decompression would take a finite time before reaching the warning level. Mr. Davis further observed that the presence of warnings due to attititude display disagreement, excessive speed and fire were investigated but with negative results.

3.4.6.14 During the course of investigations, Mr. Davis had compared Kanishka CVR recording with the recordings of an explosive decompression on a DC-10, a bomb in the freight hold of a B-737 and a gun shot on the flight deck of a B-737. According to Mr. Davis the spectrum of VCR tape of B-737 showed a much low frequency content with very little content at upper frequencies. This bomb, in the forward baggage hold of B-737, had exploded while the aircraft was at a low level and therefore the CVR did not have the sound accompanied with that of depressurization. That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a high explosive device, then the spectra should have shown large low frequency content, but this was absent. He further opined that, even if there was a possibility of a bomb remote from the flight deck and of a low power, even then the characteristics of a bomb would still be apparent in the time record. He also analysed the spectrum of the sound of the hand gun shot on a B-737 flight deck and according to him the said signal was sharp edged and did not compare with that of Kanishka's signal.

3.4.6.15 Mr. Davis also analysed the sounds recorded on the ATC tape. He concluded that the sounds emanated from Air India's Kanishka aircraft. According to him the transmission from the ATC is "chopped" until at approximately 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound was similar to that heard in other accidents where there had been a rapid increase in airspeed.

In the noise which continues until the end of the transmission is heard a crying sound. This was originally thought to be a human cry. He, however, noted that a human cry would contain more harmonics than was noticed in this case. It was also reported by Mr. Davis that knocking sounds which were heard during the transmission were initially thought to be due to hand-held microphone vibration. This was discounted because of the frequency of the sounds. He noticed that almost identical sounds were heard on the DC-10 CVR after the decompression had occured and the source of that sound had not been identified. On the DC-10 the pressurization audio warning commenced 2.2 seconds after the decompression. Analysing the ATC tape Mr. Davis observed that no such warning was identified during the open microphone transmission.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-

"It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182.

"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.

"Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. Such a situation would be most unusual, if not unique, in that we have never failed to detect sounds of structural failure, decompression, explosives etc., on any accident CVR, even though the event occurred at the rear of the aircraft. If such a device was used on AI 182 it is considered that it would have to be a very small device in order not to be detected (unlikely in itself). Such a device would be unlikely to cause the sudden total destruction which occurred in this instance. It is considered that a device of sufficient power to produce this effect could not fail to be detected on the CVR. The B-747 explosions referred to earlier, blew holes several feet wide in the structure but the crew were still able to control and operate the aircraft.

"It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

3.4.6.17 In reply to a question it was stated by Mr. Davis, when he was examined in Court, that it was true that there was no evidence that rapid decompression was caused by any structural failure. In an answer to another question, as to whether in his opinion there is a low frequency content present in every situation whereever there has been a high explosive device detonated, Mr. Davis answered in the affirmative, he however added that "But we do not have sufficient numbers to indicate that that would always be the case". Mr. Davis, however, agreed that DC-10 aircraft was quite dissimilar to Boeing 747, and the sound of an explosive decompression in the aft cargo hold of a DC-10 would not be identical to an explosive decompression in the aft cargo hold of a Boeing 747.

3.4.6.18 Mr. Davis further agreed that he was looking for low frequencies in Kanishka tape, but he did not know what type of low frequencies should be looked out for because there was no available data anywhere in the world for the sound of a bomb explosion in a Boeing 747. Mr. Davis was however emphatic in saying that he could not measure the distance of the origin of the sound from the cockpit area mike. In his report, and also in the earlier part of the examination, Mr. Davis had referred to the absence of low frequency component in the spectrum and had sought to conclude that such absence showed that there was no detonation of a high explosive device. In an answer to the question put by the Court however, Mr. Davis appeared to have altered his stand. This is evident from the following deposition of Mr. Davis :-

"Court Ques Am I to understand that there must necessarily be a low frequency whenever an explosion occurs?

Ans. No. What we thought was there would be. There was only one sample of explosion in B-737. But we would need more accidents of that nature to able to say that yes we must have a

low frequency component.
Court Ques: Am I to understand that the absence of a low frequency component would not therefore necessarily mean that the sound was not that of an explosion?
Ans. Because of the absence of a low frequency component we would not be able to say positively that there was an explosion or it was not explosion."
Court Ques : Would the frequency of a particular type of sound change depending upon the environment in which that sound occurs?
Ans Yes.
Court Ques If an event results in low frequency sounds in one type of environment, can it mean that the same event can result in a high frequency sound in a different environment?
Ans. That must be possible".
3.4.6.19 Mr. S.N. Seshadri's Report and Deposition
A detailed analysis of the CVR and the ATC tapes was also carried out by Mr. S.N. Seshadri at BARC. For the purposes of comparison, CVR tapes of Iranian Air Force Boeing 747 accident as well as that of Indian Airlines Boeing 737 accident were also analysed at BARC.
3.4.6.20 The original CVR tape of Kanishka was played on a 4 channel tape recorder modified to run at 1-7/8" per second. The output of this tape recorder was copied faithfully on an eight channel HP 3968A instrumentation tape recorder. Channels 1 to 4 were used for recording the CVR data and channels 5 for recording a time marker. For further processing and signal analysis this copy of the original tape was used.
3.4.6.21 The observations of the data so recorded, as contained in the said report inter-alia are as follows :
"Repeated and careful listening to all the four channels revealed the presence of explosive sounds on all these channels occuring nearly

at the end at the same time. Speech information is present on channels 3 and 4 during the last few minutes. Channel 1 does not contain any speech data during this period. Channel 2 contains indecipherable speech data about 20 to 25 seconds before the explosive sound".

"It was decided to analyse in detail the tape data during the final few seconds within which significant audio and electrical changes were observed to be present. Data from all the four channels were displayed on a Tektronix 2-channel storage oscilloscope Model 466 for initial observations. Based on this study the relevant portion of the tape was selected for more intensive snalysis. Simultanious ultraviolet recording of all the four channels on this portion of the tape was next carried out".

The following observations are relevant.

1. Channel 3, which corresponds to the area mike shows the first indication of a rising audio signal. This instant is termed, for conveniece, as zero time reference. The signal level rises from the ambient level in the cockpit by about 18.5 db in approximately 45 milliseconds. The signal then starts falling and stablises at a level about 10 db higher than the ambient level before zero time. The signal continues to remain at this level for about 275 milliseconds. The total duration of the signal from zero reference is thus about 360 milliseconds.
2. Channels 1 and 2, which are the radio channels of the pilot and the flight engineer respectively, show start of electrical disturbance signals 45 milliseconds from zero time at which the audio signal on channel 3 is at its maximum. These signals, which have do minant frequencies in the range of 70 to 210 Hz, persist for about 100 milliseconds on both channels. Subsequent to this, channel 1, shows an audio burst lasting about 200 milliseconds. Channel 2 shows a delayed audio burst lasting 25 milliseconds, 220 milliseconds from zero time, or in other words, 175 milliseconds after the peak signal from channel 3. A low

amplitude tail appears after this burst and lasts around 40 milliseconds. Channel 4 which is the co-pilot's radio channel shows an electrical disturbance commencing at 85 milliseconds from zero time and lasting around 60 milliseconds. The frequency distribution during this period is similar to those on channels 1 and 2. This is followed
by an audio burst of 230 milliseconds duration. The frequency spectra of the audio portions of channels 1,2 and 4 are reasonably similar."

3.4.6.22 "Correlation of Events of ATC Shannon Tape and Channel 4 of CVR tape :

"It was observed that during the last few minutes before the stoppage of the CVR, information recorded on the ATC tape and channel 4 of the CVR tape are identical. However, the ATC tape contains a series of audio bursts approximately corresponding to the instant at which a single explosive sound is recorded on channel 4. Thus a doubt arose whether the series of audio bursts recorded on the ATC tape had originated from channel 4 of Kanishka CVR since these are not recorded on the CVR tape. In order to obtain an answer to this it was necessary to check with very good accuracy the simultaneity of the explosive sound on channel 4 and the series of audio bursts on the ATC. The procedure followed for the same is given below.

"The ATC Shannon tape and the CVR tape were run on two independent tape recorders. It was found that the speeds of the two tapes were mismatched. In order to match speeds the earliest speech signal on both the tapes.

"Seven seventy that checks maintain three five zero" was used as the reference point. The speech signals which mostly contain the conversation between the co-pilot and ATC Shannon lasts for about 146 seconds. Channel four was kept ready for starting exactly at the reference point. The ATC was next played starting well before the reference point. The tape recorder playing

channel 4 was started manually exactly at the time when the reference point on the ATC was audible. By noting the time of ending of the conversation on both the tapes which corresponds to
"Right Sir squaking two zero zero five one eight two" the speed of the recorder playing the ATC tape was corrected by pitch control to approach the speed of CVR tape. The process was repeated a number of times till audibly the speeds were matched. The two tapes were next synchronously played and both the channels were simultaneously recorded on a third recorder to a point well after the explosive sound on channel 4. This tape was used for all further analysis.
"The first significant observation was that the explosive sound on channel 4 coincided with the beginning of the series of audio bursts on the ATC tape as heard by the ear. It was thus clear that both the recordings correspond to those generated by Kanishka during its last moments.
"To confirm this preliminary conclusion which was judged solely by the ear, accurate instrumented tests were carried out. The two channels were simultaneously recorded on an ultraviolet recorder at the four speeds, 0.1"/sec, 1"/sec, 10"/sec and 160"/sec for study of synchronism as well as frequency details. It was noticed that the two waveforms were not exactly suynchronised though by the ear they appeared to be so. In order to find out exactly the difference in synchronisation the following tests were done:
UV recordings at 16" per second were taken at three representative points relating to the communication of ATC with Kanishka. These points correspond to speech portions at 070838 "Five eh Squawking and eh Air India", at 070958 "Right Sir Squawking" and near the blast on channel 4. It was found that the ATC was running slightly faster. At the first point the ATC was leading by 90 milliseconds, and at the second point by 130 milliseconds. The time interval between these points is about 80

sec. By extrapolating this lead to the time of the blast which occurs about 243 sec. from the second point, it is clear that the lead of the ATC with respect to channel 4 at this point will be given by 130 + (130-90) (243/80) which is approximately 250 milliseconds. This error is very small."

"Thus one can conclude that the sounds recorded on the ATC Shannon tape are those which emanated from Kanishka during its last seconds."

3.4.6.23 "Frequency Analysis:

Mr. Seshadri also carried out frequency analysis of the CVR and the ATC tapes. His opinion with regard to the same was the follows:

"Significant audio and electrical disturbances were observed in the final few seconds of the CVR tape. It was therefore decided to analyse all the four channels for their frequency contents at the various places
in this pertinent region. For Fourier analysis of each signal, digitized time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

3.4.6.24 "The frequency analysis of electrical disturbances in channels 1,2 and 4 indicate presence of low frequencies in the region of 20 Hz to 600 Hz. The dominant frequencies are in the range of 70 Hz to 210 Hz.

3.4.6.25 "The frequency spectrum of the background noise in channel 3 just before the explosive sound has a broad band spectrum with some dominant frequencies in the region of 650 Hz to 1550 Hz. At the bang, many additional frequencies appear. The frequency spectrum of bang on channel 3 indicates an increase in the bandwidth.

3.4.6.26 "The frequency spectrum of channel 1 at the bang position indicates a fairly broad spectrum with dominant frequencies in the range of 150 Hz to 1 KHz. Channel 2 displays a frequency spectrum at the bang position in which low frequencies are dominant. It has a significant frequency range between 20 Hz to about 1 KHz. The frequency spectrum of channel 4 at the bang is wide-band with a broad peak in the range of 150 Hz to 800 Hz.

3.4.6.27 "At the beginning of the crackling sound, the frequency spectrum shows narrow band peaks around 1.6 KHz. About 90 and 300 milliseconds later, the spectrum changes with additional peaks appearing around 400 Hz, 600 Hz and 1150 Hz. Frequency analysis was also carried out at 600, 800 and 1000 milliseconds before the start of the crackling sound."

3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal

time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

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3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal
peaks to its maximum of 18.5 db above ambient level in about 45 milliseconds. A loud audible blast is heard when this channel is played at this point. An analysis of the frequency spectra before this loud blast and during the blast shows a definite change in the frequency composition. From all the above results it can be concluded that an explosion occurred in the aircraft. The exact position in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the Cockpit judging from the rise time of 45 milliseconds.

3.4.6.29 "Explosive sounds on all the four radio channels preceded by electrical disturbance reinforce the evidence provided by channel 3.

3.4.6.30 The synchronised recording and detailed analysis of the

ATC and channel 4 confirm that the sounds recorded in the ATC Shannon tape are undoubtedly attributable to the transmissions from AI 182 Kanishka during its last moments. The sounds indicate possible breaking up of the aircraft in mid air and the air blast which follows a decompression. A very detailed UV recording does not indicate the presence of a second explosion."

3.4.6.31 "Copies of CVR tapes of well understood air crashes pertaining to an Indian Airlines Boeing 737 in 1979 and Iranian Air Force Boeing 747 in 1976 were analysed for possible reference in connection with the analysis of the CVR tape of Kanishka.

3.4.6.32 "A definite explosion near the Cockpit was the cause of the crash of the Indian Airlines Boeing 737. An explosive sound recorded on the Cockpit Area Mike shows a rise time of about 8 milliseconds which corresponds to a distance of about 8 feet. This indicates that the rise time is a measure of the distance from the Cockpit Area Mike at which an explosion has occurred.

3.4.6.33 "The Iranian Air Force Boeing 747 broke up in mid air. Analysis of the CVR tape clearly indicates that the frequency spectra of the electrical disturbances are similar to those obtained for Kanishka. Thus the series of audio bursts recorded on the ATC Shannon tape have been most probably generated by the break-up of kanishka in midair.

3.4.6.34 Mr. Seshadri was also examined in Court on 27th January, 1986. In his deposition he very succintly explained some aspects of the work which was done by him. He also dealt with the aspect of AGC to which reference has been made by Mr. R.A. Davis and Mr. Paul Turner in their reports. The relevant part of the testimony in this connection is as follows :-

"We wanted to make sure that the CVR recording and the ATC corresponded to the same aircraft Kanishka. When we played the tapes for the first time we found that there was a difference of about 1 second. Though this figure may be tolerable because of

the accuracy of the tape speeds, we wanted to investigate further to make really sure that the ATC corresponded to Kanishka. For this purpose we had simultaneously "recorded channel 4 of the CVR and the ATC on a single tape on 2 channels after synchronising the common speech signals to the best of our ability by the ear. We started with the first speech which was available on both the tapes, namely, "770 that checks maintain 350". This was a conversation with the TWA aircraft which is available on both channel 4 and the ATC. The last sound which is recorded common to CVR and ATC is the speech of the co-pilot who says "right Sir, squaking 2005 182". After this recording though by the ear the explosive sounds on the ATC. as well as the CVR seemed to match, we wanted to check it in more detail. For this purpose we had detailed UV recordings of different portions of the synchronised tapes pertaining to the conversation between ATC and Kanishka. This was done and we noticed that the ATC was running slightly fast. We had about 80 seconds reference time of conservation from Air India Boeing Kanishka and the ATC for reference and we had to extrapolate the information in this section for another 243 seconds at which time the explosive sound occurs. During the beginning of this 80 seconds reference period, we find that the ATC was leading by 90 milli-seconds and at the end of 80 seconds the lead of ATC was 130 milli-seconds. Thus, in 80 seconds, the ATC had gained 40 milliseconds.
"This extrapolated to 243 seconds and gives a figure of 250milliseconds. This is how we arrived at the conclusion that both are synchronised within 250 milliseconds. I would like to bring to the notice of the Court that we have taken great pains to confirm this information by reapeating the tests a number of times. We did not take the 400 cycle signal available on the tape as the time reference. We took for reference the bunching of signals produced by the conversation and the gaps in between the convervation which are very clear on both tapes. Hence we are

sure that our results are right. The UV recording which was made has been filed along with my report.

"The main channel which was examined was the CAM channel. This was agreed to by all the experts who were present during the first analysis of the tape at the BARC between 16th and 20th July, 1985. One of the most noticeable things is that channel 3 which corresponds to cockpit area shows the first sign of disturbance. Let us say for reference that the disturbance starts at 0 time. In about 45 milliseconds the signal rises to a peak value which is approximately 18.5 db above the ambient level before the commencement of the signal. After this point the signal decays roughly exponentially in about 40 milliseconds to be almost a steady level which is 10 db above the ambient level before the explosive sound. From this we could draw conclusions. Assuming that an explosion occurred on the aircraft. The explosion produces a shock wave with a steep wave front which travels in air as well as through the aluminium body and the speed of travel will depend upon the distance of the explosive from the point of observation. It will depend on the cube root of the explosive and it will also depend on the ratio of the distance to the cube root of the weight of the explosive. The shock wave is very fast. It can travel at about 10 times the speed of sound. Also when the shock wave hits the aluminium body of the aircraft the vibrating panels which are defined by the stringers and longerons transmit the sound to the CAM location. Because the speed of sound in aluminium is about 19,200 feet per second which is 16 to 18 times that of the speed of sound in air and the shock velocity is also about 10 to 12 times. This signal will be received

"first by the CAM. Nevertheless the shock wave gets attenuated diffracted and refracted during its travels to the cockpit. Hence the signal received at the cockpit will be an attenuated signal and this small signal we have taken as instantaneous with the time of explosion. As the time passes the sound waves travel from the explosion site reinforcing the sound in the cockpit area thereby there is a rise time. Then when all the complete sound information is transmitted we get the peak of the signal and thus the rise time corresponds to the delay between the first rise in signal to the peak as compared to the speed of sound. One may ask the question what is the speed of sound because the aircraft has an explosion and is exposed to the outside environment but since the de-pressurization of the aircraft through the explosive fracture will take a minimum of a few seconds, we can reasonably assume that the pressure of the air in the aircraft corresponds to about 5000 to 6000 feet of altitude. At this presure and temperature, the sound velocity is roughly 1000 feet per second and from the 45 milliseconds delay we concluded that the explosion should have occurred about 40 to 50 feet from the cockpit. A question may be asked that the decay of the signal might be due to the AGC of the CVR coming into action. Mr. Turner, who is an acknowledged expert in the field of CVR has reported that Messrs Fairchild tested the cockpit voice recorders with a 10 db rise and fall of signals at the threshold of AGC and they got a result indicating a decay time of 33 milliseconds. The fall in the waveform of Channel 3 is about 40 milliseconds and is well near 33 milliseconds, so an argument may be advanced that the sound continued to remain steady and the fall in the signal level was effected by the AGC. In order to confirm this we tested the Cockpit Voice Recorder which was identical to the one which was on Kanishka by applying 1 KHz waveform of rectuangular modulation. To our surprise, we found that the decay time roughly was 130 milliseconds as compared to 33 milliseconds given by Mr. Turner. We repeated the tests with an initial background and without any background at all. We further tested with ramp waveforms, in other words, "slowly rising and falling waveforms of triangular shape with modulations of 1000 cycle carrier. This also confirms our finding. In order to clarify how the tests were performed so that others can judge whether it was a realistic test, I will explain the procedure. The modulated waveform was produced by a signal generator. This was fed to an amplifier. The amplifier output was fed to a loudspeaker. The output of the amplifier was checked to ensure that there was no distortion. Thus the signal going into the loudspeaker is the same modulated signal which has been applied at the input of the amplifier. This sound coming from the loudspeaker was recorded on the CVR through the CAM in the laboratory. This is how the test was performed. We were given a CVR tape by the Department of Civil Aviation purported to be that of an explosion which occurred on a Boeing 737 aircraft which crash- landed at Madras. We did the CVR analysis of this aircraft. We first recorded the output of the CVR of Indian Airlines CAM channel on a UV recorder. We found the rise time to be very small. This was of the order of a few milliseconds, about 8 milliseconds or so. We have been told that the explosion occurred just by the side of the front toilet i.e. just behind the cockpit. This to some extent confirms that the rise time is related to the distance of the explosion from the detecting CAM. The next thing that we did was the frequency analysis of this waveform. Mr. Davis has indicated in his report that if an explosion occurs on board the aircraft there should be low frequencies present. When we analysed the frequencies of the Kaniskha aircraft Channel 3, we did not find very low frequencies in case of an explosion abroad the aircraft. When we analysed the Boeing 737 tape we did not find any low frequencies in the signals. The report of Mr. Davis also provides the frequency analysis of a pistol shot which has been fired in the cockpit of the aeroplane. This also shows no low frequency components. So our conclusion, that it is not essential for low frequencies to be present in case of an explosion abroad an aircraft, was confirmed. I will go a step further to say that the frequency received by an area mike which responds to an explosive action abroad the aircraft will contain frequencies of the structure of the defracted " and dragging shock wave, the resonant frequencies of the aluminium panels defined by the longerons and the stiffening channel members and also some frequencies which may be of objects that the shock wave encounters in its path. It is, therefore, impossible to calculate the frequency spectrum that one would expect in the cockpit due to an explosion taking place in the aircraft".

3.4.6.35 In answer to a question Mr. Seshadri categorically stated that the word "explosion" in his report meant "a bomb, a very fast device".

3.4.6.36 Mr. Paul C. Turner's Report

Lastly, a reference may be made to the report dated 13th November, 1985 of Mr. Paul C. Turner. The evaluation of Mr. Turner of the analysis done by him of the CVR and the ATC tapes, as contained in the said report, was as follows:-

"With the foregoing as background, we can make several observations. The CVR record on the CAM channel, captain's channel and flight engineer's channel show that they were all affected at about the same time; the copilot's perhaps 20 milliseconds later. Major disturbances which are recognized as electrical system disturbances can be seen to begin about 60 milliseconds after the initial disturbance. This approximates the time it would take for the electrical system protective circuitry to become active.

3.4.6.37 "A steep wave front which would be indicative of a shock wave cannot be seen on the CAM channel sound spectrum; however, the spectrum analaysis shows that impulse type sounds occurred at the beginning of the event recorded on the CAM channel of the CVR. Since audio signals propagate through aluminium approximately 16 times the speed of sound in air, the CAM channel would probably have been affected by structurally transmitted noise before being affected by airborne noise. The geometry of the aircraft was such that structure borne disturbances could be recorded before the airborne transmitted information appeared at the cockpit microphone and an air transmitted shock wave or steep wave front may not be evident on the CVR.

3.4.6.38 The captain's and copilot's selector box channels recorded signals which appeared to be electrically inducted and similar to those seen on the Huete Boeing 747 breakups. These are then followed by a signal resembling audio frequency noises similar to an open microphone in a noisy environment or the opening of a receiver squelch. Both effects have been seen during aircraft breakups. The audio noise on the captain's and copilot's channels appears to have come from a different source. The flight engineer's channel does not contain audio noise. A spectral diagram of the copilot's and captain's channel noises just show broad band noise across the spectrum. The signal frequncies extend beyond the frequency range of a microphone both on the high and the low end. It does not fit the normal microphone envelope. Spectral diagrams of the event on the CAM channel show the normal microphone preamplifier envelope summed with wide band signal of unspecified origin. Since the signal quits abruptly with a doublet, it indicates that the interference was added upstream of the CVR and was not just reflected in the CVR power supply.

3.4.6.39 "The CVR record shows a signal stayed on for about 200 milliseconds when it appears that the power may have been interrupted to both the radio channel and the CAM channel of the CVR at the same time. It further appears that the signals to the CVR were probably interrupted at 360 milliseconds from the initial disturbance possibly by severance of the signal wires. It further appears from the action of the erase head and record that the main electrical system began to fail at this point and the CVR bus voltage value dropped to a value below 70 volts but not below 20 volts. This fluctuating voltage continued intermittently for a minimum of 1-1/4 seconds at which time the voltage evidently dropped to some value below 20 volts and the recorder ceased to operate. The power for operation of the No. 1 VHF transmitter can be explained by the operation of the standby bus and battery and connection of the No. 1 VHF radio to this standby bus.

3.4.6.40 "The necking down of the signal to a low value shows that no signal was coming to the CVR from the CAM preamplifier. The lack of a signal on the radio channels, which do not need to be erased before being recorded, further suggest that the wires were severed or

"that the transmission to Cork began after what appeared to be the loss of the primary electrical system approximately 1-1/2 seconds following the event. Standby power would have become available upon loss of the primary power, the number one VHF would have become available, and CVR would have ceased to operate.

3.4.6.41 "The action of the erase circuitry in the CVR suggests that the fluctuating voltage seen was coming from the main electrical system bus. Anything else causing this fluctuating voltage down stream of the CVR circuit breaker would probably blow it.

3.4.6.42 "The signal received in Ireland indicated that a radio, most probably this aircraft's No. 1 VHF transmitter, stayed operational for about 5.4 seconds following the event at which time the entire aircraft electrical system ceased to function. This assumes that the No. 1 transmitter ceased to operate due to standby bus failure.

3.4.6.43 "In the conclusion, it appears that a catastrophic event occurred on Kanishka. It was reflected in all channels of the CVR and the CVR power supply at the same time. The main electrical bus began to fail within 0.35 second and the standby bus survived for only 6 seconds more at which time the aircraft's electrical system ceased to function. It appears that the event occurred in a manner to affect the cockpit area microphone operation severely and to force operation of the automatic gain control on the CVR. This loud noise continued for the life of the aircraft's main electrical system as reflected in the CVR.

3.4.6.44 "The mechanism of how the ATC transmission was made from Kanishka to Cork is unclear. The sound was not recorded on the CVR, indepentent studies by Canadian and British investigators have the Cork ATC call originating approximately 1-1/2 seconds following the event on the CVR. This is about the time that standby power would have become available to the No. 1 VHF.

3.4.6.45 "This report should be viewed as an accident investigation tool only and used in conjunction with other evidence gathered during the investigation.

3.4.6.46 "The United States Noard/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

3.4.6.47 It is pertinent to note that according to Mr. Turner there was "catastrophic event" which had occurrred on Kanishka. He has, however, not elucidated as to what this event was.

3.4.6.48 After the receipt of the report, the Court requested the NTSB that Mr. Turner should come and depose. It is unfortunate that permission was not granted to him. Faced with this situation and as it was thought necessary that some clarification was called for, the Court sent a telex to Mr. Turner whereby he was asked to give replies to the queries contained therein. He was requested that the reply be sent by 27th January 1986. A copy of the telex was also forwarded to the American Embassy at New Delhi for sending the same to NTSB by way of confirmation. Previously all communications addressed to NTSB were being routed through American Embassy. No reply has been received by the Court till this day either from NTSB or from Mr. Paul Turner. According to paragraph 5.14 of Annex 13 the State is required, on request from the State conducting the investigation of an accident, to provide to that State with all the relevant information available to it. It was, therefore, obligatory on the NTSB to have seen that the information sought for by the Court by way of answers to the queries was supplied.

3.4.6.49 Court Evaluation

From the reports of all the experts and the testimonies of M/s Caiger, Davis and Seshadri it is clear, and it is agreed to by all of them, that there was a breakup of the aircraft in mid-air. The experts also agreed that the sounds recorded on the ATC Shannon tape at 0714:01 Z emanated from the Kanishka aircraft.

3.4.6.50 Mr. Caiger has not said either in the report or in his statement as to what was the cause of the bang. Mr. Davis, on the other hand, is categorical in stating in his report that there was explosive decompression (meaning rapid decompression) on the aircraft. He has, however,
stated in the report that there is no evidence of an explosive device. The main reason for his coming to this conclusion is that he had not been able to find low frequencies in the spectra of the CVR of Kanishka. Mr. Seshadri, on the other hand is equally vehement in concluding that an explosive device had detonated in the front cargo hold of Kanishka.

3.4.6.51 It may be that the frequency spectrum of Kanishka CVR did not contain low frequencies but, as has been admitted by Mr. Davis himself in answer to a Court question, it is not necessary that in the case of every detonation there must necessarily be low frequencies in the spectrum. Frequency spectra of 'Kanishka CVR before 'bang' and at the 'bang' position are shown in Figs. 2 & 3, indicating presence of additional high frequncies at the bang. Indeed in the case of Indian Airlines Boeing 737, which admittedly was a case where there was an explosion of a device within about 8 feet of the CAM, the frequency analysis showed absence of low frequencies. Frequency spectrum of Indian Airlines Boeing 737 CVR is shown at Fig. 4. Merely, because therefore, there were no low frequencies present would not mean that there was no detonating device on board the Kanishka. The CVR of Indian Airlines Boeing 737 has not been analysed either by Mr. Caiger or Mr. Davis. The analysis was, however, conducted by Mr. Seshadri and as is evident from his report, there were marked similarities between the spectra of Indian Airlines 737 and Air India's Kanishka CVR. One of the important reasons for coming to this conclusion, which has been indicated by Mr. Seshadri, is the rise time of the bang signal. From the analysis of the Indian Airlines Boeing 737 tape it was observed that it had taken 8 milliseconds for the peak to be reached. It was also seen that the explosive device was approximately 8 feet away from the cockpit area mike. Keeping this in view Mr. Seshadri observed that in the case of Kanishka the peak of the bang signal was reached in about 40 milliseconds. He, therefore, concluded that the origin of the bang sound was about 40 feet away from the cockpit area mike.

3.4.6.52 It would be pertinent to note that even according to the report of Mr. Davis the rise time in the case of Kanishka, which has been given for the peak is about 40 milliseconds. He, however, does not attach much importance to this because according to him after about 40 ms automatic gain control would become effective.

3.4.6.53 Mr. Davis has no personal experience of the time which it would take for the Automatic Gain Control to take effect. He has got the figures from the manufacturer. Mr. Davis admitted that the time which it will take for the AGC to be effective is not indicated in any published document of the manufacturer.

3.4.6.54 Mr. Seshadri, however, personally carried out the experiments on a Boeing 747 by using an instrument similar to what was on board Kanishka. From the testimony of Mr. Seshadri it is apparent that the results which he got were different. As per his testimony, for the AGC to be effective it will take 130 ms. If this be so then it may be possible to conclude that in the case of Kanishka the peak was reached in 40 ms. and thereafter the signal decayed and the signal was in no way effected by the AGC.

3.4.6.55 A reference may also be made, at this stage, the frequency spectrum of the sound of the hand gun which was fired on a boeing 737 flight deck. Frequency spectrum prepared by Mr. R.A. Davis is shown at Fig. 5. He has stated that the rise time for reaching the peak is almost instantaneous. Same is the case with regard to the frequency spectrum prepared by him of a bomb in a B-737 aircraft where the bomb had been placed in the freight hold which is shown in Fig. 6. A perusal of that spectrum also shows that the peak was reached in approximately 5 ms. The forward freight hold compartment of Boeing 737 is much more than five feet away from the cockpit area mike. If the theory of Mr. Seshadri was to be applied then as per the frequency analysis of this Boeing 737 bomb, the distance from the area mike could not have been more than 5 ft. It is, however, known, as per the report of Davis, that the bomb was actually in the freight hold which would mean not nearer than about 25 feet.

3.4.6.56 From what has been stated in the various reports, as well as in the testimony of the 3 experts who apperared in the Court, the only safe conclusion which can be drawn is that possibly enough study has not been done, due to lack of adequate data, which can lead one to the conclusion as to the exact nature of the sound and the distance from which it originated.

3.4.6.57 The fact that a bang was heard is evident to the ear when the CVR as well as the ATC tapes are played. The bang could have been caused by a rapid decompression but it could also have been caused by an explsoive device. One fact which has, however, to be noticed is that the sound from the explosion must necessarily emanate a few milliseconds or seconds earlier than the sound of rapid decompression because the explosion must necessarily occur before a hole is made, which results in decompression. In the event of there being an explosive detonation then the sound from there must reach the area mike first before the sound of decompression is received by it. The sound may travel either through the air or through the structure of the aircraft, but if there is no explosion of a device, but there is nevertheless an explosive decompression for some other reason, then it is that sound which will reach the area mike. To my mind it will be difficult to say, merely by looking at the spectra of the sound, that the bang recorded on the CVR tape was from an explosive device.

3.4.6.58 There are various hypothesis and theories which the experts have to investigate before any acceptable conclusions are arrived at. It so happens that in the present case we have the opinions of four experts, but they do not agree with one another on some material aspects. Two of the experts, namely, Mr. Caiger and Mr. Davis are categorical in saying that it is not possible to measure the distance of the origin of the sound on the cockpit area mike, whereas Mr. Seshadri has come to a different conclusion. Mr. Paul Turner in his report dated 13th November, 1985 in silent on this aspect, though in his earlier report dated 19th July, 1985 he had categorically said that there was an explosive device close to the cockpit.

3.4.6.59 With regard to the nature of the sound also we have 3 different opinions. Mr. Caiger is unable to give the nature of the sound, Mr. Davis says it is rapid decompression while Mr. Seshadri says it is a sound of an explosive device followed by decompression.

3.4.6.60 In the absence of any other technical literature on the

subject, it is not possible for this Court to come to the conclusion as to which of the Experts is right. The only conclusion which can, however,
be arrived at is that the aircraft had broken in midair and that there has been a rapid decompression in the aircraft. Just as it is not possible to say that the spectrum discloses that the bang is due to an explosive device similarly, and as has also been admitted by Mr. Caiger and Mr. Davis, it is not possible to say that the bang is due to break up of a structure.

3.4.6.61 The bang could have been due to either of the aforesaid two causes i.e. a bomb explosion or the sound emanating due to rapid decompression. The advantage of carrying out the said analysis is that a number of possible causes of the accident are eliminated. On the other hand, if the analysis is viewed in conjunction with other evidence on the record it is further possible to determine the exact nature or cause of the bang. In the present case the bang, as already noticed, could have been due to the sound originating from the detonation of a device or by reason of rapid decompression. Other evidence on the record, however, clearly indicates that the accident occurred due to a bomb having exploded in the forward cargo hold of Kanishka. The spectra analysis and the conclusions of Mr. S.N. Seshadri are corroborated by other evidence.

TESTS AND RESEARCH

3.5.1 During the course of investigation a number of groups were formed to study and analyse evidence and data which was available. Materials like CVR, ATC and DFDR tapes were also given to the various participants.

3.5.2 The groups as well as other experts studied and analysed the material with them and submitted their reports which have been referred to earlier.

3.5.3 The experts examining the CVR tapes did carry out a number of tests. Different graphs and traces were prepared and the sound was analysed by them. The result of their analysis has been referred to in Chapter 3.4 on Flight Recorders.

3.5.4. The metallurgical examination of some of the recovered pieces was carried out at BARC. The examination of some of the pieces showed different types of damages having been recorded on the targets such as petalling and curling round the holes, spikes etc. The said team carried out certain explosion experiments. Their report on the experiments so carried out has already been set-out in paragraph 3.2 above.

3.5.5 The Indian Air Force has set up an Institute of Aviation Medicine at Bangalore. The Court visited the said Institute on 9th December 1985. During that visit an experiment was conducted in the explosive decompression and high altitude chamber to demonstrate what actually happens during explosive decompression and subsequently on exposure to hypoxia.

3.5.6 Subjects were taken to 8,000 feet in the explosive decompression chamber with oxygen. They were exposed to an altitude of 25,000 feet within one second. During the course of this explosion a loud bang was heard and inside the chamber there was misting and drop in temperature. After this the chamber was allowed to run at 22,000 feet for roughly two minutes and an experiment to show the adverse affects of hypoxia on the subjects was done. In this experiment, subjects were asked to write a given sentence while their oxygen supply was cut off. It was observed that initially the subjects kept on writing the sentence correctly and then
after about 120 seconds they started making errors while writing the sentence and finally they stopped writing. At this stage oxygen was re-started and within a few seconds, the subjects started writing their sentence once again. The experiment was completed at this stage and the altitude chamber was brought down to ground level.

3.5.7 The subjects were taken out and were asked questions as to what did they feel. They explained that at the time of explosive decompression, they heard a loud bang, felt cold and saw misting inside the chamber. They also found air escaping from their lungs. On further enquiry about the experiment pertaining to hypoxia, they said that they felt light headed and after that they did not know what happened till they once again noticed that they were writing on a piece of paper.

SECURITY

3.6.1 The evidence and the statements filed on record show that Canadian Security arrangements in place prior to 23rd June, 1985 met the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand baggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

3.6.2 Air India, as required by Canadian regulation, had a security programme. Because of the threat level assessed against the Airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and had received and arranged for extra security for the month of June, 1985. For Air India flight 181/182, Air India provided a security officer from its New York Office to oversee the security at Toronto and Montreal.

3.6.3 As it became apparent during the course of investigation that security would be an important aspect whilch would require the attention of the Court, Mr. Rodney Wallis, Director, Facilitation and Security, International Air Transport Association was good enough to appear in Court on 24th January, 1986. His testimony on certain aspects of security was recorded in camera by the Court on that date. The expert evidence has been taken into consideration while formulating some of the recommendations.

INTERNATIONAL COOPERATION

3.7.1 The manner in which persons and organisations from five different countries combined their resources and efforts in connection with this accident is an object lesson in international cooperation.

3.7.2 From the time the accident occurred, till the conclusion of the investigation proceedings by the Court in Delhi, there has been a consistent interplay amongst different persons and organisations. When all the persons got together, for the first time, at Cork the group was very heterogeneous. Each one had his own point of view, which did not necessarily coincide with that of another. At times, the atmosphere was charged with a bit of tension which continued even when the Court was constituted to investigate into the accident.

3.7.3 It was noticed that not only were the participants a bit apprehensive and suspicious but, during the course of investigation, there were also occasions when there appeared some acrimony between a few of them.

3.7.4 In such a sensitive situation, careful handling was called for. The participants' honesty of purpose could not be doubted. All that was wanted was that there should be an effort to try and understand the point of view of all the persons. This is precisely what the Court tried to do.

3.7.5 It is indeed fortunate that the efforts of the Court, in this regard, succeeded. After the Court had decided that it was not the purpose or the function of the investigation to affix responsibility for any lapse which may have been committed, one could see the general relieving of tension. With the passage of time there was a gradual building up of the confidence of the participants in the conduct of the investigation. The participants' interest for air safety transcended all barriers and any apprehension or suspicion, which was present in the minds of some, was soon dispelled. In its place there grew a deep sense of urgency, anxiety and cooperation in an effort to see that all the participants rendered utmost assistance for the satisfactory completion of the task in hand.

3.7.6 The main beneficiary of this international cooperation was not only the Court investigating the accident but it was the cause of air safety which benefited the most. Countries and Organisations went out of the way to help each other, financially and otherwise, even when they were not obliged to do so. Money and services were readily and voluntarily offered and usually the requirements of the Court were always fulfilled.

3.7.7 As the accident had occurred only about 100 miles off the coast of Ireland, the centre of activity, initially, was centred at Cork. The Government of Ireland, and the Irish people in particular, acted as though they regarded this as a national disaster. Not only did they render every assistance with regard to the search and rescue operation, hospital facilities, police etc. but the people acted as if one of their own kith and kin had died. In the situation which existed they were pillars of strength to the relatives of the deceased. Not only did complete strangers comfort such relatives but, more often than not, they even joined in their grief. The residents of Cork did everything possible to try and mitigate the sorrow of the victims' relatives. Everyone did their small bit, even the children of Cork queued up to place flowers at the coffins of the victims.

3.7.8 The Representatives of the Government of Canada also came to the scene, at the initial stages itself, and rendered full help and cooperation till the last. The major brunt of the mapping and the salvage operations was borne by Canada. Willingly and without any demur it incurred huge expenses, which must have been to the tune of a few million dollars, in carrying out these operations. It rendered full help and assitance to the Court whenever called upon to do so. For example, it offorded full facilities and help to the team which had been sent to Canada by the Court in August, 1985. It was only with the help of the Canadian Government, and the CASB and RCMP in particular, that the Court was able to obtain evidence and information relating to the accident. Without Canadian help the conduct of the investigation would have only been speculative in nature.

3.7.9 On their own, and without any request from the Court or from the Government of India, the Government of United States decided to lend a helping hand in the salvage operations. This was done
at a very critical juncture when financial help and expertise were required so as to salvage the important critical pieces of the wreckage. It arranged for the services of a salvage expert and it also made necessary arrangements for the deployment of a second ship, duly fitted with necessary equipment to enable it to salvage some of the heavier pieces of the wreckage. The Court understands that the amount which was contributed in meeting the expenses by the United States was to the tune of U.S. $ 700,000.

3.7.10 The Government of United Kingdom also provided ship and helicopters in connection with the search and rescue operations. Even during the time when salvage operations were being carried out it was the British Helicopters which assisted in transporting personnel to and from the ship which were engaged in the salvage operations. The A.I.B. at Farnborough, on being asked by the Court to do so, carried out a very detailed analysis of the CVR and the ATC tapes.

3.7.11 Being the state of Registry of the aircraft and also the state holding the investigation, the major brunt of the work fell on the shoulders of officers of the Government of India and BARC. They acted as coordinators who had to oversee the work being carried out by persons belonging to diverse organisations and coming from different countries. Young engineers of Air India took turns in going aboard the ships and manning the Control Centre at Cork. They worked in conjunction with the engineers of Boeing and CASB and the crew members of the ships during the salvage operations. Without their enthusiastic participation the progress of the salvage operations would have been severely hampered.

3.7.12 The Scientists from BARC and National Aeronautical Laboratory, Bangalore were ever ready and willing to work together with the experts from abroad. Whenever called upon to do so, they rendered whatever assistance which was desired by the Court and the other participants.

3.7.13 It was seen that when the persons, coming from different countries and backgrounds, worked together with sincerety and honesty of purpose then they functioned smoothly and harmoniously, and usually arrived at an agreed solution or finding. These days it is indeed rare to see such a degree of international cooperation between different persons, organisations and countries.

ANALYSIS AND CONCLUSIONS

4.1 From the evidence which is available what has now to be determined is as to what caused the accident.

4.2 Finding the cause of the accident is usually a deduction from known set of facts. In the present case known facts are not very many, but there are a number of possible events which might have happened which could have led to the crash.

4.3 The first task is to try and marshal the facts which may have a bearing as to the cause of the accident.

4.4 It is undisputed, and there is ample evidence on the record to prove it, that Air India's Kanishka had a normal and uneventful flight out of Montreal. The aircraft had been in air for about five hours and was cruising smoothly at an altitude of 31,000 feet. The readout from the CVR shows that there was no emergency on board till the catastrophic event had occurred. This is corroborated by the printout available from the DFDR. The event occurred at approximately 0714 Z and that brought the aircraft down, and it probably hit the surface of the sea within a distance of 5 miles. The time within which the plane came down at such a steep angle could not have been more than very few minutes. There was a sudden snapping of the communication between the aircraft and the ground. The aircraft had also suddenly disappeared from the radar.

4.5 It is evident that an event had occurred at 31,000 feet which had brought down 'Kanishka'. What could have possibly happened to it? The aircraft was apparently incapacitated and this was due either to it having been hit from outside; or due to some structural failure; or due to the detonation of an explosive device within the aircraft.

4.6 Evidence indicates that after the event had occurred, though the pilots did not or were not in a position to communicate with the ground, they nevertheless appeared to have taken some action. According to Mr. Laflamme, witness No. 12, the examination of the wreckage showed that spoilers had been deployed and this must have been done
with a view to enter into emergency descent. He has further speculated that such an emergency descent would support or perhaps cause a rupture in the forward area or a partial damage to the hydraulic system or damage to the control system which created such a condition that the pilots were not able to control the flight. The wreckage fruther showed that the jack screw for the stabilizer trim was found in the nose-up position and it was hard to explain how this got there merely as a result of impact with the water. The trim being in that position could only have been due to the pilot selecting it or as a result of a situation created by an explosion. In that position, and at a high aircraft speed, there would have been an extremely high g-loading on the

aircraft.

4.7 It can further be speculated that if an explosion takes place in the forward cargo compartment, the oxygen stream might have been damaged so that when the pilots donned their masks as part of the emergency drill for explosive decompression, they were not breathing enriched oxygen and the time of useful consciousness at about 31,000 feet would be significantly less than 30 seconds under high stress and if the pilots became unconscious as a result of this, then the aircraft would have got out of control which would explain the subsequent events.

4.8 None of the participants have produced any evidence which could lead one to the conclusion, that there was any external hit to the aircraft. In fact in the report dated 13th November, 1985, Mr. Paul Turner has stated as follows:

"The United States Norad/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.

4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.

4.11 The circumstantial and direct evidence which leads to the aforesaid conclusion is as follows :

A. Connection with an explosion at Narita Airport :

On 23rd June, 1985 there was an explosion at the Narita Airport. The explosion occurred when a bomb exploded in a suit case which was to be interlined to Air India's Flight No. 301 from Tokyo to Bangkok. The following events, which had occurred prior to this explosion, clearly establish the connection between the two incidents :

(i) On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight Indian accent. He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vacouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

(ii) On the same date at approxmimately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

(iii) On 20 June, 1985 at about 1210 PDT (1910 GMT), a male appearing to be of Indian origin purchased the tickets with cash from a CP Air Ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to 'M. Singh'. The telephone contact number was also changed. The final itinerary was as follows :

(a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22nd June, 1985

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22nd June, 1985

(b) L. Singh - CP 003 Vacouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June, 1985
- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 time in Tokyo, local 23 June, 1985

(iv) On 22 June, 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that the was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

(v) On Saturday morning, 22 June, 1985, a CP Air passenger agent worked check-in position number 26 at the CP AIR ticket counter, Vancouver International Airport, and recalls dealing with a passenger of Indian origin booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto his baggage could not be interlined. The passenger insisted and, as the line-up were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that 'M. Singh' checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage.

(vi) The flight manifest for CP 003 shows that on the same day the person using the name of 'L. Singh' with an interline ticket to Bangkok also checked through the same counter, was assigned seat 38H, and checked one piece of baggage.

(vii) A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as 'M. Singh' and 'L. Singh' did not board these respective flights.

(viii) In a statement of William Long, annexed to the affidavit of I.G. Pole, Police Officer, City of Toronto, he has stated that on 22nd June, 1985 he was employed as a driver whose responsibility was to deliver interlined baggage between terminal 2 to Terminal 1 and vice versa at Toronto. He has further stated that he had picked up 4 bags from Terminal 1 which were destined for terminal 2 Air India. Three of these bags were from U.S. Air originating from New York city. Regarding the last bag he stated as follows :

"The fourth bag destined for Air India was, I distinctly remember looking at the baggage tag and it was pink with the CP logo in blue and
letters saying CP on it there were also numbers but I can't remember the number, from CP Air and I remember it was from Vancouver. On the bottom of the tag it said vancouver using the initials YVR and the flight number which I can't remember. The bag was destined for India. When I arrived at the CP Air belt there were a number of bags from other airlines on the belt included in these were the three U.S. Air bags destined for Air India. As I was finishing loading the carts, a CP Air station attendant who had been unloading bags from containers, I noticed as I checked once more for anymore bags, drop another bag on the conveyer belt. This was the bag destined for Air India. It was dark brown Samsonite Hard sided Type 01A on the Baggage Identification Chart. After they were loaded onto the cart I took them over to Air Canada domestic belt at Gate 89-91".
To further questions posed to him, Long stated that this bag from CP Air weighed approximately 70 lbs and there was something which rattled inside the bag. He could not say what it was but he said that "it sounded small". When specifically asked whether he thought there was something big inside the bag, he answered in

the affirmative, and added that he did not know what was in it but it was heavy. There was discrepancy in the time when he is alleged to have picked up the bags which he had indicated in his schedule when compared with CP Air Vancouver flight which had arrived at 1622 hours. When this was pointed out to Long, he answered "I could have may be got the time wrong, it was during the busy period. It could have been an estimate time. But I do remember the bag came off CP air. It could have been 16:34 Hrs. I don't know."

(ix) The aircraft departed from Toronto for Mirable and London with the suitcase unaccompained by the passenger who had checked it in at Vancouver. Similarly, CP Air 003 departed Toronto for Tokyo with the baggage of one passenger 'L. Singh' to be interlined to Air India flight AI 301 to Bangkok even though 'L Singh' had not boarded that flight.

(x) The linking of the two occurrences namely the blast at Narita Airport and the Air India accident becomes startingly evident if we look at the following chronology of events:

CPA 003 (VANCOUVER-TOKYO)CPA 060 (VANCOUVER-TORONTO)Connection toConnecting toAir India 301Air India 182WESTBOUNDEASTBOUNDAll Times GMTThurs20 June, 19850057A male called C.P. Air Reservations in Vancouver and after discussing a number of routings, booked a one-way ticket and CPA 060 to Toronto with connections to Air India 182 under the name of Jaswand SINGH. A return ticket was also booked on CPA 003 to Tokyo connecting with Air India 301 to Bangkok in the name of Mohinderbel SINGH.

1912A male attended the CP Air Ticket Office in Vancouver. He paid $ 3005.00 in cash for the above tickets after changing the ticket of Mohinderbel SINGH to L. SINGH and changing from a return to a one-way ticket. He changed the Jaswand

SINGH ticket to M. SINGH.

Saturday22 JuneA Mr. SINGH calledReservations and got1330confirmation on his one-wayticket to Torontowith luggage to be sentthrough to India.M. SINGH checked in withseat 10B confirmed to1550Toronto. Wanted suitcaseinterlined to AI 182.Agent relents.1618CPA 060 departedVancouver 18 minuteslate. M. SINGH not inassigned seat.L. SINGH checked in for CPA003 and one suitcase interlinedto Air India 301. Assigned seat38H.CPA 060 arrived Toronto202212 minutes late. Somepassengers and baggageinterlined to AI 181.
CPA 003 departed 17 min. latefor Tokyo. L. SINGH not in2037assigned seat.Sunday23 JuneAir India 181 departed0015Toronto for Mirabel1 hour 40 minutes late.0100Air India arrived Mirabel.0218Air India 182 departedMirabel 1 hour 38 minuteslate.CPA 003 arrived Narita Airport,Tokyo. Arrived 14 minutes early0541Baggage cart explodes in transitarea. 2 killed, 4 injured, 06190714Air India 182 disappearedfrom Radar
Air India 301 departed Narita.08050815Air India 182 Scheduledarrival Heathrow (fuel stop).
(xi) It would indeed to too much of a coincidence that two persons, whose tickets were bought at the same time and who had checked in under the names of 'L. Singh' and 'M. Singh' missed their respective flights, more so when 'M. Singh' had insisted at the check in counter at Vancouver that he should be interlined, even though his seat from Toronto on AI 181/182 was not confirmed, and his baggage (one suitcase) accepted and be routed through to Delhi. If there had been some reason for 'gate no-show' by both of them, one would ordinarily have expected both, or at least one of them, to have made efforts, at that time or thereafter, either to ask for refund of money or they should have contacted the airline staff at the Airport and asked that they

should be put on another flight.

(xii) A large amount of money had been spent on the purchase of the two tickets and a question which comes to mind is as to why was this money spent if both the tickets were to be wasted and no one was to travel on them, after having checked in and obtained boarding cards. Furthermore, no effort has been made by any of these two persons to try and lodge a claim for the baggage which they had checked in.

(xiii) The aforesaid facts clearly indicate the connection between
the travel plans of so called 'L. Singh' and 'M. Singh'. In fact the manner in which the reservations were changed to the names of 'M. Singh' and 'L. Singh' shows the anxiety of some one to hide behind the identity of persons who bore notorious names.

(xiv) The interlined baggage exploded at Narita Airport and there is strong probability that the suticase from Vancouver, which was interlined to AI 182, contained a device similar to the one which had exploded at Narita Airport on 23 June, 1985.

B. CVR and DFDR both stopped simultaneously:

There was simultaneous interruption of electrical power to the flight recorders. The electrical supply could have been interrupted either because of the cables being cut or because of total electric failure. Power supply wires to the CVR and the DFDR run under the passenger cabin ceiling on the left and the right hand side. The supply of electricity through these cables originates from the MEC compartment, which is in front of the forward cargo hold. If the CVR and the DFDR had stopped due to the breakage of electrical supply wires as a result of possible explosion in the aft cargo hold there would have had to be an instantaneous break of almost the entire section of fuselage, because both these recorders had stoped simultaneously. In such a catastrophic event it is not possible that the bottom skin panels of the aft cargo compartment would remain undistorted, or would have no rupture or holes in them. Furthermore, in such an event the tail portion of the aircraft would have been found in the beginning of the wreckage trail, but this was not so. On the other hand, and explosion in the forward cargo compartment would have resulted in damage to the electrical buses located in the MEC and that would, in turn, result in cutting off the electrical power supply causing simultaneous stoppage of the recorders.

C. The ATC Transponder Stopped Transmitting :

The transponder is located at the bottom of the one of the forward rakes immediately forward of the front cargo compartment. Signals from this also stopped being received by the secondary radar at Shannon. Keeping in view that the CVR and the DFDR had stopped simultaneously at about the same time, when the signals from ATC transponder had also ceased, it is reasonable to presume that there must have been a complete breackdown of electrical supply which had affected all the three units. The only event which could have caused such a damage to paralyse the entire MEC compartment could only have been an explosion in the forward cargo hold. It was not possible that any rapid decompression caused by a structural failure could have disrupted the entire electricl power supply from the MEC compartment. In known cases of aircraft being subjected to rapid decompression there has never been such an instantaneous and total stoppage of electrical power and in fact aircrafts have been known to have continued to fly and communicate with the ground even after decompression.

D. Non-supply of Oxygen :

Oxygen supply cylinders are located in the ceiling of the forward cargo compartment. Any rupture of the only pipeline which supplies oxygen to the passengers would result in there being no surge of oxygen flow, which alone drops the oxygen masks. The inspection of the wreckage shows that there is no indication of the oxygen masks ever having dropped. A rupture of this pipeline, simultaneously with power rupture, could only have been caused if there had been a detonation of the explosive device in the front cargo hold.

E. Damage in air :

The examination of the floating and the other wreckage shows that the right hand wing leading edge, the No. 3 engine fan cowl, right hand inboard mid flap leading edge and the leading edge of the right hand stabilizer were damaged in flight. This damage could have occurred only if objects had been ejected from the front portion of the aircraft when it was still in the air. The cargo door of the front cargo compartment was also found ruptured from above. This also indicates that the explosion perhaps occurred in the forward cargo compartment causing the objects to come out and thereby damaging the components on the right hand side.

F. Evidence of Overpressurization :

The examination of the structural panels and the other parts of the forward cargo compartment and the aft cargo compartment, recovered from the sea bed, indicates that overpressure condition had occurred in both the cargo compartments. The failure of the passenger cabin floor panels in upward direction also indicates that overpressure was created in both the compartments. It cannot be disputed that whenever an explosive detonates very high pressure shockwaves are formed which travel in all directions and high speed fragments of the container, or the loose material, also move away from the source of explosion. It is, therefore, clear that there was overpressurization in the cargo compartments which resulted in such rupture of the cabin floor panels.

G. Holes in the front cargo hold panels

While the skin panels of the aft cargo compartment are fairly straight and undamaged, the panels of the front cargo compartment are ruptured and have a large number of holes. This shows that there was occurrence of an event in the front cargo compartment and not in the aft cargo compartment.

H. Buckling of Seats :

The seats towards the rear of the aircraft had only the aft legs buckled, whereas the seats towards the front had both the front and the aft legs buckled. This indicated that the whole floor was subjected to a vertical force and was more severe towards the front. Moreover, the upper deck storage cabin was found among floating wreckage. The bottom of this cabin was pushed up in the shape of a dome with no evidence of impact damage. This deformation was indicative of having been caused, possibly, as a result of a shockwave.

I. Metallurgical Examination Results :

A metallurgical examination, especially of Targets 362 and 399, clearly confirms that there was an explosion in the forward cargo compartment. Microscopy around some of the holes discloses that they have such characteristics like twinning which can be present only if the holes had been puntured due to the detonation of an explosive device.

J. CVR Tape Analysis :

The report of CVR tape analysis by Mr. S.N. Seshadri also corroborates the aforesaid evidence i.e. that there was a bomb in the forward cargo hold of the aircraft.

RECOMMENDATIONS

5.1 ICAO, IATA and the States should :-

(a) undertake an ongoing review of established aviation security standards to prevent the placement of explosive substances on board commercial aircraft;

(b) establish a programme of monitoring the implimentation of security measures in airports around the world, in cooperation with the Governments concerned. For each airport studied, it should report its findings and recomend any improvements that may be required;

(c) consider establishing a group of civil aviation experts to investigate serious breaches of security. The purpose of these investigations would be to determine the facts of an incident so that necessary measures could be developed and implemented world wide to prevent similar breaches in the future.

Note : As it may take some time for ICAO and IATA to implement these recommendations, at least those countries which have international air traffic should take up effective measures without delay.

5.2 ICAO should :-

(a) develop a model clause on security that could be used in the bilateral air agreements that govern the exchange of air traffic rights between countries;

(b) consider establishing standards for the training of security personnel.

5.3 IATA should develop practical procedures for reconciliation of interlined passengers and their baggage at intermediate airports.

5.4 Interlining of checked-in baggage should not be done if a passenger does not have a confirmed reservation on the onward carrier flight.

5.5 The baggage of interlined passengers should be matched with passengers by the onward carriers before loading the baggage on the aircraft.

5.6 Whenever a Government becomes aware of particular high risk security threat it should notify not only the airline at risk, but also all connecting airlines in order that extra precaution can be taken at potential points of introduction of interline baggage into the system.

5.7 When an Airline is aware of a high security threat it should communicate the same to the host state as well as, if possible and prudent, to the other airlines operating there.

5.8 Passenger count should be done at boarding gate and in case of 'no gate show' of a passenger, his baggage must be off-loaded.

5.9 All checked-in baggage, whether it has been screened by X-ray machine or not, should be personally matched and identified with the passengers boarding an aircraft. Any baggage which is not so identified should be off-loaded. This is advisable as examination of the baggage with the help of an X-ray machine has its own limitations and is not fool proof. Some explosives hidden in Radios, Cameras etc. may not be readily detected by such a machine. In fact an explosive not placed in a metallic container will not be detectable by an X-ray machine. Similarly, a plastic explosive can be given an innocuous shape or form so as to avoid detection by an X-Ray. Reliance on an X-Ray machine alone may in fact provide a false sense of security.

5.10 Effectiveness of the instrument known as PD-4 is highly questionable. It is not advisable to rely on it.

5.11 All unaccompanied baggage should be placed on the aircraft after their contents have been physically checked. In the alternative, it should be loaded only after it has been placed in a decompression chamber and the host state is satisfied that the baggage is clean and the shipper has been identified.

5.12 Airlines should have effective backup security equipment or procedures available in case of machanical break down of security equipment.

5.13 All hand baggage, including that of the crew, should be opened and the contents physically checked even if the said baggage has been x-rayed. This will no doubt be a bit time consuming and laborius but if security is to be meaningful, then slight inconvenience has to be endured in order to ensure a safer flight.

5.14 The manufacturers of aircraft should take effective steps for protecting sensitive parts of the aircraft from explosive damage.

5.15 Studies should be undertaken to determine the feasibility of physically separating the avionics bay and emergency oxygen systems from the cargo area in aircraft so that these sensitive and essential areas of the aircraft cannot be damaged or destroyed by a relatively small explosive deivce concealed in luggage.

5.16The seats should have safety belts which can act as restraint for the upper part of the body e.g. like a shoulder harness with inertial restraint.

5.17The seats in the aircraft should be so designed so as to incorporate shock absorbing systems within the seat and they should be manufactured by using material which does not break easily.

5.18In addition to the cockpit voice recorder, there should be in the cockpit a video/scanning camera which would record the movements and the audio sounds in the cockpit. This will not only assist in ascertaining as to how the pilots act during as emergency but, in the case of hijacking, would also assist in the identification of the hijackers.

5.19The CVR should record all the conservation and sounds in the cockpit for the entire duration of the flight, and not merely for the last 30 minutes.

5.20The CVR and the DFDR should be powered from two alternative sources of energy.

5.21The oxygen for the flight crew should be supplied from two different sources i.e. in the event of an emergency the pilot and the co-pilot must don the oxygen mask and the oxygen must be supplied from different source.

5.22Suitable provisions should be incorporated in Annex 13 which would give power to an Investigator to record evidence outside the country of investigation and also to summon witness from abroad. It should also be mandatory on the contracting States to give information sought for by an Investigator.

(B. N. KIRPAL)

February 26, 1986   COURT

We agree with the conclusions and recommendations stated above.

ASSESSORS

(V. Ramachandran) (J.S. Gharia)

(J.S. Dhillon) (J.K. Mehra)

(B.K. Bhasin)

ACKNOWLEDGEMENTS

When I was appointed as the Court to investigate into the accident, the magnitude of the task involved was known. With the help, assistance and cooperation of a team of dedicated workers, the work was, however, completed in not too long time. The assistance received from those who helped me cannot be too highly praised.

From amongst my Assessors, Captian B.K. Bhasin was the only one who was permanently stationed in Delhi. We met for the first time on 15th July, 1985 and little did I realise then that, by the time our work would be over, how much I would be depending upon him. Not only was his advice on the technical aspects of flying and air safety invaluable but, whenever any difficulty or a problem arose, I invariably turned to him for assistance and advice which I readily got. I found him having a very practical and positive approach to all the problems but, at the same time, he very rightly was not prepared to compromise on any principal issues.

The only interest Dr. V. Ramachandran appeared to have was to do his work to perfection. No praise can be too high for the manner in which this Metallurgist from landlocked Bangalore volunteered and boarded the salvage ships which were carrying out operations in the cold and choppy waters of Atlantic Ocean. He sarificed all comforts and went to sea with a view to be present on board the ships at the time when salvaged pieces of wreckage were brought on board. His deep knowledge of metallurgy greatly assisted the examination of the salvaged pieces of wreckage. In this connection the entire metallurgical

examination was planned and organised by him.
Whenever any information was required concerning explosives, Mr. J.S. Gharia was ever eager and in a position to provide the information.
Mr. J.K. Mehra looked into the engineering aspect of the accident and he spent a lot of time in going through various Air-India Maintenance Manuals. He always made discussions very lively and interesting.
Captain J.S. Dhillon came out of his retirement and provided useful information to the Court on some aspects of flying.
This work would never have been satisfactorily completed without the help and assistance received by the Court from late Mr. S.N. Seshadri of Bhabha Atomic Research Centre. From the time when the CVR was first played by him at BARC on 16 July, 1985 till the very end, he most willingly and pleasantly undertook any assignment which was given to him by the Court. It was a great national loss when he suddenly passed away on 2nd February, 1986, only a few days after he had deomonstrated his brilliance when his testimony, regarding the analysis of the CVR tape, was recorded by me in the Court.
I am also grateful to the other Scientists and staff of B.A.R.C. who rendered considerable assistance to the Court. The facilities made available by Dr. P.K. Iyengar, Director, B.A.R.C. with regard to the finalisation and completion of the report cannot be easily forgotten. In the absence of late Mr. S.N. Seshadri, with whom I had developled a personal rapport, Dr. Ashok Mohan and Mr. V.K. Chadda met with all our requirements in the finalisation and preparation of the Report. Dr. Asundi of BARC and the other Metallurgists of that Organisation and of the National Aeronautical Laboratory also spent a considerable amount of their time and energy in successfully carrying out metallurgical tests and examination of the salvaged pieces.
During the investigation I had to visit Ireland on two occasions. I

immediately realised the extent of help, assistance and guidance which was being rendered to all of us by Mr. Kiran Doshi, the Indian Ambassador to Ireland. There was no problem to which he did not have a solution. On my visit to Dublin not only did I enjoy the hospitality of Kiran and his wife Razia but it also gave an opportunity to personally meet Mr. Mitchel, the Minister of Communications, and senior officials of his Ministry, and to express my gratitude to them for all the help and assistance which the Government and people of Ireland had, most willingly, rendered.

At Tokyo the Indian Ambassador and members of his staff looked after all our needs and arranged meetings with the Japanese officials whom we wanted to meet.

As representatives of the Court in Cork, Mr. P.R. Chandrasekhar and Mr. C.D. Kolhe did a commendable job. They kept me informed of the progress which was taking place at Cork and, whenever required to do so, they took vital decisions while coordinating the mapping and salvage operations.

Mr. H.S. Khola, Director of Air Safety, New Delhi willingly carried out all the directions of the Court. Special mention must also be made of Mr. Satendra Singh, Regional Controller of Air Safety, Bombay, who worked day and night when the flight recorders were first opened and the copies of the tapes made and the data analysed.

I have also to express my gratitude to the Counsel who assisted the Court in the Investigation. Without their help and cooperation, it would not have been possible to complete the work in 7-1/2 months.

On my trip to Bombay, the Staff and Management of Centaur Hotel made my stay very comfortable. It was like a home away from home. The work done during the salvage operarations by four young engineers of Air-India was highly commendable and valuable. All of them namely, Mr. Balasubramanium, Mr. L.S.

Carvalho, Mr. G.D. Nayar and Mr. A.K. Sheode, worked round the clock even during adverse climatic conditions.

The Registrar of the Delhi High Court, Ms. Usha Mehra spared no efforts in rendering every assistance whenever the same was required. She ably marshalled all the resources available in the High Court in order to ensure the smooth and efficient functioning of my office. My own personal staff in particular, headed by Mr. V.P. Ahuja, Court Master and Mr. Balram Chopra, Private Secretary, as usual, rose to the occasion. While Mr. Ahuja kept complete control of hundreds of documents and affidavits which had been filed, Mr. Chopra besides bearing the brunt of the typing work, very ably supervised the work of other Stenographers.

It was most fortunate that I was able to persuade Mr. S.N. Sharma to accept the trying job of being the Secretary to the Court. His vast experience in such Investigations, he had been a Secretary in three such Investigations earlier, made my task much lighter. Moreover, as an Aircraft Engineer, he was always ready to explain technical intricacies involved in the case. Without his help I could not have completed my work within the stipulated time.

(B. N. KIRPAL)

26th February, 1986 COURT

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:48 PM PDT
To: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Subject: **AI 182 AAR**

Dear Jaspreet,

I'm sending the AAR for three accidents that directly relate to AI 182, AI 182, PA 103, and UAL 811. TWA 800 is at website:

The answers to AI 182 are in these reports if read with an objective view and the consideratin that all were similar to UAL 811.

Sincerely,
Barry

http://www.ntsb.gov/Publictn/2000/aar0003.htm

Abstract: On July 17, 1996, about 2031 eastern daylight time, Trans World Airlines, Inc. (TWA) flight 800, a Boeing 747-131, N93119, crashed in the Atlantic Ocean near East Moriches, New York. TWA flight 800 was operating under the provisions of 14 Code of Federal Regulations Part 121 as a scheduled international passenger flight from John F. Kennedy International Airport (JFK), New York, New York, to Charles DeGaulle International Airport, Paris, France. The flight departed JFK about 2019, with 2 pilots, 2 flight engineers, 14 flight attendants, and 212 passengers on board. All 230 people on board were killed, and the airplane was destroyed. Visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules flight plan.

The National Transportation Safety Board determines that the probable cause of the TWA flight 800 accident was an explosion of the center wing fuel tank (CWT), resulting from ignition of the flammable fuel/air

mixture in the tank. The source of ignition energy for the explosion could not be determined with certainty, but, of the sources evaluated by the investigation, the most likely was a short circuit outside of the CWT that allowed excessive voltage to enter it through electrical wiring associated with the fuel quantity indication system.

Contributing factors to the accident were the design and certification concept that fuel tank explosions could be prevented solely by precluding all ignition sources and the design and certification of the Boeing 747 with heat sources located beneath the CWT with no means to reduce the heat transferred into the CWT or to render the fuel vapor in the tank nonflammable.

The safety issues in this report focus on fuel tank flammability, fuel tank ignition sources, design and certification standards, and the maintenance and aging of aircraft systems. Safety recommendations concerning these issues are addressed to the Federal Aviation Administration.

Canadian Aviation Bureau canadien Safety Board de la sécurité aérienne AVIATION OCCURRENCE AIR INDIA BOEING 747-237B VT-EFO CORK, IRELAND 110 MILES WEST 23 JUNE 1985 1.0 INTRODUCTION

Air India Flight 182, a Boeing 747-237B, registration VT-EFO, was on a flight from Mirabel to London when it disappeared from the radar scope at a position of latitude 51°O'N and longitude 12°50'W at 0714 Greenwich Mean Time (GMT), 23 June 1985, and crashed into the ocean about 110 miles west of Cork, Ireland. There were no survivors among the 329 passengers and crew members. The depth of the water at the crash site is about 6,700 feet.

At 0541 GMT, 23 June 1985, CP Air Flight 003 arrived at Narita Airport, Tokyo, Japan, from Vancouver. At 0619 GMT a bag from this flight exploded on a baggage cart in the transit area of the airport within an hour of the Air India occurence. Two persons were killed and four were injured. From the day of the occurrences, there have been questions about a possible linkage between the events.

This Submission examines the information available to the Canadian Aviation Safety Board (CASB) with respect to the circumstances surrounding the AI 182 accident. The sources of information include: information made public to the Indian Inquiry as a result of the RCMP investigation; the flight data recorder (FDR), cockpit voice recorder (CVR) and Shannon ATC tape recording analyses by Canadian, United Kingdom, and Indian authorities; the medical evidence obtained from Dr. Hill of the Accident Investigations Branch of the United Kingdom; and the evidence obtained by examination of the wreckage recovered, the wreckage distribution pattern, photographs, and videotapes of the wreckage on the ocean bottom.

2.0 EXAMINATION

2.1 Vancouver

On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight East Indian accent.* He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vancouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of

Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

On the same date at approximately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

On 20 June 1985 at about 1210 PDT (1910 GMT), a male appearing to be of East Indian origin purchased the tickets with cash from a CP Air ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to M. Singh. The telephone contact number was also changed. The final itinerary was as follows:

a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22 June 1985

*See Appendix A for chronology of events.

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22 June 1985

b) L. Singh - CP 003 Vancouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 (local time in Tokyo), 23 June 1985

On 22 June 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy East Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that he was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

On Saturday morning, 22 June 1985, a CP Air passenger agent worked check-in position number 26 at the CP Air ticket counter, Vancouver International Airport, and recalls dealing with a passenger booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto he could not interline his baggage. The passenger insisted and, as the line-ups were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that M. Singh checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage. The flight manifest for CP 003 shows that on the same day the person using the name of L. Singh with a ticket to Bangkok also checked in through the same counter, was assigned seat 38H, and checked one piece of baggage.

A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as M. and L. Singh did not board these respective flights.

2.2 Toronto

Air India Flight 181 from Frankfurt arrived at Toronto on 22 June 1985 at 1430 EDT (1830 GMT) and was parked at gate 107 of Terminal 2. All passengers and baggage were removed from the aircraft and processed through Canada Customs. Passengers continuing on the flight to Montreal were given transit cards, and on this flight 68 cards were handed out. These transit passengers are required to claim their luggage and proceed through Canada Customs. Prior to entering the public area, there is a belt which is designated for interline or transit baggage. Transit passengers deposit their luggage on this belt which carries it to be reloaded on the aircraft. This baggage was not subjected to X-ray inspection as it was presumed to have been screened at the passengers' overseas departure point. When the transit passengers checked in to proceed to Montreal, their carry-on baggage was subjected to the normal security checks in place on this date. Passenger and baggage security checks were conducted by Burns International Security Services Ltd. and all passenger and baggage processing for both off-loading and on-

loading was handled by Air Canada staff.
Air India Flight 181 was composed of the following:
- passengers continuing to Montreal (68)
- passengers from connecting flights

AC	102	(Saskatoon)	2	
AC	106	(Edmonton)	4	
AC	192	(Winnipeg)	1	
AC	170	(Winnipeg)	4	
AC	136	(Vancouver)	10	
CP	060	(Vancouver)	1	Standby (M. Singh)

- passengers originating at Toronto
- diplomatic bags from the Vancouver India Consul General via AC 508
- produce cargo from India
- cargo in the form of 5th pod engine components loaded in the aft cargo compartment.

It should be noted that some passengers from India book flights to Montreal with their intended destination being Toronto. The reason is that the fare to Montreal is cheaper and therefore some passengers get off the flight in Toronto, claim their luggage and leave without reporting a cancellation of the trip to Montreal. It has been established that 65 of the 68 transit passengers reboarded the flight to Montreal.

Air India personnel were in charge for the overall operation at Toronto regarding the unloading and loading of both passengers and cargo. Although the actual work was performed by various companies under contract, Air India personnel oversaw the operation. The Air India station manager was away on vacation on 22 June 1985. The evidence does not clearly establish who had been assigned to replace the station manager and assume his duties.

Air Canada had stored in a hangar an engine that had failed on a previous Air India flight from Toronto on 8 June 1985. Air Canada received a message from Air India stating that the failed engine was to be mounted as a 5th pod on Flight 181/182 on 22 June 1985. The engine was prepared for loading and component parts were crated for loading into the aft cargo compartment. On 22 June, the component parts were taken from the hangar and placed outside to be delivered to the aircraft by MEGA International Air Cargo. The component parts were placed just inside the airport fence separating the restricted and unrestricted areas. The installation began immediately upon the arrival of Flight 181 and was completed at 1530 EDT (1930 GMT). The front engine cowling was crated but would not fit through the aft cargo door. The crating was rearranged, and the door stops on the cargo door were removed to permit the loading of the crate and the remaining engine parts were loaded on pallets. Due to problems with loading the 5th pod and component parts, the departure was delayed from 1835 EDT (2235 GMT) to 2015 EDT (0015 GMT, 23 June).

CP Air Flight 060 arrived in Toronto at 1610 EDT (2010 GMT) and docked at gate 44, Terminal 1. A number of passengers on this flight were interlined to other flights including passenger M. Singh wait-listed on Air India Flight 181/182. It has been established that this passenger did not board Flight CP 060 but did check baggage onto the flight. This baggage was to be interlined to the Air India flight departing from Terminal 2. In this case, CP Air employees would have off-loaded all baggage from CP 060 and deposited the baggage at Racetrack 6 on the ring road of Terminal 1 to be transported to the Air Canada sorting room at Terminal 2.

Consolidated Aviation Fuelling and Services (CAFAS) is a company which is contracted to pick up and deliver baggage from one terminal to the other. The CAFAS driver on duty at the time recalls picking up a bag from a CP Air flight originating in Vancouver and destined for Air India at Terminal 2. As this piece of luggage did not turn up as found luggage, it is deduced that normal practice was followed, and the luggage was interlined and loaded on AI 181/182.

MEGA International Air Cargo is a firm that handled air cargo and containers for Air India. Since the flight was carrying a 5th engine and component parts, no commercial cargo could be loaded at Toronto. MEGA delivered the engine component parts to be loaded in the cargo compartment by Air Canada employees. Later, MEGA received two diplomatic bags and delivered these to the aircraft. The bags were loaded into the valuable goods container (see Appendix B). These bags were not subjected to X-ray or any other security checks.

All checked-in baggage for AI 181/182 was to be screened by an X-ray machine which was located in Terminal 2 at the end of international belt number 4. This location would permit all baggage from the check-in counters and interline carts to be fed through the X-ray machine before being loaded. It has been established that this machine worked intermittently for a period of time and stopped working during the loading process at about 1700 EDT (2100 GMT). Rather than opening the bags and physically inspecting them, the Burns security personnel performing the X-ray screening were told by the Air India security officer to start using the hand-held PD-4 sniffer.

One Burns security officer checked the bags with the sniffer while another put stickers on the bags and forwarded them. The security officer forwarding the baggage recalls the sniffer making short beeping noises not long whistling ones. The security officer who used the sniffer claims it never went off, and the only time any sound was made was when it was turned on and off. At those times, it would emanate a short beep (refer to section 2.8 for further information regarding the PD-4 sniffer).

Burns International Security had a contract with Air India for the security of the aircraft while it was docked. The security arrangements contracted from Burns were as follows:

- security at the bridge door leading to the aircraft;
- security inside the aircraft from the time the passengers disembarked upon flight arrival until flight departure;
- security guards assigned the physical inspection of all carry-on baggage in the departure room; and
- security guards in the international baggage make-up room conducting screening of baggage using an X-ray machine and a hand-held PD-4 sniffer.

The statements taken from Burns security personnel in Toronto indicated that a significant number of personnel, including those handling passenger screening, had never had the Transport Canada passenger inspection training program or, if they had, had not undergone refresher training within 12 months of the previous training.

As a result of official requests made by Air India in early June 1985 for increased security for Air India flights, the RCMP provided additional security as follows:

- one member in a marked police motor vehicle patrolling the apron area;
- one member in a marked police motor vehicle parked under the right wing from time of arrival until push-back;
- one member on foot patrol at Air India check-in counter; and
- one member at the loading bridge during boarding.

In addition, all RCMP members working in that particular area of Terminal 2 were aware of the Air India flight and would check in with the assigned personnel during their patrols in the area of the aircraft and check-in/boarding lounges. Uniformed members are to patrol and monitor security within the airport premises as detailed in section 2.5 below.

Passenger check-in was handled for Air India by Air Canada under contract with Air India. The check-in included passengers originating in Toronto and interline passengers but did not include the transit passengers to Montreal. The check-in passengers were numbered using a security control sheet in accordance with instructions from Air India; however, the check-in and interline baggage was not numbered, and no attempt was made to correlate baggage with passengers. Hence, any unaccompanied interline baggage would not have been detected.

The flight and cabin crew had been in Toronto for the week prior to this flight and were to take the aircraft to London where they would be replaced by another crew. The crew members themselves and their carry-on baggage were not subjected to any security checks; however, their checked-in baggage was screened in the same manner as other baggage.

2.3 Montreal

Air India Flight 181 from Toronto arrived at Mirabel International

Airport at about 2100 EDT (0100 GMT, 23 June) and parked in supply area number 14 at 2106 EDT (0106 GMT). The 65 passengers destined for Montreal along with three Air India personnel deplaned and were transported by bus to the terminal building. The remaining passengers remained on board as transit passengers and were not permitted to disembark at Montreal. Air Canada baggage handlers off-loaded four containers of cargo, three containers of baggage and a valuables container. Two diplomatic pouches from the Indian High Commission in Ottawa were delivered to the aircraft by MEGA International Cargo. One pouch weighing one kilogram was hand-delivered to the flight purser for storage in a valuables locker within the cabin and the other pouch was loaded into the valuables container.

During the check of the aircraft at Montreal, the second officer pointed out to an Air Canada mechanic that a rear latch on the fan cowl for the 5th engine did not appear to be properly secured. The mechanic examined the latch and found it well secured, but the handle was not flush and was hanging about five degrees. The mechanic applied high-speed tape to the latch handle for aerodynamic smoothness. This repair was examined by the second officer who was satisfied with the work. No records were completed by Air Canada in connection with this temporary repair.

At about 1730 EDT (2130 GMT), Air Canada, which is Air India's contracted agent, opened its check-in counter to passengers who would be flying on Air India Flight 182. Burns security personnel were also assigned at this time to screen the checked baggage. Passenger tickets were checked, issued a number, and copies of the tickets were removed and retained by Air Canada. Boarding passes were then issued and affixed to the numbered tickets. Also attached to the ticket booklets were numbered tickets which corresponded to each piece of checked baggage. The numbered checked baggage was sent to the baggage area by Air Canada personnel to be security-checked by Burns security personnel. The passengers for AI 182 after checking in were free to enter the departure area. At the entrance to the departure area, Burns security staff used X-ray units and metal detectors to screen passengers and carry-on baggage. At about 2100 EDT (0100 GMT), the passengers proceeded to gate 80 where they gave their boarding passes and numbered tickets to an Air Canada agent. The agent kept the numbered flight tickets and checked the numbers against the passenger list. Also, at gate 80, a secondary security check was done on passengers by a Burns security officer using a metal detector. Hand-carried baggage was subjected to further physical and visual checks. A total of 105 passengers boarded the flight at Mirabel Airport; there were no interline passengers.

Between 1900 (2300 GMT) and 1930 EDT (2330 GMT), Burns security personnel identified a suspect suitcase using the X-ray machine. The suitcase was placed on the floor next to the machine. The Burns security supervisor told Air India personnel that a suspect suitcase had been located and was advised within 15 to 20 minutes to wait for the Air India security officer who would be arriving on the flight from Toronto. Subsequently, a second suspect suitcase was identified and a little later a third. The three suitcases were placed next to the X-ray machine.

Between 1930 (2330 GMT) and 1945 (2345 GMT), all the Burns security personnel at the X-ray machine were assigned to other duties and the three suspect suitcases remained in the baggage area without supervision. At about 2140 (0140 GMT), the Air India security officer went to the baggage room and inspected the three suitcases with the X-ray machine and a sniffer that was in the possession of the security officer. The Air India security officer decided to keep the three suitcases and, if further examination proved negative, send them on a later flight.

At approximately 2155 (0155 GMT), the Air Canada Operations Centre supervisor contacted the airport RCMP detachment regarding the suspect suitcases. At about 2205 (0205 GMT), an RCMP member located the suitcases in the baggage room and requested that an Air India representative be sent to the baggage room. About five minutes later, the Air India security officer contacted the baggage room by telephone and advised that he could not come to the room immediately. The Air India security officer arrived in the baggage room at about 2235 (0235 GMT) and, when asked to determine the owners of the suitcases, informed the RCMP member that the flight had already departed [2218 (0218 GMT)].

The three suspect suitcases were later examined with negative results. The remainder of the checked baggage which cleared the security check was identified by a green sticker. The baggage was then forwarded to Air Canada personnel who loaded the baggage in containers to be placed on board the aircraft. A later check with Canada Customs and Air Canada at Mirabel revealed no unclaimed baggage associated with AI 181/182. A similar check at Dorval Airport was conducted with negative results.

No record was kept as to the location and number of individual pieces of checked-in luggage. Records were kept as to the location of the containers according to destination, where loaded and the number of pieces of luggage in each container (see Appendix B).

The Mirabel Detachment of the RCMP provided the following security at the airport on 22 June 1985:

- one member in a police vehicle for airside security;
- one member on patrol in the arrival and departure areas;
- one member on general foot patrol throughout the terminal; and
- one member as a telecommunications operator in the detachment office.

In addition, due to the increased threat to Air India flights, the RCMP provided the following supplementary coverage to Air India Flight 181/182 on 22 June 1985:

- one member in a police vehicle escorted the aircraft to and from the runway and the terminal building and remained with the aircraft while it was stationary;
- one member in a police vehicle remained at the entrance to the ramp;
- two members patrolled the area of the ticket counter and access corridors, and one of these members also served in a liaison capacity with the airline representatives.

2.4 International Standards and Recommended Practices

International security standards and recommendations to safeguard international civil aviation against acts of unlawful interference are listed in ICAO Annex 17 to the Convention on International Civil Aviation. Suggested security measures and procedures are amplified in the ICAO Security Manual for Safeguarding Civil Aviation Against Acts of Unlawful Interference.

Annex 17 requires contracting States of which Canada is one to "take the necessary measures to prevent weapons or any other dangerous devices, the carriage or bearing of which is not authorized, from being introduced by any means whatsoever, on board an aircraft engaged in the carriage of passengers."

In addition to other recommendations, Annex 17 recommends that contracting States should establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage, cargo, mail and stores to be carried on board aircraft.

The Security Manual specifies that,

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Recently, ICAO has proposed amendments to Annex 17. These proposals arise from a decision taken by the Council in its 115th Session on 10 July 1985. The Council instructed its Committee on Unlawful Interference, as a matter of urgency, to review the entirety of Annex 17 and to report on those provisions which might be immediately introduced, upgraded to Standards, strengthened or improved. Among the proposed amendments is the following upgrading in the Standards:

- Each contracting State ensure the implementation of measures at airports to protect cargo, baggage, mail stores and operator's supplies being moved within an airport to safeguard such aircraft against an act of unlawful interference.

2.5 Canadian Law

In terms of Canadian statutory requirements, the Civil Aviation Security Measures Regulations and the Foreign Aircraft Security Measures Regulations made pursuant to the Aeronautics Act require specified owners or operators of aircraft registered in Canada or specified owners or operators who land foreign aircraft in Canada to establish, maintain, and carry out security measures at airports consisting of:

- systems of surveillance of persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;

- systems of searching persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas that are inaccessible to any person other than a person who has been searched and the personnel of the owner or operator;
- a system that provides, at airports where facilities are available, for check-points at which persons intending to board the aircraft of an owner or operator can be searched;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas in which cargo, goods and baggage that have been checked for loading on aircraft are inaccessible to persons other than those persons authorized by the owner or operator to have access to those areas;
- a system of identification that prevents baggage, goods and cargo from being placed on board the aircraft if it is not authorized to be placed on board by the owner or operator; and
- a system of identification of surveillance and search personnel and the personnel of the owner or operator.

Specified carriers including Air Canada, CP Air, and Air India were required to provide a description of their security measures to the Canadian Minister of Transport.

An Order-in-Council on 29 September 1960 established that the RCMP was responsible for the direction and administration of police functions at major airports operated by Transport Canada. The duties of the Police and Security Detail at these designated airports include the following:

- carry out policing and security duties to guard against unauthorized entry, sabotage, theft, fire or damage;
- enforce federal legislation;
- respond to violations of the Criminal Code of Canada, Federal, Provincial, and Territorial statutes, and perform a holding action pending arrival of the police department having primary criminal jurisdiction;
- man guard posts; and
- provide a police response in those areas of airports where pre-board

screening takes place.
Section 5.1(9) of the Aeronautics Act states that "The Minister may designate as security officers for the purposes of this section any persons or classes of persons who, in his opinion, are qualified to be so designated." Pursuant to this section Transport Canada has established criteria for persons or classes of persons that are designated as security officers in a Schedule registered on 11 April 1984. The criteria also specify that a security guard company and its employees will meet Transport Canada requirements provided that the company:

- is under contract with a carrier to conduct passenger screening under the Aeronautics Act and Regulations;
- is licensed in the province or territory;
- complies with the security guard criteria as follows in that the guard must:
  - be 18 years or older,
  - be in good general health without physical defects or abnormalities which would interfere with the performance of duties,
  - be licensed as a security guard and in possession of the licence while on duty, and
  - meet the training standards of Transport Canada consisting of successfully completing the Transport Canada passenger inspection training program, attaining an average mark of 70 per cent, and undergoing refresher training within 12 months from previous training;
- uses a comprehensive training program which has been approved by Transport Canada and is capable of being monitored and evaluated;
- keeps records showing the date each employee received initial training and/or refresher training and the mark attained; and
- provides supervision to ensure that their employees maintain competency and act responsibly in the conduct of searching passengers and carry-on baggage being carried aboard aircraft.

2.6 Canadian Security Procedures

In accordance with the Canadian Aeronautics Act and pursuant regulations, air carriers are assigned the responsibility for security. Transport Canada provides the following security services for the air carriers using major Canadian airports, including the international airports in Vancouver, Toronto and Montreal:

- security and policing staff including RCMP airport detachments;
- specific airport security plans and procedures;
- secure facilities (e.g., secure areas, pass identification systems, etc.); and
- security equipment and facilities (e.g., X-ray detection units, walk-through metal detectors, hand-held metal detectors, explosive detection dogs).

As of 22 June 1985, the following general security measures were in place at Canadian airports:

- metal detection screening of passengers; and
- X-raying of carry-on baggage.

Checked baggage was not normally subject to any security screening. A few air carriers such as Air India had extra security measures in place because of an assessed higher threat level (see section 2.7 below).

On 23 June 1985, Transport Canada required additional security measures to be implemented by all Canadian and foreign air carriers for all international flights from Canada except those to the continental United States. These measures required:

- the physical inspection or X-ray inspection of all checked baggage;
- the full screening of all passengers and carry-on baggage; and
- a 24-hour hold on cargo except perishables received from a known shipper unless a physical search or X-ray inspection is completed.

Further, on 29 June 1985, Transport Canada directed that all baggage or cargo being interlined within Canada to an Air India flight was to be physically inspected or X-rayed at the point of first departure and that matching of passengers to tickets was to be verified prior to departure.

2.7 Air India Security Program in Canada

In accordance with the Foreign Aircraft Security Measures Regulations, Air India had provided the Minister of Transport with a copy of its security program. It included measures to:

- establish sterile areas;
- physically inspect all carry-on baggage by means of hand-held

devices or X-ray equipment;
- control boarding passes;
- maintain aircraft security;
- ensure baggage and cargo security; and
- off-load baggage of passengers who fail to board flights.

Under these procedures established by Air India, passengers, carry-on baggage, and checked baggage destined for AI 181/182 on 22 June 1985 were subjected to extra security checks. A security officer from the Air India New York office arrived in Toronto on 22 June 1985 to oversee the security operation at Toronto and Montreal.

On 17 May 1985, the High Commission of India presented a diplomatic note to the Department of External Affairs regarding the threat to Indian diplomatic missions or Air India aircraft by extremist elements. Subsequently, in early June, Air India forwarded a request for "full and strict security coverage and any other appropriate security measures" to Transport Canada offices in Ottawa, Montreal and Toronto, and RCMP offices in Montreal and Toronto.

2.8 PD-4 Sniffer

On 18 January 1985, prior to the inaugural Air India flight out of Toronto on 19 January, a meeting on security for Air India flights (Toronto) was held with representatives from Transport Canada, RCMP and Air India. At this meeting, a PD-4 sniffer belonging to Air India was produced. It was explained that it would be used to screen checked baggage as the X-ray machine had not yet arrived. At that time, an RCMP member tested its effectiveness. The test revealed that it could not detect a small container of gunpowder until the head of the sniffer was moved to less than an inch from the gunpowder. Also, the next day the sniffer was tried on a piece of C4 plastic explosives and it did not function even when it came directly in contact with the explosive substance. It is not known if this was the same sniffer used on 22 June 1985.

2.9 Medical Evidence

Medical examination was conducted on the 131 bodies recovered after the accident. This comprises about 40 per cent of the 329 persons on board. It should be noted that assigned seating is based on preliminary information. Also, the exact position of passengers is not certain because it is not known if passengers changed their seats after lift-off. On the information available, the passengers were seated as follows:

Passengers:*

Seats Bodies

	Available	Occupied	Identified
Zone A	16	1	0
Zone B	22	0	0
Upper Deck	18	7	0
Zone C	112	104 + 2	29
Zone D	86	84 + 1	38
Zone E	123	105 + 3	50
SUB-TOTAL	377	301 (+6 infants)	117
Crew:			
Flight Deck	3	3	0
Cabin	19	19	5
TOTAL	399	329	122

There were 30 children recovered and they showed less overall injury. The average severity of injury increases from Zone C to E and is significantly less in C than in Zones D and E.

Flail pattern injuries were exhibited by eight bodies. Five of these were in Zone E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E.

There were 25 bodies showing signs of decompression, including 7 children. They were evenly

*See Appendix C for interior seating arrangement.

distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft

(4 in Zone C, 5 in Zone D, 11 in Zone E, 2 crew and 1 unknown), and 16 had little or no clothing.

Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

There is a general absence of signs indicating the wearing of lap belts.

Pathological examination failed to reveal any injuries indicative of a fire or explosion.

2.10 Flight Recorders and Shannon Air Traffic Control (ATC) Tape Analyses

VT-EFO was equipped with a Fairchild A100 Cockpit Voice Recorder (CVR) and a Lockheed 209E Digital Flight Data Recorder (DFDR). These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the aft pressure bulkhead. The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor.

The Shannon Air Traffic Control Centre was in contact with VT-EFO and recorded radio communications with the aircraft. At the time of the accident, 5.4 seconds of noise was recorded, and the transponder signal seen on the radar scope was lost from the aircraft. This signal which displays aircraft altitude showed no deviation before disappearing from the radar scope.

2.10.1 Analysis by National Research Council, Canada

From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder. The initial waveform of the cockpit area microphone signal is not consistent with the sharp pressure rise expected with detonation of an explosive device close to the flight deck, but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, the possibility that it originated from such a device elsewhere in the aircraft cannot be excluded.

By correlating the oscillograph records of the CVR and the Shannon ATC VHF recording, it was estimated that the unusual sounds recorded on the ATC tape started 1.4 ± 0.5 seconds after the start of the sudden sound detected by the cockpit area microphone and lasted intermittently for 5.4 seconds. It was felt the closeness in time of the two noises indicated the 5.4 seconds recorded on the ATC tapes originated from AI 182. The ATC recording that followed the cockpit area microphone sounds appeared at first to contain a series of short intermittent sounds. Listening to the sounds, it also appeared that a human cry occurred near the end of the recording. Spectral analysis of these sounds and comparison with voice imitations revealed that the recorded sounds do not contain all the pitch harmonic frequencies normally associated with voice sounds. The origin of these sounds has not been determined.

An examination of the DFDR showed no abnormal variations before the accident. With the spare engine, this aircraft was restricted to altitudes below 35,200 feet and indicated airspeeds less than 290 knots. During the last 27 minutes of the flight, the computed airspeed did gradually increase to nine knots above this limit in the first part of this period and the power was readjusted several times. The speed fell below the 290 knot limit at about 07h:09m GMT as recorded by the DFDR; power was increased again at about 07h:10m causing the aircraft to accelerate to six knots above the limit by the time the accident occurred at 07h:13m:59s. The observed excursions outside the specified limits are not considered significant.

The aircraft was flown with 1.5-degree left-wing-down with 4.2 degrees clockwise control wheel as compared to the aircraft without the 5th engine installation. Also, 9.4 per cent of right rudder pedal was applied giving a 1.1-degree right deflection of the upper and lower rudders.

Considering the carriage of the 5th engine on the left side, these figures are not considered abnormal.

When synchronized with the other recordings, it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR.

Irregular signals were observed over the last 0.27 inches of the DFDR tape. Laboratory tests indicated that the irregular signals most likely occurred as a result of the recorder being subjected to sharp angular accelerations about the lateral axis of the recorder, causing rapid changes in tape speed over the record head. This equates to an angular acceleration on the recorder about the aircraft's longitudinal axis in a left-wing-down sense. Therefore, these tests indicate that the digital recorder was subjected to a sharp jolt separate from any violent motion of the aircraft.

The other possibility for the irregular signals is that the Flight Data Acquisition Unit which generated the serial digital data signal and which is located in the electronics bay under the cabin floor forward of the cargo compartment could have suffered some damage or had an intermittent power supply that caused it to generate the irregular signals.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom

The AIB analysis was restricted to the CVR and the Shannon ATC tape. The correlation of the CVR and ATC tapes showed that the ATC recording started after the CVR had stopped recording and 1.1 ± 0.4 seconds from the start of the sudden sound. The total duration of the signal on the ATC tape was 5.4 seconds.

An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Evidence of the presence of audio warning signals buried amongst the noise was investigated with negative results. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.

The analysis of the ATC tape audio determined three or four words could be heard at the beginning of the transmission, but extensive filtering did not allow the sounds to be transcribed. Two bursts of tone occurred during the first second. The spectrum of the tone does not coincide with any B747 audio warning. The transmission is chopped until at about 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound is similar to that heard in other accidents where there has been a rapid increase in airspeed. Toward the end of the transmission a crying sound was heard; however, a study of the noise indicates a human cry would contain more harmonics. The origin of this sound was not determined. Knocking sounds were also heard during the transmission. These were initially thought to be due to hand-held microphone vibration, but this was discounted because of the frequency of the sounds. Almost identical sounds were heard on the DC-10 CVR after the explosive decompression had occurred. Their source was not identified. On the DC-10, the pressurization audio warning sounded 2.2 seconds after the decompression. No such warning was identified on the ATC tape.

*Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization. A loud noise is associated with this event but not necessarily an explosion.

Every aircraft provides a different signature when the press-to-transmit button is released. These signatures were compared with transients which occurred during the open microphone transmission. There is a close match with the previous AI 182 signatures. Therefore, it is almost certain that the ATC tape recording originated from AI 182.

The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182. It further states there is strong evidence to suggest a sudden explosive decompression of undetermined origin occurred.

Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. However, the AIB report is of the opinion that the device would have to be small not to be detected as it is considered that a large high-explosive device could not fail to be detected on the CVR.

2.10.3 Analysis by Bhabha Atomic Research Centre (BARC), India

The BARC analysis was restricted to the CVR and the Shannon ATC tape.

Channel 3 of the recording which corresponded to the cockpit area microphone showed the first indication of a rising audio signal. The signal level rises from the ambient level in the cockpit by about 18.5 decibels in approximately 45 milliseconds. The signal starts falling and stabilizes at a level about 10 decibels higher than ambient for about 375 milliseconds. The total duration of the signal is about 460 milliseconds.

The timings of the CVR and the Shannon ATC tape were correlated, and it was determined that the explosive sound on the CVR coincided with the beginning of the series of audio bursts on the ATC tape. The report concluded that the sounds recorded on the ATC tape emanated from AI 182 at the time of the occurrence.

The noise on the CVR was compared with an explosion which caused the crash of an Indian Airlines B737. In this occurrence, the explosive sound recorded on the cockpit area microphone showed a rise time of about 8 milliseconds. It was also determined that the explosion occurred 8 feet from the microphone. The report concluded that the rise time is a measure of the distance from the cockpit area microphone to the source of an explosion. Hence, the exact location in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the cockpit judging from the rise time of 45 milliseconds.

The report concluded that the series of audio bursts on the ATC tape were most probably generated by the break-up of AI 182 in mid-air.

2.11 Aircraft Structures Examination

The examination of aircraft structures consisted of the following areas: floating wreckage, wreckage mapping and surveying, wreckage distribution, photographic and video interpretation of wreckage, wreckage recovery and initial examination, and examination of recovered wreckage.

2.11.1 Floating Wreckage

During the search, aircraft wreckage was sited and recovered by several search vessels. The wreckage was transported to Cork, Ireland, where preliminary examination was conducted. This examination took place in June and July, 1985.

The wreckage consisted mainly of various leading edge skin panels of the left and right wings, left wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canoe fairing pieces, landing gear wheel well doors, pieces of elevator and aileron, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggage, suitcases, personal effects and a number of internal fittings. The floating wreckage constitutes about three to five percent of the aircraft structure.

The wreckage was then transported from Ireland to Bombay, India where it underwent further examination by the Floating Wreckage Structures Group which then produced a report which was submitted to the Indian Inquiry. The report concluded:

- There was no evidence of fire damage.
- There was no evidence of lightning strike damage.
- The cabin floor panels from the forward and rear sections of the aircraft separated from the support structure in an upward direction (floor to ceiling) pulling free from the attaching screws and, in some cases, breaking the vertical web of the seat track/floor beams.
- The position of the leading edge flap rotary actuator and the damage to the flap structure indicated that the leading edge flaps were in the retracted position.
- The six spoiler actuators found were in the retracted position. The lower surface of all the spoiler panels showed signs of spanwise skin splits with the edges curled into the core of the honeycomb. The report concluded that this was possibly due to the loading of the spoilers by being deployed in flight at high speed, resulting in compression on the

lower surfaces. This, in turn, caused splitting of the lower skin into the honeycomb.

- The right wing root leading edge, number 3 engine inboard fan cowling, the right inboard midflap inboard leading edge, and the right stabilizer root leading edge all exhibited damage possibly due to objects striking the right wing and stabilizer before water impact.

In addition to the above conclusions, the following significant information regarding the floating wreckage is noted in the report:

- The aircraft was carrying a -7Q engine at the 5th pod and a -7J 5th pod kit in the aft cargo compartment. In all there were 14 engine fan cowls (four in the aft cargo compartment). Out of these 14 fan cowls, nine, including six from the working engines and three from the aft cargo compartment, and two additional pieces of fan cowls were found. Five of the fan cowls from the working engines showed folding damage lines at about the three and nine o'clock positions. The number 3 engine inboard fan cowl had severe impact damage on its leading edge and had small outward puncture holes but no penetration through the outer skin in the lower centre region. The two fan cowls of the -7J 5th pod kit stowed in the aft cargo compartment showed severe damage. One piece was cut at one corner in an arc of about 20 inches diameter and its external skin was peeled back.
- The cockpit entry door and the side bulkhead panel were found relatively intact but had come out of their attachments.
- Twelve toilet doors out of 16 were found and were relatively intact but had come out of their attachments.
- Cabin interior panels and overhead bins of the main and upper decks which were recovered exhibited only minor damage.
- The wooden boxes which contained the fan blades of the 5th pod engine were loaded in container 24L in the forward cargo compartment and were found broken apart exhibiting no burn marks.
- One passenger oxygen bottle and one portable oxygen bottle were recovered and showed no sign of damage.

Mr. V.J. Clancy, an aviation explosives expert representing Boeing Aircraft Corporation, prepared a preliminary report based on his examinations of certain items of recovered and floating wreckage. Mr. Clancy's report notes the following with respect to floating wreckage:

- A foam-backed floor panel which showed a small number of perforations was recovered. Mr. Clancy recommended that it should be X-rayed and a detailed examination completed.
- One of the lavatory doors had, into its inner surface, a number of fragments of glass mirror - presumably from breakage of a mirror normally fitted into the lavatory. Most of the fragments, buried edgeways, were oriented parallel to each other. The remainder were approximately at right angles to the others. Mr. Clancy concluded that it would be improbable that any reliance could be placed on the penetration by mirror fragments as being indicative of an explosion.
- Three steel oxygen cylinders which were stowed in the forward cargo compartment were recovered. One had been dented apparently by the impact of an object measuring about one to two centimetres. The depression had a maximum depth of about four millimetres.
- A few suitcases recovered among the floating wreckage were examined. Mr. Clancy felt that one might provide useful information. It was of red plastic material with a blue lining. Mr. Clancy reported that plastic material has been found to retain identifiable traces of explosive after long immersion in the sea. Also, the lining which was severely tattered resembled that of one found after an explosion in an aircraft in Angola.
- A wooden spares box was found on the foreshore of Wales. It was of the kind used on the aircraft. It was charred on one side and partially on the bottom. The depth of charring suggested that the burn time was three to four minutes. This box was normally stowed in the aft cargo compartment; however, on this flight it may have been stowed in the forward compartment.
- Two pieces of the cover of an overhead locker originating above either door 2R or 4R were also found on the foreshore. They were partially damaged and blackened by fire. Mr. Clancy concluded that this indicated the presence of fire.
- Two pieces of U-section alloy channel partially filled with plastic

foam were found on the foreshore. The alloy was of a kind not used in aircraft structure; however, it could have been from some fitting supplied by a sub-contractor. Also, since the pieces were found near an area where practice firings at targets are carried out off the west coast of the United Kingdom, it could have come from some other source. One piece of the alloy bore marks ("mooncraters") typical of an attack by very high velocity fragments such as produced by an explosion. X-rays showed the presence of a few small particles buried in the foam which Mr. Clancy recommended should be extracted and examined. He also felt that this provided the strongest single indication of an explosion and that it was essential to determine if these pieces came from the aircraft or any of the equipment or cargo aboard the aircraft.

The CASB in its examination of the floating wreckage noted the following:

- The fan cowls of the number 4 engine had a series of five marks in a vertical line across the centre of the Air India logo on the inboard facing side of the fan cowl. These marks had the characteristic airfoil shape of a turbine blade tip. It is possible that a portion of the turbine parted from the number 3 engine and struck the cowl of the number 4 engine.
- The upper deck storage cabinet which was located on the left side had unusual damage to its bottom. A large rounded dent in the bottom inboard edge of this stiff cabinet structure revealed smooth stretching without breakthrough. The damage did not seem to be achievable by inertia or impact forces as the cabinet except for the bottom was undamaged. The damage was considered by a CASB investigator to be compatible with the spherical front of an explosive shock wave generated below the cabin floor and inboard from the cabinet; however, it is not known if this damage could be caused by some other means.
- The right wing root fillet which faired the leading edge of the wing to the fuselage ahead of the front spar had a vertical dent similar to that which would have resulted had the fillet run into a soft cylindrical object with significant relative velocity. The paint on the inboard chord appeared to be scorched brown in the centre areas of three honeycomb panels. It has been determined that sudden heat can turn these panels

brown, but it is not known if other reasons for the discolouration exist. The fillet abutted the fuselage side at the aft end of the forward cargo compartment.

- There was blackened erosion damage to the bottoms of some seat cushions. The damage had an appearance similar to that which would have been caused by an explosive device. It is not known if marine life feeding on the cushions or some other cause could have produced the same effect.
- The charred wooden spares box contained some sand and small shellfish. The flesh from the shellfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

An electronic device was found among some floating wreckage and was forwarded to the Bhabha Atomic Research Centre for analysis. There was some concern that it could have been used to detonate an explosive device. The device was forwarded to the RCMP who in conjunction with the CASB determined it to be an item manufactured for use in radiosondes (weather balloons) and was not modified as a detonating device.

2.11.2 Wreckage Mapping and Surveying

The Canadian Coast Guard Ship (CCGS) John Cabot was given the task of mapping the wreckage on the ocean floor. On 19 July 1985, the Cabot with a SCARAB deep submersible on board departed Cork. On arrival at the site, and based on surface wreckage distribution and bottom side scan sonar plots, four transmitters were placed on the sea bed. These transmitters provided signals for the ALLNAV navigation system used to accurately plot the sea bed wreckage.

Based on all the data available, the SCARAB was launched on 24 July 1985 to begin the bottom search in position 51°01.9'N 12°41.0'W. During the mapping, stage areas were designated for search and each progressive area was determined based on the information gained during the search. The search was conducted using sonar and video. Wreckage found was recorded on video tape and on 35mm positive film.

The first object plotted on the sea bed was a torn suitcase located at lat 51°02.63'N, long 12°53.15'W and was the most westerly object located.

This suitcase has not been recovered, nor has it been positively identified as having come from the accident aircraft.

As the search progressed eastward, the first positive identification of aircraft wreckage was made at lat 51°02.9'N, long 12°49.93'W. Slowly, over a period of about 90 days, a detailed bottom wreckage plot was developed.

While mapping was in progress, some of the wreckage was revisited to obtain additional data. During the transit through areas already searched, wreckage not previously plotted was found, and, in some areas, the density of wreckage physically precluded 100 per cent coverage.

Components and major structural items were identified from all sections of the aircraft and when the mapping of the sea bed ended, most of the aircraft had been found and photographed. Although positive identification of each piece of wreckage could not be made, it was decided in late October 1985 that the search phase was essentially completed and wreckage recovery could begin. A bottom wreckage distribution plot is contained separately in an envelope as Appendix F.

2.11.3 Wreckage Distribution

The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling on the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled.

Although badly damaged, sections 41, 42 and 44*, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is

probable that some of the wreckage may not have been plotted or photographed.
Sections 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the westernmost identified aircraft component located at lat 51°02.90'N and long 12°50.1'W. The wreckage extended in a line about 110 degrees True to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern.
A?? third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southeast orientation. One of the operating engines was displaced 0.5 nautical miles to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.
*See Appendix D for location of aircraft sections and aircraft body stations (BS).

2.11.4 Photographic and Video Interpretation of Wreckage

2.11.4.1 Photographic Interpretation

All wreckage sighted was recorded on video tape and all major items were recorded on 35mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage patterns. For example, the sine wave bending of target 7* appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into account.

2.11.4.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

2.11.4.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gear were in the 'up' position at the time of impact.

2.11.4.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

*See Appendix E for location of targets on aircraft.

2.11.4.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

2.11.4.6 Section 42

Portions of section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers.

All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

2.11.4.7 Section 44

Section 44, containing the aircraft structure between body station (BS) 1000 and BS 1480 including that area where the fuselage and wings were mated was located in the same general area as the forward sections of the aircraft. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one-third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gear were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

2.11.4.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northernmost area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

2.11.4.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of BS 1480 and, for purposes of this Submission, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were identified (targets 35, 37, 73 and 296), and one portion of the bulkhead was never located. Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognizable as having come from a specific area of the aircraft.

Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from BS 1600 to BS 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

The tail cone and the auxiliary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure of air or water.

The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabilizer was missing and the auxiliary spar was exposed. There was localized damage to the right-hand root of the leading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

2.11.4.10 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from sections 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42, and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat-belts were not fastened.

2.11.5 Wreckage Recovery and Initial Examination

During the wreckage mapping, some small items were recovered, and an unsuccessful attempt was made to recover a portion of the forward cargo door. On completion of the sea bed survey, an offshore supply ship, Kreuztrum, chartered by the National Transportation Safety Board (NTSB), joined John Cabot for a wreckage recovery operation. Prior to the commencement of the wreckage recovery, the structures group met at the Boeing facility in Seattle, USA and reviewed the video tapes and photographs of the wreckage. Based on their findings, a list of items was identified as being most desirable for recovery. The priority list was prepared by a group in Cork, Ireland, headed by Dr. V. Ramachandran. On 8 October 1985, the John Cabot sailed, and on 9 October 1985, the Kreuztrum sailed for the accident site. The following target numbers and items were recovered during the mapping and wreckage recovery stages of the investigation: 7, 8, 35, 47, 117, 193, 223, 245, 287, 296, 299, 362/396, and 399 (as the location on the aircraft of some of the targets was not known when Appendix E was created, some are not shown in the appendix). The first officer's seat, some suitcases and small debris were also recovered using a metal frame basket. Initial examination of the wreckage was carried out in Cork and then it was transported to Bombay for detailed examination.

2.11.6 Examination of Recovered Wreckage

Although all the recovered wreckage was examined, only those items exhibiting characteristics which provided some evidence as to what may have happened to the aircraft during its final moments of flight are discussed. CASB engineering personnel and other participants examined the recovered wreckage at Cork and Bombay. The observations made during their examinations are discussed below.

2.11.6.1 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from BS 1480 to 1860 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear, and the torn edge was buckled in waves, like the trace of a sine wave. On the right side, between the one-quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at BS 1480. The skin tear located at about BS 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distorted and elongated.

The left and right trunnion vertical support fittings located at BS 1480 were examined optically using the stereomicroscope. Both trunnions were fractured through the three bolt holes. The right fracture characteristics were consistent with an overload mode of failure. Although most of the left fracture surface was also characterized by overload features, there were heavily corroded areas where the fracture mode could not be confirmed through optical examination. One lug fracture was sectioned from the left trunnion and prepared for scanning electron microscope (SEM) examination. After the corroded area was cleaned, the examination revealed some ductile characteristics on the fracture surface. There was no evidence of intergranular fracture observed to suggest a stress corrosion cracking mode of failure, nor was there any evidence of progressive failure observed. The corrosion appeared to have developed after the accident.

2.11.6.2 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from BS 1860 to 1960 and from stringer 46L to 46R. A small section from the aft end along the belly skin splice at stringer 46L was removed for examination. SEM examination revealed that the fracture was characterized by slightly elongated ductile dimples along its length, including areas adjacent to the edges of the rivet holes. On the aft edge of each rivet hole examined, a distinctive shear lip was observed. These features are consistent with an overload mode of failure along the skin splice with an apparent direction of failure from aft to forward.

2.11.6.3 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 o'clock position. The piece from 12 to 1 o'clock had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 o'clock position, the outer edge showed sinusoidal buckling, and the edge sector at 9 o'clock was partially collapsed and its edge was turned under. Samples taken for optical stereomicroscope and SEM examination revealed that the fracture characteristics were consistent with an overload mode of failure. The examination suggested a general direction of failure from the aft to the forward edge of the rear pressure bulkhead panel.

2.11.6.4 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occupied the 7 to 9 o'clock position. Optical and SEM examination were undertaken on this item.

The fracture along the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation. Representative fracture samples were cut from the left-hand and right-hand edges of the fracture surfaces. Optical and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

2.11.6.5 Target 47 - Aft Cargo Compartment

This portion of the aft cargo compartment roller floor was located between BS 1600 and BS 1760. Based on the direction of cleat rotation on the skin panel (target 7) and the crossbeam displacement on this structure, target 47 moved aft in relation to the lower skin panel when it was detached from the lower skin. No other significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

2.11.6.6 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between BS 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

2.11.6.7 Target 399 - Left-Hand Side Triple Seat with Tray Arms

It would appear that this section was from row 18, seats A, B and C, the first set of triple seats aft of door 2L. The notable damage to this unit was as follows: front leg aisle side buckled and crushed in place; front leg window side buckled and crushed in place; forward edge tube to seat broken and bent downwards at joint with fore and aft tube between window and centre seats; and fore and aft tube between centre and aisle seat broken at start of T-connection to rear edge of seat tube. The damage suggests that the failures resulted from vertical loading. All the life-jackets were in place.

2.11.6.8 Target 399 - Fuselage Side and 2R Entry Door

The fuselage segment was located between BS 780 and 940. This piece was badly damaged and buckled inwards along a line through the lower door hinge. There were 12 holes or damaged areas on the skin generally with petals bending outwards. The curl on a flap around a hole had one full turn. This curl was in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal. When this target was recovered from the sea, along with it came a few hundred tiny fragments and medium-sized pieces. One of the medium-sized pieces recovered with this target was a floor stantion about 35 inches long. It was confirmed that this stantion belonged to the right side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the stantion.

Scientists from the Bhabha Atomic Research Centre, the National Aeronautical Laboratory and the Explosives Research and Development Laboratory in India conducted a metallurgical examination of certain items of wreckage. Their report on target 399 concluded that:

- the curling of the metal on the floor channel was indicative of a shock wave effect;
- the large number of tiny fragments from the disintegration of nonbrittle aluminum was a characteristic indication of explosive forces; and
- the indications of punctures, outward petalling around holes, curling of metal lips, reverse slant fracture, formation of spikes at fracture edges and certain microstructural changes all were indicative of an explosion.

2.11.6.9 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segment was located between BS 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

2.11.6.10 Target 362/396 - Lower Skin Panel - Forward Cargo Area

This section of skin panel was located between BS 720 and 860 and is just below target 399. The skin was badly crumpled and torn and had several punctures. It was pulled free from a large mass of debris which included some mangled cargo floor beams and roller trays. Some of the punctures had a feathered or spiked profile, with spikes angled at approximately 45 degrees to the edge. Other puncture holes gave clear indication of being formed by underlying stiffeners at impact. Two of these holes contained pieces of web stiffener. Most of the punctures were the result of penetrations from inside.

In the preliminary report of Mr. V.J. Clancy, representing Boeing, the following observations regarding target 362/396 were made:

- There were about 20 holes in the lower skin panel clearly resulting from penetration from inside.
- In addition to the fact that perforation was from inside, there were certain features which suggested that they were made by high velocity fragments such as those produced by an explosion. Mr. Clancy's report describes these features as follows:

- the presence of toothed or spiked edges at some parts of the metal which has petalled out from the perforations;

(Tardif and Sterling, Canadian Aeronautics and Space Journal, 1969, 15, 1, 19-27, obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.)

- the presence of marked curling (in some cases of more than 360 degrees) of some of the petals;

(Tardif and Sterling stated that such curling was a feature of explosively produced fragments.)

- the virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal;

- the virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object, thereby suggesting that the production of at least many of the perforations were separate independent events; and
- the presence of one perforation (identified as number 14) resembling a "bullet hole" that was clearly punched out - a type of hole usually associated with a high velocity missile.
- There was evidence that the forward part of the skin panel had been folded back inward along the line of station 760 and then bent back again along a line slightly forward of this station.
- Such folding, perhaps violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces, thus producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.
- One hole (identified as number 13) was almost certainly caused by a slipping wire rope used as a sling.
- Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken of this area for further examination for evidence of fire or explosives.
- A large number (several hundred) of small fragments were recovered. These varied in size from an inch or less to a few inches. They included fragments broken out of sheet metal, and these were reported to be from the same area as T362.
- The production of a large number of small fragments is generally regarded as an indication of an explosion.
- One piece, which was isolated, was about an inch square of sheet alloy with characteristic spikes on one edge similar to those described by Tardif and Sterling.

The following is an excerpt from the report by Mr. V.J. Clancy wherein he gives his opinion and conclusions regarding target 362.

"Opinion

The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a

firm conclusion.
Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.
A more detailed study, metallurgical and fractographic, is required.
The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.
The single "bullet hole," No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.
If the forward part of this item was forcefully and rapidly folded back to impact on the other part, it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility.
The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.
The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."
Mr. Clancy concluded that:
"there is strong circumstantial evidence that an explosion occurred but neither individually nor collectively do the several pointers give the degree of confidence necessary for a firm and final conclusion, at this time."
With respect to target 362/396, in his report Mr. Clancy recommended:
"that firing trials be carried out projecting various size missiles at targets

similar to the material of T362 to obtain reference samples for laboratory comparison with the perforations in T362."

The Indian report, in addition to the observations made by Mr. Clancy, noted the following with respect to the metallurgical examination:

- The microstructure in the various areas examined on target 362/396 confirmed explosive loading in this part of the aircraft.
- The holes and other features observed in targets 362/396 and 399 must have been due to shock waves and penetration by fragments resulting from an explosion inside the forward cargo hold.
- The chemical nature of the explosive material was not identified. No part of an explosive device, its detonator or timing mechanism was recovered.

2.11.6.11 Examination of Wreckage in India with CASB Participation

The examination of the targets recovered did not reveal any pre-existing defect, premature cracking or pre-impact corrosion damage associated with any of the failures.

3.0 DISCUSSION

3.1 Initial Event

From the correlation of the recordings of the DFDR, CVR and Shannon ATC tape, the unusual sounds heard on the ATC tape started shortly after the flight recorders stopped recording. The conversations in the cockpit were normal, and there was no indication of an emergency situation prior to the loud noise heard on the CVR a fraction of a second before it stopped recording. The DFDR showed no abnormal variations in parameters recorded before it stopped functioning. The only unusual observation was the irregular signals recorded over the last 0.27 inches of the DFDR tape. Laboratory tests indicated the possibility that these signals resulted from the recorder being subjected to a sharp disturbance at the time it stopped recording. The other possibility for the irregular signals on the DFDR is that they were caused by a disturbance to the Flight Data Acquisition Unit in the main electronics bay. Since there was an almost simultaneous loss of the transponder signal, this indicates the possibility of an abrupt aircraft electrical failure. The medical evidence showed a general absence of signs indicating that seat-belts were fastened. From the video and photographic examination of the wreckage on the bottom, it was ascertained that the majority of seats located did not have the seat-belts fastened. The above evidence indicates that the initial occurrence was sudden and without warning. The abrupt cessation of the data recorder could be caused by airframe structural failure or the detonation of an explosive device as the initial event. The millisecond noise on a CVR as observed in this case is usually, as described in the available literature, the result of the shock wave from detonation of an explosive device. However, in this case, certain characteristics of the noise indicate the possibility that the noise was the result of an explosive decompression. There is some disagreement regarding the cause and location of the source of the noise heard on the CVR, that is, whether the noise resulted from an explosive device or an explosive decompression and whether the noise originated from the rear or closer to the front of the aircraft.

3.2 Passenger/Flight Deck Area

From the examination of the wreckage recovered and wreckage on the bottom, there is no indication that a fire or explosion emanated from the cabin or flight deck areas. The medical examination of the bodies also showed no fire or explosion type injuries. However, pieces of an overhead locker coming from above door 2R or 4R had been blackened by fire. There was blackened erosion damage to the bottoms of some seat cushions, showing damage possibly from an explosive device, and the upper deck storage cabinet had a large rounded dent in the bottom inboard edge which might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet. It should be noted that the pieces of the overhead locker were found on the Welsh shore some time after the accident, and it is not known if the pieces were subjected to a fire after the accident. Also, it is not known if the damage to the seat cushions and the upper deck storage cabinet could have been caused by other means. Nevertheless, the above evidence suggests that some areas of the passenger cabin may have been subjected to minor fire and explosive damage possibly emanating from below the cabin floor.

3.3 Aircraft Break-up Sequence

The medical evidence showed a proportion of the passengers with indications of hypoxia, decompression, flail injuries and loss of clothing. The incidence of hypoxia and decompression indicates that the aircraft experienced a decompression at a high altitude. The flail injuries and loss of clothing indicate a proportion of the passengers were ejected from the aircraft before water impact. The severity of injuries increased from Zones C to E and was significantly less in Zone C than in Zones D and E.

The wreckage of the forward portion of the aircraft up to and including the aircraft body wheel well area and the wings was lying about 0.8 miles north of the vertical and horizontal stabilizers. Hence, it is likely that the aft portion of the aircraft separated from the forward portion before striking the water. In addition, the wreckage found west of longitude 12°48' consisted of suitcases and aft cargo compartment lower skin panels. There was also a wide scatter of sections 46 and 48 in an east-west direction, whereas the wreckage of the forward portion was mainly localized within a relatively small area.

The higher severity of injuries in the aft end of the passenger cabin appears to coincide with the break-up of the aft end, sections 46 and 48 of the aircraft. The fact that items from the aft cargo compartment were found further west than the tail section indicates that the aft cargo compartment ruptured first during the break-up sequence of the aft end. The forward portion of the aircraft was highly localized, which indicates that it struck the water in one large mass.

3.4 Aircraft Structural Integrity

As described earlier, the sudden nature of the occurrence indicates the possibility of a massive airframe structural failure or the detonation of an explosive device.

3.4.1 Aircraft Break-up

The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer before water impact. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.

The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile to the west indicating that there was some break-up of the number 3 engine before water impact.

The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction. Also, passenger seats viewed and recovered exhibited that they had been subjected to an upward force from below. They showed that the seats to the rear in sections 46 and 48 had their back legs buckled, and the seats toward the front had both front and back legs buckled. This indicates the vertical force was greater at the front than the rear of the aircraft. It is possible that this vertical force on the floor was caused by the force of the water during impact, but the rear of the aircraft broke up before impact and therefore any vertical loading on the floor in this area is unlikely to have occurred at impact. Twenty-three passengers also showed evidence of vertical impact injuries. These could have been caused from a force from below during flight or at water impact. Sixteen of these passengers had little or no clothing indicating that some may have been ejected before water impact. Therefore, there is some indication that the upward force on the floor may have occurred in flight and was more severe toward the front.

3.4.2 Aft Pressure Bulkhead

The localized impact mark found on the leading edge of the right horizontal root leading edge is indicative of an object striking the stabilizer in flight before water impact. This suggests that the loss of the tail plane was not the first event. The horizontal and vertical stabilizers were found separated and each was intact and in good condition. Items from the aft cargo compartment were found further to the west of the tail plane. The absence of the type of damage to the tail plane as was found in the Japan Airlines (JAL) Boeing 747 accident where the aft pressure bulkhead failed and which took place shortly after this occurrence, and the rupture of the aft cargo compartment before the loss of the tail indicate that there was not an in-flight failure of the aft pressure bulkhead. In addition, examination of the recovered portions of the bulkhead shows evidence of overload failures from the rear to front only and no evidence of any pre-existing defect, premature cracking or pre-impact corrosion damage.

3.4.3 Target 7 - Lower Fuselage Skin Panel

Target 7 which extends from BS 1480 to 1860 shows a break at the joint at BS 1480. The forward keel joint splice plate is bent and the keel joint holes are distorted and elongated. Some of the fracture surface was heavily corroded. An in-flight failure in this area would cause a massive failure of the aircraft's structural integrity. Further examination showed the fractures to be overload, and there was no evidence of an intergranular type fracture to suggest a stress corrosion cracking mode of failure. The corrosion was concluded to be post-impact and, therefore, there is no evidence to suggest an in-flight failure in this area as the initial event.

3.4.4 Structural Failure

The examination of the floating and recovered wreckage and the analysis of the photos and videos of the wreckage on the bottom failed to indicate any evidence of a failure of the primary or secondary structure as a result of a pre-existing defect. The initial event has been established as sudden and without warning. The abrupt cessation of the flight recorders indicates the possibility of a massive and sudden failure of primary structure; however, there is evidence to suggest that there were ruptures in the forward and aft cargo compartments prior to any failure of the primary structure in flight. Therefore, available evidence tends to rule out a massive structural failure as the initial event.

3.4.5 Explosive Device

A violent explosion occurring within an aircraft in flight usually leads to a complicated break-up mode and sequence of failure. Fractures of metal caused by an explosion are normally different in character to those caused by overstressing or crash impact forces. Shattering of metal into very small and numerous fragments and minute deep penetration of a metal surface are not usually found in aircraft accident wreckage. The size and characteristics of these particles often accompanied by rolled edges, surface spalling, pitting or evidence of heat are indicative of an explosion.

Of the floating wreckage, there is little to indicate the possibility of an explosion:

- the lining in one suitcase was severely tattered;
- although the wooden spares box was burned, this could have happened after the occurrence;
- although pieces of an overhead locker were damaged by fire, it is not known if the burning happened at the time of the occurrence;
- although the pieces of U-section alloy clearly indicated evidence of an explosion, it is quite possible that these pieces were not associated with the aircraft;
- the bottoms of some seat cushions show indications of a possible explosion;
- the inside of the right wing root fillet appears to have been scorched; and
- the deformation of the floor of the upper deck storage cabinet might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet.

It is not known if the suitcase came from the aft or forward cargo compartment, and the location of the seats from which the cushions came is also unknown.

The scorching of the right wing root fillet and the damage to the upper deck cabinet suggest, if there was an explosion, it emanated from the forward cargo compartment.

From the examination of the recovered wreckage, the following deductions can be made:

- Target 47, which is a portion of the aft cargo compartment roller floor, shows no indications characteristic of an explosion emanating from the aft cargo compartment.
- Target 362/396, which is a lower skin panel from the forward cargo compartment is badly crumpled and torn and has about 20 punctures resulting from penetration from inside. It appears that some folding occurred on water impact which brought stringers or stiffeners from the aircraft structure into forceful contact with the internal surface of the panel producing most of the penetrations. However, there are certain punctures which indicate no evidence of impact marks on the inside surface and show evidence of being produced by high velocity fragments. Part of the inner surface of the skin panel appeared to have been blackened by soot from a fire.
- Target 399, consisting of a piece of the skin and stringers on the right side in the area of the forward cargo compartment contained holes and several hundred metal fragments. The damage to the floor stantion and the presence of the fragments are consistent with an explosion.

The examination of the recovered wreckage contains no evidence of an explosion except for targets 362/396 and 399 which contain some evidence that an explosion emanated from the forward cargo compartment.

An explosion in the forward cargo compartment would explain the loss of the DFDR, CVR and transponder signal as the electronics bay is immediately ahead of the cargo compartment.

3.5 Security Aspects

There is a considerable amount of circumstantial and other evidence that an explosive device caused the occurrence. Therefore, it is reasonable to examine the security measures in place on 22 June 1985. The evidence indicates that if there was an explosion, it most likely occurred in the forward cargo hold, not the passenger and flight deck areas or exterior to the fuselage. Although an explosive device could have been placed in a cargo hold in a number of ways, the available evidence points to the events involving the checked baggage of M. and L. Singh in Vancouver. The investigation determined that a suitcase was interlined unaccompanied from Vancouver via CP Air Flight 060 to Toronto. In Toronto, there is nothing to suggest that the suitcase was not transferred to Terminal 2 and placed on board Air India Flight 181/182 in accordance with normal practice. The aircraft departed Toronto for Mirabel and London with the suitcase unaccompanied. Similarly, a suitcase was interlined unaccompanied on CP Air Flight 003 from Vancouver to Tokyo to be placed on Air India Flight 301 to Bangkok. The explosion of a bag from CP 003 at Narita Airport, Tokyo, took place 55 minutes before the AI 182 accident. Therefore, the nature of the link between the two occurrences raises the possibility that the suitcase which was unaccompanied on AI 182 contained an explosive device.

3.5.1 Canadian Security Situation

Canadian security arrangements in place prior to 23 June 1985 met or exceeded the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand luggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

In Canada, the Department of Transport (Transport Canada) is responsible for establishing overall security standards for airports and airlines, and for the provision of certain security equipment and facilities at airports. By regulation, air carriers are responsible for applying security standards for passengers, for baggage and cargo and for ensuring security within individual aircraft. The RCMP provides airport physical security and responds to criminal incidents.

Air carriers contract for or otherwise provide the personnel who operate the security check-points through which passengers and their carry-on baggage enter the secure area of the airport terminal. These personnel also operate security equipment for the screening of cargo, passengers and checked baggage. Usually, air carriers use the service of private security firms. Transport Canada has established certain standards required for licensed security guards, such as the successful completion of the Transport Canada passenger inspection training program and annual refresher training. As stated earlier, a significant number of the security guards did not meet the criteria with respect to the completion of the training program and refresher training. In addition, the criteria do not require training for the screening of cargo and checked baggage. ICAO Annex 17 recommends that contracting States establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage or cargo intended to be carried on board aircraft. For all Canadian airlines, Canadian regulations before 23 June 1985 required a system of identification that prevented baggage, goods and cargo from being placed on board an aircraft if it was not authorized to be placed on board by the airline operator. However, if someone were to purchase a ticket, check in baggage and not board the aircraft, the baggage would in all likelihood have been authorized by the airline to be placed on board the aircraft. Therefore, it was possible to interline baggage unaccompanied and this explains how a suitcase was interlined to AI 181/182 from CP 060. It is not the normal practice of airlines to interline baggage if there is not a confirmed reservation to the destination. In this case, the ticket agent allowed the suitcase to proceed; however, if there had been a confirmed reservation, the suitcase would have been interlined unaccompanied without question.

3.5.2 Air India Security

Air India, as required by Canadian regulation, had a security program. Because of the threat level assessed against the airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and received extra security from Transport Canada and the RCMP for the month of June 1985. For Air

India Flight 181/182, Air India provided a security officer from its New York office to oversee the security arrangements at Toronto and Mirabel. The security program at each airport was under the overall supervision of the respective Air India station managers. In Toronto, it was not clear who, if anyone, was undertaking this function.

It is not known if the suitcase interlined from CP 060 was screened before or after the X-ray machine broke down in Toronto. Although baggage not examined by X-ray was screened by a PD-4 sniffer, there are indications that the sniffer could have been ineffective in detecting explosives, especially plastics. Rather than using the sniffer, it would have been more effective to open all bags and physically inspect them. Even though a number of security personnel were not adequately trained in the screening of passengers and baggage, it is not known whether more training would have prevented an explosive device from being placed on board.

Although airline procedures required baggage to be accompanied, the agents checking in passengers in Toronto used a passenger security numbering system but did not number checked-in baggage, and baggage was not correlated with passengers. Therefore, the interlined unaccompanied suitcase from CP 060 was not detected. At Mirabel, checked-in passengers and baggage were numbered so that the number of passengers checking in baggage could be correlated with the number of passengers boarding the aircraft. Had a passenger-baggage correlation been carried out in Toronto, the suitcase from CP 060 would have been detected. The airline procedures would have prevented the placement of the suitcase on the aircraft.

Once loaded on the aircraft, the suitcase would have been placed in container 11L and 12L (see Appendix B) if in the forward cargo compartment, in container 44L or 44R if in the aft cargo compartment, or in position 52 if in the bulk cargo compartment. It could not be determined in which cargo compartment the suitcase was loaded.

Therefore, although the procedures were in place to prevent an explosive device from being placed on board the aircraft in checked-in baggage, there was a breakdown in the X-ray machine used to screen baggage, and there are indications that the PD-4 sniffer was inadequate. Also, the security numbering system used in Toronto was ineffective in preventing unaccompanied interlined baggage from being placed on board the aircraft.

4.0 CONCLUSIONS

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion.

4.2 Other Findings

Even though they may not be causal or related to the accident, the following additional conclusions can be drawn from the investigation with respect to certain security arrangements and their application pertaining to this flight:

1. In compliance with the International Civil Aviation Organization Annex 17 to the Convention on International Civil Aviation, the Department of Transport of Canada has made regulations requiring foreign aircraft operators who land in Canada to establish, maintain, and carry out certain security measures at airports.
2. In accordance with these regulations, Air India submitted a security program to the Minister of Transport which included security measures with respect to aircraft, cargo, baggage, and passengers.
3. On 22 June 1985, an unaccompanied suitcase was interlined from

Vancouver to Toronto on CAP Flight 060 for transfer in Toronto to Air India Flight 181/182.

4. The baggage loaded in Toronto was screened through an X-ray machine process but, during the course of this procedure, the X-ray machine broke down.

5. After the X-ray machine breakdown, an explosives detector was used to screen the baggage; the baggage was not opened and physically examined.

6. The effectiveness of the explosives detector is in doubt.

7. It is not known whether the unaccompanied suitcase interlined from Vancouver was screened before or after the X-ray machine broke down.

8. The security numbering system used in Toronto did not prevent unaccompanied interlined baggage from being placed on board the aircraft.

9. The normal procedures for interlining baggage in Toronto indicate that the unaccompanied suitcase was loaded on Air India Flight 181/182.

SECRETARY
MR. S. N. SHARMA
FEBRUARY 26, 1986

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INTRODUCTION

1.1.1 On the morning of 23rd June, 1985 Air India's Boeing 747 aircraft VT-EFO (Kanishka) was on a scheduled passager flight (AI-182) from Montreal and was proceeding to London enroute to Delhi and Bombay. It was being monitored at Shannon on the Radar Scope. At about 0714 GMT it suddenly disappeared from the Radar Scope and the aircraft, which has been flying at an altitude of approximately 31,000 feet, plunged into the Atlantic Ocean off the south-west coast of Ireland at position latitude 51° 3.6'N and Longitude 12° 49'W. This was one of the worst air disasters wherein all the 307 passengers plus 22 crew members perished.

1.1.2 The fact that emergency had arisen was first noticed by Shannon Upper Area Control (UAC) after the aircraft had disappeared from the Radar Scope. The control gave a number of calls to the aircraft but there was obviously no response. Thereafter various messages were transmitted and that is how the rest of the world came to know of the accident.

1.1.3 Shannon Control at 0730 hours advised the Marine Rescue Coordination Centre (MRCC) about the situation which appeared to have arisen. MRCC, in turn, explained the situation to Valencia Coast Station and requested for a Pan Broadcast. Thereafter ships started converging on the scene of the accident and they commenced search and rescue operations.

1.1.4 The aircraft in question - Kanishka, was named after the most powerful and famous king of the Kushanas who perhaps ruled in India from AD 78 to AD 103. Besides being a great conqueror, he was an ardent supporter and follower of Budhism - a religion which preaches non-violence. Emperor Kanishka, however, met a violent end. After 25 years of reign he was killed by some of his own subjects. His life was thus brought to an abrupt end.

1.1.5 It is indeed ironical that the Jumbo Jet which bore the name 'Kanishka' also met with a violent and a sudden end on that fateful morning of 23rd June, 1985.

INITIAL ACTION TAKEN BY THE GOVERNMENT OF INDIA

1.2.1 Initial intimation of the accident was received by Air India who, in turn, communicated the same to Mr. H.S. Khola, Director of Air Safety, Civil Aviation Department, New Delhi. The Accident Investigation Branch of United Kingdom also sent information to the Director General of Civil Aviation, New Delhi to the effect that the accident had taken place on international waters and as such it was India which was the authority to investigate the accident in accordance with the provisions of ICAO Annex 13.

1.2.2 Thereupon Order No. AV.15013/8/85-AS dated 23rd June, 1985 was issued by the Director General of Civil Aviation whereby Mr. H.S.Khola was appointed Inspector of Accidents for the purpose of carrying out the investigation into the aforesaid air accident. This appointment was made under Rule 71 of the Aircraft Rules, 1937.

1.2.3 While search and rescue operations were underway at the site of the accident, a team of officials headed by Dr.S.S. Sidhu, Secretary, Ministry of Tourism & Civil Aviation rushed from India to Cork. The said team was joined by Mr. Kiran Doshi, the Indian Ambassador to Ireland, and also by two officers of the Indian Navy who were attached to the Indian High Commission at London. Subsequently two Medical Experts from India also joined the said Team.

1.2.4 The Indian Team arrived at Cork, Ireland on 24th June, 1985. Representatives of the Governments of United States of America, Canada and United Kingdom also reached there that day. They were met by the representatives of the Government of Ireland.

1.2.5 The members of the Team saw the rescue and salvage operations being conducted. They also visited the Cork Regional Hospital and had discussions with Irish and other Authorities with a view to release the bodies of the victims which were being brought to Cork.

1.2.6 For facilitating the process of investigation the Inspector of Accidents after consulting the representatives of the aforesaid Governments formed the following groups:

a. Structures, Power Plant and Systems Group.

b. Operations Weather & ATS Group.

c. Medical and Human Factor Group.

d. Search & Rescue Group.

The aforesaid groups were required to collect evidence and to submit their respective reports to the Inspector of Accidents.

1.2.7 The bodies which were being recovered were brought to the Cork Regional Hospital for identification and post-mortem. At that time it was considered proper that apart from the two medical experts from India, Wing Commandor Dr.I.R. Hill, who is an expert in aviation pathology should also be called from United Kingdom.

1.2.8 It was also being speculated that the accident may have occurred due to an explosion on board the aircraft. In order to see whether there was any evidence of an explosion which could be gathered from the floating wreckage which was being salvaged, the Government of India requisitioned the services of Mr. Eric Newton, a Specialist in the detection of explosives sabotage in aircraft wreckage.

1.2.9 In order to coordinate and guide the operations of the various ships working at the crash site, a control centre was set up at Cork Airport on 30th June, 1985.

1.2.10 The control centre was manned by representatives of the Governments of Ireland, Canada and United States. The Indian Naval Officers from the High Commission at London were overall in-charge of this centre. After the flight recorders had been recovered the centre continued to function, but the representatives of the United States departed.

1.2.11 For retrieving the Cockpit Voice Recorder (CVR) and Digital Flight Data Recorder (DFDR), a cable ship named Leon Thevenin was engaged which had on board Submersible Robot (Scarab) which was fitted with a Sonar receiver and TV Cameras. The aforesaid ship was engaged and after an intensive search CVR and the DFDR (more popularly known as 'the black boxes') were located and retrieved on 10th July and 11th July, 1985 respectively.

1.2.12 The Government of India, in exercise of the powers conferred by Rule 75 of the Aircraft Rules, 1937 vide Notification No. AV. 15013/10/85-A, dated 13th July, 1985, directed that a formal investigation of the accident be carried out. Mr Justice B.N. Kirpal, Judge of the Delhi High Court, was appointed as the Court to hold the said investiation. The Central Government also appointed Dr. V. Ramachandran of National Aeronautical Laboratory, Bangalore; Mr. J.S. Gharia of Explosive Research and Development Laboratory, Pune; Captian J.S. Dhillon, retired Director of Operations, Air India, Bombay; Mr. J.K. Mehra, retired Manager (Technical Training), Indian Airlines, Hyderabad and Captain B.K. Bhasin, Deputy Managing Director of Indian Airlines, New Delhi to act as Assessors of the said Investigation. The Court was required to make its report to the Central Government by 31st December, 1985, which date was later extended to 28th February, 1986.

1.2.13 Mr. S.N. Sharma, Director of Airworthiness, Civil Aviation Department, was appointed as Secretary to the Court vide Ministry of Tourism & Civil Aviation letter No. AV/15013/10/85-A, dated 22nd August, 1985. The appointment was to take effect from 13th July, 1985.

ACTION TAKEN BY IRELAND, INCLUDING THE CORK REGIONAL HOSPITAL

1.3.1 The accident had occurred on the Atlantic Ocean approximately 100 miles south-west of the coast of Ireland. It is the Air Traffic Control at Shannon, Ireland who first became aware of the tragic event.

1.3.2 On coming to know of the accident, various authorities in Ireland took immediate action. The Shannon ATC asked the Marine and Rescue Coordinating Centre there to take emergency action. Thereupon MRCC, Shannon asked Valantia Coast Radio Station (CRS) for a PAN broadcast requiring all the vessels in areas 51N/1250W to keep a look out for the wreckage of an aircraft. The PAN broadcast was repeated and all ships were directed to proceed to the site of accident which was determined as

5101.9N/1242.5 W.

1.3.3 Irish authorities also took great pains in rendering every possible assistance to the Indian and other authorities. Some of the wreckage which had floated in to the west coast of ireland was transported to Cork where a boat house had been hired by the Government of India. The wreckage which was placed in the said boat house was protected from any outside interference by the local Gardai (police).

1.3.4 Irish ships proceeded to the scene of accident and helped in search and rescue operations. The ATC at Shannon gave details about the accident, in so far as they were aware of it, and copies of the ATC tapes were supplied. Aer Lingus, national airline of Ireland, provided assistance by making available its local engineering facilities to the coordinating centre at Cork and also to the other authorities.

1.3.5 Cork is a city having a population of approximately 1,34,000. One of the hospitals which was opened in 1978 is the Cork Regional Hospital which had been set up to meet the needs of the people. This 600-bed hospital was designated for the purposes of the Major Accident Plan of the Southern Health Board and thus became the appropriate centre for the reception of the casualities of the Air India disaster. Since the hospital first opened, it had dealt with a number of major accidents involving road, rail and marine incidents. The Major Accident Plan of the Southern Health Board sets out formally, the strategy and procedure which the hopital is required to follow while deailing with major accidents.

1.3.6 On the morning of 23rd June, 1985 at approximately 11.20 A.M. the hospital was put on alert following the disappearance of the Air India Flight 182 off the south-west coast of Ireland. The first message which was communicated to the hospital indicated that it was unlikely that there would be any survivors. The key hospital personnel were alerted and a meeting was arranged in the hospital for the purposes of discussing and making arrangements for the receipt of the bodies on the basis of the information which was available at that time.

1.3.7 On being informed that there were no survivors in the accident and that the hospital should be prepared to receive a large number of bodies, then, in accordance with the Major Accident Plan, mortuary facilities were improvised by appropriating the gymnasium attached to the Deparatment of Rheumatology. Subsequently it became evident that additional mortuary and postmortem facilities would be needed. In order to decide where the second mortuary was to be located, the hospital had to take into cosideration the following factors:-

(a) The number and the condition of the bodies;

(b) The period during which the bodies would be retained;

(c) The hospital would be required to provide an on-going service for in-patients, out-patients and serious accident and emergency cases;

(d) To avoid unnecessary internal transport problems, the bodies should be near the Post-Mortem and Pathology Departments; and

(e) To facilitate traffic flow in the hospital curtilage and to to aviod unduc public access.

The hospital authorities accordingly located the second mortuary in a recreational room adjoining the gymnasium.

1.3.8 Two rooms were put at the disposal of the Garda (Police) authorities for use as Garda Control Rooms in the hospital. Telecommunications lines were set up immediately for their assistance as the Gardai was responsible for the forensic and identification procedures in regard to the bodies brought to the hospital.

1.3.9 A small Co-ordinating Group was set up consisting of the Chief Executive Officer of the Southern Health Board, Medical Co-ordinating Officer, Press Liaison Officer, a Senior Registrar who knew about Indian customs and traditions and a Hospital Administrator. This small Co-ordinating Group, whose membership never changed, worked together and were capable of assessing situations, making decisions, liaising with other agencies and services and undertaking with other agencies and services and undertaking responsibility for hospital press releases. Apart from individual contact between members, the Group had a standing arrangement to meet every morning and afternoon. In the late evening, the Group, met the Garda, Hospital Pathologists and key staff members for a general review of progress and to decide the tasks and objectives for the following day.

1.3.10 Within a few hours, the Co-ordinating Group realised that the hospital was a world focal point of the international media, and was required to:

a. Accommodate 131 bodies;

b. Provide pathological and Radiological services for each body;

c. Co-operate with the Garda in their forensic work;

d. Cater for relatives of the victims;

e. eet representatives of foreign Governments; and

f. Keep press agencies informed.

Thus began an operation which demanded a quick and dedicated response from all staff working in close cooperation with the Gardai. At the same time, the hospital was required to continue functioning in the delivery of normal in-patient and out-patient services. The Major Accident Plan, apart from alerting staff, provided the framework and basis for many decisions taken as events evolved. An additional advantage in the practical implementation of the Plan was the fact that the hospital had staff experienced in dealing with previous emergency situations and could marshal the extensive manpower resources available.

1.3.11 The hospital authorities also made the following arrangements:-

a. They briefed Government Ministers and Officials and other dignitaries who visited the hospital. They were taken round the hospital and were explained the arrangements which had been made.

b. Some of the services which were being provided at the hospital were either discontinued or postponed.

c. Bodies were received at the hospital and arrangements were made on their arrival to numerically label and certify as dead all the 131 bodies which were initially received. All the bodies, at that stage, had been individually placed in special purpose body bags. Initially, bodies were placed on tables, but, it was subsequently decided that it would be much easier for all concerned to place the wrapped bodies on polythene covered floors.

d. Arrangements were made for carrying out of the post-mortem examinations. Three Pathologists from other city Hospitals were recruited to augment the existing staff. Dr. Harbison, State Pathologist, was in charge of this aspect of the operation. All the post mortem were completed by 27th June, 1985.

e. For the preservation of the bodies five refrigerated containers with a capacity to hold 140 bodies were hired. These containers were fitted with timber shelving.

f. Government Information Service was located in the Matron's Office.

g. The Army provided troops for the unloading of the bodies from the helicoplers at Cork Airport. They also supplied and erected two large tents for storing bodies after post mortem and embalming. Under Garda escort transport of all the bodies which were recovered was undertaken by the

Army and these arrangements were co-ordinated by Chief Ambulance Officer.

h. Embalming was carried out in the hospital and bodies were then coffined and the coffins with appropriate number plaques were subsequently laid out in the numerical order on the floor when all the post mortems had been completed.

I. All the embalmed bodies were x-rayed (whole body). The examination was completed on 28th June, 1985.

j. A provision was made for a 24 hour extended catering service to meet the needs of staff, Gardai, Army and other personnel involved including visiting relatives.

k. A simple plan was devised for dealing with the relatives. This was a sensitive task bearing in mind the varying religious beliefs, customs and cultures generally of the visiting relatives. Their main function was to provide moral and emotional support to the relatives.

l. As identification progressed, special arrangements were made to assist the relatives. They were met by teams of councellors from the Hospital as soon as they disembarked at Cork Airport and subsequently at the Hospital. The relatives had the same Counsellor and Garda Officer throughout the identification procedure. An interesting development noted was that each family group of relatives, their Counsellor and

Garda officers formed a single family unit transcending cultural barriers. On subsequent visits, families appeared lost if their own Counsellor was not immediately available to them. Usually, the Counsellor and the Garda officers accompanied the relatives, at their own request, for visual identification.

m. When plans were being formulated to receive the relatives, it had been hoped to discourage them from coming to the Hospital until such time as progress had been reported on the identification process. Practical experience subsequently proved this strategy to be inappropriate for a number of reasons. Apart from facilitating the collection from relatives of salient information on the victims, the most fundamental reason was the underestimation of the abiding wish of the relatives to be physically and psychologically as close as possible to their deceased dear ones. Moreover, it was the express wish of almost all relatives on arriving at Cork Airport to proceed directly to Cork Regional Hospital; there, they were given an informal talk by Air India and Garda representatives on the progress of the investigation and the methods of identification. Many of the relatives visited the hospital daily and remained there throughout each day.

n. Coach trips were arranged to Bantry Bay for the relatives; Bantry Bay is the nearest landmark from the site of the crash. Relatives visited the seaside to pay their last respects to the departed souls. These were solemn occasions when each relative prayed in his/her own way. Rose petals and wreaths were immersed in the sea in keeping with Indian traditions. The visit gave them mental satisfaction and in the early days following the crash, helped in diverting their attention while the investigative procedures were being completed.

o. A small number of visiting relatives had personal medical problems and they were treated at out-patient and in-patient levels at the Hospital.

p. Cork/Kerry Tourism Organisation helped to co-ordinate the accommodation of relatives between a number of hotels. Approximately seven hotels were used within a radius of twenty miles of the city for

this purpose.
g. A number of press conferences were held. The Chief Executive Officer, directed that press photography and television filming be not allowed within the hospital in deference to the privacy of patients and in respect for the relatives wishes.
r. Responsibility for the identification of bodies rested with the Garda Authorities and the conditions under which bodies were released are summarised as follows :-
(I) Satisfactory identification
(ii) Consent of the Coroner
(iii) Proper authentification of the person claiming each body
All bodies arriving at Cork Regional Hospital had already been numerically labelled by the Garda Authorities. To prevent confusion, the bodies were then given identical numbers under the hospital major accident labelling system and this proved to be very helpful later during identification, investigations and recordings. A routine was established for examining and recording information about each body. Teams consisting of a doctor, nurse, clerical officer and Garda made the necessary examination, labelling and recording each body and such details as :-
a. Sex
b. Adult or child
c. Clothing
d. Jewellery and personal effects
e. Injuries
f. Obvious scars
Death was confimed in all cases. Each body was fingerprinted and photographed by Garda Technical Bureau Staff. Each body was subjected to autopsy, forensic and dental examination. All bodies were embalmed and following embalming, were photographed and x-rayed. This procedure was completed in respect of all the bodies by the evening of the fifth day of the crash. The data from these investigations was collated on an Interpol form (pink) for each body. Similar ante-mortem information was obtained from the relatives about each victim on a

separate Interpol form (yellow). When the information on the pink and yellow forms matched beyond doubt, a positive identification was made. It might be noted that the photographs originally taken by the Garda Technical Bureau Officers of each body were matched with photographs of the 131 embalmed bodies. When a positive identification was made, the relatives were shown photographs of the deceased. These photographs were available for inspection by Saturday, 29th June. As positive identification progressed,
personal effects were added to the identification process and finally, visual identification took place. For obvious forensic reasons, positive identification was necessarily slow and meticulous and, in fact, was made more difficult by reason of the fact that only 131 bodies out of the 329 passengers and crew were recovered. All 131 bodies were identified, the first positive identification was made on 27th June and the last on the 6th August. Each coffin had affixed to it a metal plaque clearly indicating the number assigned in the first instance to the body it contained. The bodies when identified were released by the Garda Authorities through the undertaker. The Coroner directed that a reasonable time would have to elapse before unidentified bodies could be disposed off an this was to be by way of burial. The final date for this purpose was fixed for 3rd August, 1985, but, this date was subsequently extended to 6th August, 1985, to coincide with the date of the Civic Commemoration Ceremony.

(s) Bodies of victims for identification were brought individually to separate viewing rooms, suitably decordated with flowers and with incense burning. Visual identification was performed in private by the relatives and moreover, it allowed them to pay their last respects in their own religious beliefs. An adjoining room was also made available where they could grieve in private. Subsequently, it was learnt that these arrangements were much appreciated by the relatives who articulated this appreciation by commenting that the arrangements provided were as near as possible to the funeral rites observed in their domestic communities. The relatives were of the opinion that the special arrangements made conveyed a deep personal and individual response to the dignity of each victim which might otherwise be lost with such a large number of bodies.

(t) Procedures were laid down which were required to be followed and observed for the purposes of preventing infection.

(u) On 6th August, 1985 an interdenominational service was held in the morning. In the evening on that day a Civic Commemoration Ceremony was held which was attended by a large number of persons.

(v) A formal inquest was held by the Coroner in the Courthouse, Cork, which commenced on 17th September, 1985 and ended on 23rd September, 1985. The Coroner's Jury returned a verdict in accordance withmedical and pathological evidence.

ACTION TAKEN BY THE COURT

1.4.1 Despite the fact that Mr. H.S. Khola had been appointed as the Inspector of Accidents under Rule 71 of the Aircraft Rules, the Government thought it proper to appoint Mr.Justice B.N. Kirpal as the Court to investigate into the circumstances of the accident.

1.4.2 The appointment of the Court was made under Rule 75 of the Aircraft Rules, which is as follows :-

"75. Formal Investigation - Where it appears to the Central Government that it is expedient to hold a formal investigation of an accident it may, whether or not an investigation or an inquiry has been made under rule 71 or 74, by order direct a formal investigation to be held and with respect to any such formal investigation the following provisions shall apply namely

(1) The Central Government shall appoint a competent person (hereinafter referred to as "the Court"), to hold the investigation, and may appoint one or more persons possessing legel, aeronautical, engineering, or other special knowledge to act as assessors, it may also direct that the Court and the assessors shall receive such remuneration as it may determine.

(2) The Court shall hold the investigation in open court in such manner and under such conditions as the Court may think fit most effectual for ascertining the causes and circumstances of the accident and for enabling the Court to make the report hereinafter mentioned.

(3) (i) The Court shall have, for the purpose of the investigation, all the powers of a Civil Court under the Code of Civil Procedure, 1908 and without prejudice to those powers the Court may :-

(a) enter and inspect, or authorise any person to enter and inspect, any place or building, the entry or inspection whereof appears to the court reguisite for the purpose of the investigation; and

(b) enforce the attendance of witness and compel the production of documents and material objects; and every person required by the Court to furnish any information shall be deemed to be legally bound to do so within the meaning of section 176 of the Indian Penal Code.

(ii) The assessors shall have the same powers of entry and inspection as the Court.

(4) The investigation shall be conducted in such manner that, if a charge is made or likely to be made against any person, that person shall have an opportunity of being present and of making any statement or giving any evidence and producing witness on his behalf.

(5)Every person attending as a witness before the Court shall be allowed such expenses as the Court may consider reasonable: Provided that, in the case of the owner or hirer of any aircraft concerned in the accident and of any person in his employment or of any other person concerned in the accident, any such expenses may be disallowed if the Court, in its discretion, so directs.

(6)The court shall make a report to the Central Government stating its findings as to the causes of the accident and the circumstances thereof and adding any observations and recommendations which the Court thinks fit to make with a view to the preservation of life and avoidance of similar accidents in future, including, a recommendation for the cancellation, suspension or endorsement of any licence or certificate issued under the rules.

(7)The assessors (if any) shall either sign the report, with or without reservations, or state in writing their dissent therefrom and their reasons for such dissent, and such reservations or dissent and reasons (if any) shall be forwarded to the Central Government with the report. The Central Government may cause any such report and reservation or dissent and reason (if any) to be made public, wholly or in part, in such manner as it thinks fit."

1.4.3 The Court, which is appointed under Rule 75, does not act as a 'Commission of Inquiry' which is usually appointed under the Commissions of Inquiry Act to inquire into any definite matters of public importance. The role of the Court, on its appointment under Rule 75 of the Aircraft Rules, is essentially that of an Investigator. It is for this reason that no procedure has been prescribed in the Rules which the Court is required to follow. While carrying out its functions, the Court is not only required to comply with the provisions of the Aircraft Act, and the Rules framed thereunder, but it must necessarily also keep in view the provisions of ICAO Annex. 13.

1.4.4. As an Investigator, investigating into an accident, the Court had to perform multi-farious duties and functions. Before referring to them, it would be pertinent to point out that whereas an Inspector of Accidents, who is appointed under Rule 71, would normally be belonging to the Civil Aviation Department and would have all the machinery available to him for conducting the investigation, the Court, when it is appointed to hold an investigation under Rule 75, lacks the basic infrastructure to conduct the investigation of such a magnitude. Assessors are appointed to assist the Court but the actual investigation work cannot be carried out by them. Despite these handicaps, the investigation continued smoothly primarily due to the fact that whenever directions were issued by the Court to any of the participants before it or to the Civil Aviation Department or any other Organisations, the directions of the Court were readily complied with. On a few occasions it also became necessary to require the Assessors to conduct the investigation, which they did with the help of other organisations.

1.4.5 As an Investigator, the first task which was undertaken was to see that the tapes from the Cockpit Voice Recorder, which had been salvaged, were recoverd from the recorders and subsequently analysed. Requisite directions were issued and the tapes were removed from their respective recorders on 16th July, 1985. This operation was carried out at the Air India workshop at Santacruz in the presence of the accredited representatives of Lockheed (manufactures of DFDR), Fairchild (manufacturers of CVR), Boeing Airplane Co., Canadian Air Safety Board (CASB), National Transportation Safety Board, USA (N.T.S.B), Air India and Government of India. The tapes so recovered were subsequently played and analysed.

1.4.6 On an appointment being made under Rule 75 the Court would become incharge of overall investigation of the accident. In that capacity, and in order to effectively discharge its functions, it became necessary for the Court to undertake the following tasks :-

(a) For getting first hand information, the Court had to personally inspect the wreckage which had been recovered and was housed in a boat yard in Cork. While in Cork opportunity was also taken to go to the Cork Regional Hospital and to have discussions with and be briefed by the hospital staff. A trip was also made to Shannon with a view to see and understand the working of the Secondary Radar System which was in use there. On this visit the original ATC tape, which contained communication betwen Kanishka and the ATC, was also heard.

As it was suspected that there may be a link between the blast which had taken place at Narita Airport on 23rd June, 1985 and the accident to Air India's flight 182, it was felt necessary to inspect the site of the bomb blast at Narita Airport.

On the aforesaid visit to Tokyo, the site where the blast had taken place was inspected which gave some, though very vague, idea of the detonating power of the blast. While in Tokyo meetings and discussions were also held with the police and Aviation Authorities. The Court also had the advantage of being able to meet members of the team investigating into the Japan Airlines Flight JL 123 accident which had occurred near Tokyo on 12th August, 1985. Similarities and dissimilarities between the two accidents were, to some extent, noticed and some information was exchanged.

Information was received, that some floating wreckage had been picked on the coast of England and it was possible that some of the places, which were so received, should be subjected to further detailed chemical and metallurgical examination. In order to decide this, it became necessary to visit RADRE, Kent, U.K. As a result of the inspection and the discussions there, it was decided by the Court that the pieces so recovered should be sent to BARC at Bombay for further analysis.

(b) Directions had to be given, from time to time, with regard to the mapping and salvaging of the wreckage which was being effected. It had to be decided as to how, and in what areas, the Scarab should continue to map the wreckage and take video films and still photographs. Based on the information received therefrom and after discussions with the experts, both Indian and foreign, a list was drawn up indicating the items which had to be salvaged. As the weather was likely to be unpredictable, with a possibility of its deteriorating rapidly, a priority list of items to be salvaged had also to be prepared, and this was done. In view of the fact that the Canadian ship John Cabot and the Scarab had a limited capacity, with regard to the size and weight of pieces which could be lifted from the bottom of the ocean, decision had also to be taken with regard to the deployment of another ship. As a consequence thereof a ship 'Kreuzturm' was also engaged in salvage operations.

(c) Directions had also to be given assigning work and duties to different teams of persons. As an Investigator, the Court was incharge of the entire work of investigation which was being carried out in different parts of the world. It not being possible for the Court itself to undertake all the tasks, decisions had to be taken as to how the investigating work was to progress and who would carry out the directions issued from time to time. For example, immediately after reaching Cork on 25th July, 1985 it was felt necessary that a team should be immediately sent to Canada in an effort to get relevant information from there in connection with the flight AI 182. Accordingly, a team of 3 persons headed by Mr. H.S. Khola was directed to proceed to Canada immediately. As a result of the efforts put in by this team, and with the considerable amount of cooperation, help and assistance rendered by the Canadian Authorities valuable information was received by the Court having direct bearing on the investigation. Yet another example in this regard was of requiring Dr. V. Ramachandran, one of the Assessors and an expert in Metallurgy, to be stationed on board the salvage ships during the recovery operations. The procedure which had to be followed by him was also determined. Information about the progress of the salvage operations was communicated on telephone to the Court at all times of day and night. On receipt of such information further instructions, when ever necessary, used to be issued.

(d) Discussions were held with the Indian experts in order to understand some of the complicated questions which had arisen during the investigation.

In an effort to be able to fully appreciate the effect of decompression, the Court visited the Institute of Aviation Medicine at Bangalore where explsoive decompression was simulated for the Court's benefit. Discussions were also held with other experts of aviation medicine who were also given copies of the post-mortem reports for their opinion. National Aeronautics Laboratory was also visited in Bangalore where meeting was held with experts in aerodynamics, structure and metallurgy. Visits to Bombay where more frequent and necessary so that the Court could get first hand information with regard to the work which was being done at BARC.

The investigation involved looking into matters concerning aviation, electronics, medicine etc. Not being familiar with these branches, the discussions which were held, were of immense help and assistance to the Court who had to understand all the evidence and information which it was gathering.

(e) The accident had attracted world wide attention. Right from the start of the investigation by the Court when the recorders were first opened in Bombay on 16th July, 1985 till the conclusion of the hearing, the Press and the TV were eager for information. It was felt that rather than the media resorting to speculation of getting wrong information, the Court itself or its representative should, as and when necessary, brief the media. In this connection interviews were given, both in India and abroad, which were broadcast over the television and printed in the Press. As a result of this, correct information was disseminated with regard to the progress of the investigation without disclosing the Court's opinion on the evidence which had been received.

(f) Finally, the Court had to conduct the formal investigation in Court. For this purpose it laid down the procedure which would be followed. Rule 75 of the Aircraft Rules required that the investigation would be in open court. It was, however, felt that in this particular case it would be advisable that some evidence should be obtained in Camera. The Court, accordingly, recommended that necessary amendment should be made in Rule 75 so that the Court was given the power to hold certain proceedings in camera when the circumstances so warranted. The suggestion of the Court was accepted and that resulted in Rule 75(2) being amended and, as a result thereof, the Court was given the power to hold proceedings in camera if the stipulated conditions existed.

COMMENCEMENT OF FORMAL INVESTIGATION

1.5.1 The object of setting up a court to investigate into an accident is primarily to find out the causes and circumstances of the accident and thereafter to make recommendations. Such an investigation is not in the nature of an adversary litigation between the participants before the Court. As such it should be the endeavour of all the participants to assist the Court in arriving at a correct conclusion.

1.5.2 Under Rule 75 of the Aircraft Rules, the procedure which has to be followed in the investigation of an accident is to be determined by the Court itself. While laying down the procedure which is required to be followed, the endeavour of the Court has necessarily to be to adopt such procedure which would help the court in being able to complete its task satisfactorily, and in the shortest possible time. Whenever an accident takes place, it is of utmost importance that the cause of the accident must be ascertained at the earliest so that if any remedial measures are to be taken then those steps should be taken without any undue delay.

1.5.3 In the present case, there were a number of factors which had to be kept in view while determining the procedure whichshould be followed. The accident had occurred over international waters and approximately at a distance of about 5000 miles from the place where the investigation was to be conducted, namely, New Delhi. The ill fated flight itself had commenced from Canada, and this meant that most of the evidence would only be available there. Matters were not simplified by the fact that the debris itself was lying at the bottom of the ocean, 2 miles under water. It became apparent, at the very beginning, that to recover the entire debris would be a superhuman task and it will not be possible to do so within the limited time span which was available.

1.5.4 It was thought that it would be of assistance if all the participants got together so as to determine what procedure should be followed. The procedure had to be such which would give an effective opportunity of hearing to all the participants, without in any way unduly prolonging the investigation.

1.5.5 The Court decided that, in order to obtain the views, it would be necessary and advisable to have a Pre-hearing Conference.

1.5.6 The first decision which had to be taken was as to who were to be given a participants status. Keeping inview the provisions of Annex 13, participants status was given to Governments of Ireland, Canada, USA and India. Similar status was also given to Boeing Airplane Co. and Air India. As there might have been some similarities or dissimilarities between the present accident and the accident of the Japan Airlines Boeing 747-SR and also because there may have been a possibility of the present accident being linked with the explosion which had taken, place at Narita Airport, Tokyo on 23rd June, 1985, an Observer's status was given to the Government of Japan.

1.5.7 Notices for holding of the Pre-hearing Conference on 16th September, 1985 were accordingly issued on 29th August, 1985. The agenda for the Conference was to be as follows :-

a. To make suggestions to the Court for its consideration, regarding the procedure to be followed in the conduct of the formal proceedings in the Court.

b. To draw up a tentative list of witness.

c. To draw up a tentative list of exhibits.

d. To determine the areas to be inquired into

e. To fix a date for the commencement of the public hearing.

f. Any other matter with the permission of the Court.

1.5.8 Except for the Government of Japan, all the other participants were represented at the said Pre-hearing Conference. After discussions had been held between the Court and the Participants, some decisions were arrived at regarding different items of the agenda.

1.5.9 Firstly the following points were framed, indicating the areas to be inquired into by the Court:

a. Whether the accident was caused by a structural failure?

b. Whether the accident was caused by some human effort?

c. Whether the accident was caused by some criminal act?

d. Whether the accident was caused by an external non-criminal act?

e. Based on the evidence on record, what steps should or can be taken so as to ensure greater air safety.

1.5.10 It was further decided that, as suggested by all the participants, at least critical portions of the wreckage should be recovered.

1.5.11 With regard to the recording of the evidence it was decided that evidence will, in the first instance, be taken by filling affidavits or by filling statements alongwith affidavits. Copies of the same were to be supplied to the other participants for their consideration. These affidavits were to be filed on or before 18th October, 1985 and a second Pre-hearing Conference was to take place on 30th October, 1985 at New Delhi when it was to be decided as to which of the persons should be called for cross-examination. It was determined that it is only thereafter that hearing would commence in open court.

1.5.12 A tentative list of witnesses was also drawn up and it was decided that on the next date names of more witnesses may be added and, furthermore, the participants would be free to file any affidavits which they deem fit including affidavits in rebuttal.

1.5.13 Another important decision which was taken at the Pre-hearing Confence was that a Structural Group was formed consisting of (1) Mr. H.S. Khola or his nominee (2) Representative of the Canadian Government (3) Representative of NTSB, USA (4) Representative of Boeing Airplane Co., USA (5) Representative of Air India. This group was entrusted with the task of examining and analysing, initially in Seattle, USA, the video films and the still photographs of the wreckage.

This group was also to indicate and decide the items of priorities of wreckage which had to be recovered. The report of this group was required to be submitted by 18th October, 1985. The report of the work done at Seattle was in fact submitted only on 25th October, 1985. This group was also given the liberty to associate any other experts or persons from Boeing or any other Authority. The group was also to inspect the floating wreckage which had already been salvaged and any further wreckage which would be salvaged.

1.5.14 Although the affidavits by way of evidence had to be filed by 18th October, 1985, it was only the Government of Ireland who filed an affidavit by at date. On behalf of the Government of India, an application was filed asking for more time. The reason stated was that the affidavit which had to be filed was to be of Mr. H.S. Khola but he was out of India as he was heading the structures group which was evaluating the video films and photographs at Seattle. The Court had no option but to grant further time to the Union of India to file its affidavits and this necessarily resulted in the adjournment of the Pre-hearing Conference which had been fixed for 30th October 1985.

1.5.15 As the salvage operations were reaching a critical point it became necessary for the Court to go to Cork on 27th October, 1985. Taking advantage of the presence of the Court in Cork, other participants also came there. Besides them, representatives of CP Air and Air Canada also arrived. At one of the informal meetings between the Court and the representatives of the participants, applications were filed by CP Air and the Air Canada, inter alia, praying that they should be permitted to participate in the investigation. It might be mentioned here that CP Air had interlined one of the passangers from Vancouver to AI-182, while Air Canada was the handling agents in Canada of Air India. After hearing the participants it was decided that participant status should also be given to these two viz., CP Air and Air Canada.

1.5.16 The participant had all filed their affidavits by way of submissions. The Court indicated that formal hearings would be held for the purpose of cross-examining some of the witnesses about three weeks after the receipt of all the reports of the various groups. While in Cork, in the first week of November, 1985 some of the salvaged pieces of the wreckage were brought there. After they were inspected by all the participants and their advisers, who were present in Cork, it was decided by the Court that further detailed metallurgical and other examination of those pieces would be done at BARC, Bombay. In order that there should be no undue delay the Court decided that a Group be constituted consisting of expert representatives of all the participants and also the nominees of the Court. This group was asked to carry out metallurgical and other examination of some of the critical pieces salvaged and give its report to the Court. The group consituted as a 'Committee of Experts' was as under :-

a. Mr. A.J.W. Melson, Canadian Aviation Safety Board, Canada.
b. Mr. R.K. Phillips, Canadian Pacific Air, Canada.
c. Mr. T. Swift, Federal Aviation, Administration, USA.
d. Mr. R.Q. Taylor, Boeing Commercial Airplane Co., USA.
e. Mr. J.P. Tryzl, Boeing Commercial Airplane Co., USA.
f. Mr. J.F. Wildey II, National Transportation Safety Board USA.
g. Mr. S.N. Seshadri, Bhabha Atomic Research Centre, India (Coordinator).

1.5.17 The parties were informed in Cork that the report of Mr. H.S. Khola, Inspector of Accidents, would be available by about 8th November, 1985. It was then decided that the statements of the first batch of witnesses should be recorded from 20th November, 1985. It was also agreed that if some of the reports of the experts were not received, further examination of the witness may have to postponed.

1.5.18 After receipt of the report from Mr. Khola. on the 8th November, 1985, a notice of the holding of the Public Hearing was issued to all the participants. This notice indicated that the hearing would commence on 20th November, 1985. In the meantime, a Public Notice was also published in the daily "Times of India" in Delhi and Bombay editions on 21st October, 1985 in which it was stated as follows :-

NOTICE AIR INDIA KANISHKA ACCIDFNT INVESTIGATION

The Government of India, vide Notification dated 13th July, 1985, appointed Hon'ble Mr. Justice B.N. Kirpal as a Court to investigate into the accident to Air India's Boeing 747 aircraft VT-EFO (KANISHKA) near the Irish Coast on 23rd June, 1985, when the aircraft was engaged on a scheduled passenger flight from Montreal to Bombay via London and New Delhi.

Any person having direct knowledge, who may desire to make representation concerning the circumstances or causes of the accident, may do so in writing in the form of an affidavit duly attested by an Oath Commissioner or a Notary Public and address the same to the undersigned so as to reach him within 15 days of the publication of this Notice.

S.N. SHARMA SECRETARY COURT OF INVESTIGATION COURT NO.10,DELHI HIGH COURT SHERSHAH ROAD NEW DELHI - 110 003

Pursuant to the aforesaid public notice no affidavit was received from any one.

1.5.19 The public hearing commenced on 20th November, 1985 and the first session concluded on 28th November, 1985. During this period statements of Mr. H.S. Khola, Wing Commander Dr. I.R. Hill and Sgt. Atkinson of R.C.M.P., Canada were recorded.

1.5.20 Till that date, report on the examination of the salvaged pieces had not been received. It was anticipated that the report would be available by mid December, 1985. In order to give the parties sufficient time to study the reports of all the experts it was decided that further evidence would be recorded from 22nd January, 1986.

1.5.21 After the reports were received from BARC; AIB; Farnborrough; NTSB; USA; and Mr. Bernard Caiger of CASB, Canada and the copies of the same had also been received by all the participants, recording of evidence commenced from 22nd January, 1986 and concluded on 30th January, 1986. In all statements of 13 witnesses were recorded.

1.5.22 At this stage it will be pertinent to make a few observations with regard to the procedure which was laid down for recording of evidence etc. As already indicated, most of the evidence was such which was not available in India. As a Court investigating the accident under the provisions of Aircraft Rules, it had no jurisdication to compel attendance of any witness from abroad. The Court also had no jurisdication, either under the Rules or under the provisions of Annex 13, to require any witness to be examined in a country other than the one in which the Court is holding the investigation. The Court was informed that, if called upon, some of the persons who were outside India may not be inclined to testify before the Court.

1.5.23 Faced with the aforesaid difficulty it became necessary, therefore, to evolve a procedure which would enable the Court to get the requisite information. As long as the Court was satisfied that the information which was being received was one which had been truthfully given by a person, it was immaterial as to the manner in which the information was received. It is for this reason that it was decided that evidence will, in the first instance, be given by way of affidavits. It was also provided that the statements could also be filed along with affidavits. This latter course was permitted so as to enable some of the statements, which had been recorded by members of the Royal Canadian Mounted Police, to be placed before the Court. These statements, of course, had to be accompanied, as they were, with the affidavits of the persons who had recorded the statements.

1.5.24 At one stage, by a formal application in writing, Air India had protested against this procedure being followed. By order dated 22nd November, 1985, an objection by Air India to the filing of the statements accompanied by affidavits, was dealt with by the Court in the following words :-

"With regard to the affidavits which have been filed by the Government of Canada, I would only like to observe in the Pre-hearing Conference on 16th September, 1985, it was decided that "Evidence will, in the first instance, 1985 be taken by filing affidavits or by filling of Statements along with affidavits." It was understood that if it is not possible to file affidavits of the persons who are in a position to give information then affidavits may be filed of other persons who may have recorded the statements of the persons who are in a position to give information. This is not an adversary litigation where one of the parties may lose because of lack of proof. One of the objects of setting up a Court to investigate into an accident is to find out the causes of the accident and to make recommendations. It is necessary for this purpose to get information which may be relevant. It is true that strictly speaking the statements which are annexed to the affidavits may not be admissible as evidence in a Court of Law when there is a litigation between the parties but considering limitations which we have, namely, where a Court like the present has no jurisdication to enforce the attendance of any witness who is outside this country and furthermore, the Court has no jurisdication to compel any one to give information, the procedure which was adopted was thought to be the most practical one for obtaining information in connection with the accident. Under the circumstances, the affidavits which have been filed along with the statements which have been annexed thereto which give information with regard to the accident, have to be taken on record."

1.5.25 Another advantage of following the aforesaid procedure was that the time which would have been taken in Court in examining of the witnesses was considerably reduced. After the participants had filed affidavits, the same were to be secrutinised and it was then to be decided as to which of the deponents or persons should be called for examination in Court. Effectiveness of this procedure which was adopted is apparent from the fact that though affidavits by way of evidence were filed in Court, ultimately only 13 witnesses had to be examined in Court and sitings were held in Court only on 14 days.

1.5.26 Written arguments were filed on the forenoon of the 4th February, 1986 and oral arguments were heard in the afternoon of that day. No written arguments or oral submissions were made by the Government of Ireland, CP Air or Boeing Company.

1.5.27 Mr. I.G. Whitehall, councel for the Government of Canada took exception to some of the submissions which were contained in the written submissions filed by Air India. Mr. Whitehall contended that the Court had opined that it will not go into the question of responsibility of the unfortunate accident and therefore, there was no; justification for Air

India to include in its written submissions numberous passages which tended to fix responsibilities.

1.5.28 By the order dated 4th February, 1986, it was made clear that it was not the intention of the investigation to apportion blame if any lapse had been committed and, therefore, the Court would ignore any written submissions which tended to apportion blame or responsibility for any lapse of any participants. It might here be mentioned that such a question had earlier arisen while the statement of Sgt. Atkinson was being recorded. The Court had then held that it will not go into the question as to who was responsible for the accident. It was in view of this order that no evidence was led by any of the parties on the question as to who may have been responsible for any possible lapse which could have led to this accident.

2.1 Flight Preparation

2.1.1. Air India Boeing 747 aircraft VT-EFO 'Kanishka' was operating flight AI-181 (Bombay-Delhi-Frankfurt-Toronto-Montreal) on 22nd June, 1985. From Montreal it becomes AI-182 from Mirabel to Heathrow Airport, London enroute to Delhi and Bombay. The aircraft arrived at Toronto from Frankfurt at 1830 Z and was parked at gate No. 107 Terminal 2 at L.N. Pearson International Airport. In accordance with the Canadian regulations, all the passengers and their baggage were off loaded to complete the customs and immigration checks. Transit cards were handed out to 68 transit passengers destined to Montreal who disembarked at Toronto for customs and immigration checks.

2.1.2. The flight from Toronto to Montreal was made up of the following:-

(I) Passengers originating at Toronto and their baggage.

(ii) Transit passengers, and their baggage, continuing their flight to Montreal.

(iii) Two diplomatic bags from Indian Consulate General, Vancouver via Air Canada Cargo Flight, and some Air India Mail.

(iv) Fifth Pod engine and its associated parts.

(v) Interline passengers and their baggage from connecting flights as detailed below:-

a) Air Canada flight AC-102
from Sasktoon - 2 Passengers
b) Air Canada flight AC-106
from Edmonton - 4 Passengers
c) Air Canada flight AC-170
from Winnipeg - 1 Passenger
d) Air Canada flight AC-170
from Winnipeg - 4 Passengers
e) Air Canada flight AC-136
from Vancouver - 10 Passengers

2.1.3. One passenger by name 'M. Singh', checked in at Vancouver on Canadian Pacific flight CP-060 (Vancouver-Toronto) of 22nd June 1985, and got his one piece of baggage interlined to Air India flight AI-181
even though he had no confirmed reservation on AI-181. This passenger, however, did not board the flight CP-060 at Vancouver and also did not check-in for Air India flight AI-181/182 at Toronto.

2.1.4 The checking-in of passengers for Air India flight AI-181/182 at Toronto began at 1830 Z. The checking-in of the passengers was carried out by Air Canada personnel who are the handling agents for Air India, and was supervised by Air India personnel. The Air Canada personnel indicated the computer sequeritial numbers (security numbers) on the passenger boarding card stubs. At about 1930 Z announcement was made for the primary security check of passengers and their hand baggage. The passengers passed through the Door Frame Metal Detector and their hand baggage was checked through X-Ray machine. The passengers were also subjected to physical security check with the help of Hand Held Metal Detectors. The transit passengers to Montreal and their hand baggage were also subjected to these security checks, while their checked in baggage, after clearance by the Canadian Customers authorities was placed by the passengers themselves on the conveyor belt while they were still in sterile area. In this way there was personal identification by the passengers of all checked in baggage, except the baggage which had been interlined to this flight.

2.1.5 The flight was closed for check-in at about 2150 Z. There were 10 'NO SHOWS' and 4 'GO SHOWS'. The security checked passengers remained in the holding area gate No. 107 till boarding was announced at about 2210 Z. At the boarding gate secondary security check of the passengers and their hand baggages was carried out. The passengers were frisked with the help of Hand Held Metal Detectors and their hand baggages were opened and physically checked.

2.1.6 The security numbers on the stubs were circled on the pre-numbered Security Control Sheet to ensure that all the checked-in passengers have boarded the aircraft. Passenger boarding was completed by 2300 Z. Traffic/Sales representative of Air India verified the Security Control Sheet with the number of stubs collected and the number of passengers checked-in.

He found that all the 202 passengers, who had checked-in, had boarded the aircraft.

2.1.7 As stated earlier, 68 transit passengers had disembarked at Toronto for completing the customs and immigration checks. However, only 65 of these passengers re-boarded the aircraft as per transit cards collected at the boarding gate. It is in evidence that almost every flight of Air India to Canada, two or three transit passengers do not re-board the flight at Toronto. Some Toronto passengers travelling to India buy their tickets "Montreal-India-Montreal" instead of "Toronto-India-Toronto", for which the fare is higher, and they travel by bus to Montreal to catch the Air India flight to India. On their return journey, when they get down at Toronto for customs and immigration checks, they simply do not re-board the flight even though their reservations are upto Montrteal. These passengers sometimes inform Air India personnel at Toronto about their not re-boarding the aircraft. On 22nd June, 1985, however, no such passenger informed Air India personnel.

2.1.8 There was a crew change at Toronto. The flight and cabin crew members who took over the flight AI-181/182 had been laid over in Toronto for the week prior to the accident flight and were scheduled to take the flight upto London where they were to be relieved by another set of crew. Capt H.S.Narendra was the Commander of the flight, with

Capt S.S.Bhinder as co-pilot and Mr.D.D.Dumasia as the Flight Engineer. In addition there were 19 cabin crew members. All the crew members reported together at the airport at 2130 Z. As per the practice existing at that time, the flight crew and cabin crew members were not subjected to frisking checks and their hand baggage were also not security checked. Their checked-in baggage was, howevewr, security checked along with the other checked-in baggage of passengers.

2.1.9 The interline baggage was brought to the international baggage make-up area by the Air Canada staff but, as mentioned earlier, it was not personally identified and matched with the passengers.

2.1.10 The checked-in baggage of the originating passengetrs and crew members of AI-181/182 was sent on a conveyer belt to the baggage make-up area. All the checked-in baggage along with the interline baggage was required to be security checked on the X-ray machine which was located in the baggage make-up area at the end of international belt No.4.

2.1.11 It has been reported that the X-ray machine worked intermittently for some period and at about 2045Z it broke down and there was no picture on the screen. The Machine could not be repaired on that day as it was a week-end and no technician could be contacted. Air India's Security Officer then advised that the rest of the baggage be checked with a PD-4 explosive detector provided by him. He also demonstrated the use of the PD-4 detec- tor to the concerned personnel. It has been reported that about 60 to 70 baggages were checked and cleared by the PD-4 detector.

2.1.12 The security checked baggage was loaded in the containers by the Air Canada personnel. The loading of the baggage in containers was over by about 2230 Z. The ramp personnel of Air Canada carried the container and loaded them in the aircraft.

2.1.13 From March, 1985, after the introduction of Air India flight AI-181 through Toronto, diplomatic bags from Indian Consulate General at Vancouver were being sent to India by Air India flight from Toronto. Accordingly, two diplomatic bags, duly sealed and escorted, were delivered to Air Canada office at Vancouver on 21st June and they arrived at Toronto by Air Canada flight AC-580. One of the bags Sl.No. 49 contained 13 empty large diplomatic bags while the other bag Sl.No. 50 contained diplomatic mail. The total weight of the bags was 13.8 Kgs.

2.1.14 In addition to the above, a few envelopes containing some flight documents addressed to Accounts Office, Air India, Bombay, and one envelope addressed to Commercial Headquarters, Air India, Bombay from Air India Town Office in Toronto, were collected by Messrs Mega International.

2.1.15 The aircraft was refueled by CAFAS with 14,602 litres of fuel.

2.1.16 On 8th June No. 1 engine of Air India Boeing 747 aircraft VT-EGC had failed during take off. The failed engine was to be ferried to Bombay on flight AI-181/182 of 22nd June.

2.1.17 The failed engine and the associated parts were placed in Air Canada Engineering Hangar at Toronto airport since June 8,when the aircraft was brought to the engineering hangar for engine replacement. Air India had requested Air Canada on 15th June for preparing the failed engine for installation as fifth pod mounting of the aircraft on 22nd June.

2.1.18 On 15th June Air India deputed one of their foremen to Toronto to bring back the failed engine. From 17th to 21st June, Air Canada technicians prepared the failed engine for installation as fifth pod. This preparation involved removal of cowlings, fan blades, locking of compressor rotors etc. Air Canada Engineering/Maintence personnel loaded the aircraft/engine parts on 4 pallets and one container. These pallets and container were then delivered at 0100 Z on 22nd June by Air Canada personnel to Messrs Mega International cargo warehouse at Toronto Airport within restricted airport area. (Messrs Mega International Cargo Warehouse at Toronto Airport within restricted airport area. (Messrs Mega International is the cargo handling agent of Air India at Toronto). The fifth pod engine was transported by Air Canada directly from their premises to the 'Kanishka' aircraft for mounting it on the fifth pod.

2.1.19 Installation of the engine on the fifth pod began immediately on arrival of flight AI-181 at Toronto on 22nd June and the work was completed by 1930 Z. One of the mechanics of Air Canada installed the Mach Air Speed Warning Switch in the Main Equipment Centre as part of the fifth pod engine installation.

2.1.20 The pre-loaded four pallets and one container were brought to the aircraft by M/s Mega International personnel from their warehouse in the afternoon of 22nd June for loading them into the aircraft cargo compartment at positions assigned by the Air Canada load agent. Difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fitting from the aft cargo compartment door cut-out. After removal of the fittings, the cowl could be loaded. All the removed fittings were then reinstalled.

2.1.21. On account of the delay in loading the cowls, departure of the flight was delayed by one hour and twentyfive minutes.

2.1.22 Maintenance Manager of Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft and no snag was observed by him. The commander duly accepted the aircraft.

2.1.23 Senior Flight Despatcher, Air India, Toronto did the flight despatch of AI-181/182 for sectors Toronto-Montreal-London. He briefed the flight crew members about flight plan, weather, Air Traffic Control and fuel requirements. The flight plans for the sectors Toronto-Montreal-London were duly accepted and signed by the Commander.

2.2 Progress of the Flight

2.2.1. The Aircraft took off from Toronto Runway 24L at 0016 Z on 23rd June, 1985. The Maintenance Manager, Security Officer and Passenger Service Supervisor of Air India travelled on board the aircraft for their duties at Montreal. In all there were 270 passengers on board in addition to 22 crew members.

2.2.2. The route from Toironto to Montreal was V-98/JHL-594/MSS/V 203/FRANX at flight level 290. The flight was uneventful and the aircraft landed at Montreal at 0110 Z. No snag was reported by the flight crew. The aircraft was parked at Cluster 1 Bay No.114.

2.2.3 Sixtyfive passengers destined to Montreal along with the three

Air India personnel mentioned above deplaned at Montreal. The remaining 202 passengers, who had joined the flight at Toronto, remained on board the aircraft as transit passengers were not allowed to disembark at Montreal.

2.2.4 Baggage handlers off loaded three containers of baggage, one valuable container and four cargo containers from the aircraft.

2.2.5 Transit Check 'C' of the aircraft was carried out at Montreal. The Flight Engineer also carried out his pre-flight inspection and found that rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to an Air Canada Technician who flaired the handle and applied the high speed tape. There was no other snag observed during the inspection. The personnel of CAFAS refueled the aircraft with 96,000 litres of fuel. Total fuel on board at the time of take off from Montreal was 104,000 Kgs. which was adequate for 8 hours 40 minutes of flying. The commander accepted the aircraft and signed the 'Certificate of Acceptance' of the aircraft.

2.2.6 At approximately 2130 Z Air Canada personnel opened the passenger check-in counter for flight AI-182 (The flight AI-181 terminates at Montreal and the flight from Montreal to London-Delhi-Bombay is designated as AI-182). The checked-in baggage was sent to the baggage make-up area. Between 2300-2350 Z, a suspect suitcase was identified as the X-Ray showed what appeared to be some wires next to the suitcase opening. The suitcase was placed on the floor next to the X-Ray machine. Subsequently two more suspect suitcases were located. These suitcases were also placed next to the X-Ray machine to await the arrival of the Air India Security Officer who was to arrive on Air India flight AI-181 from Toronto. The remainder of the checked-in baggage, which cleared the security check, was loaded in containers by Air Canada personnel for loading on board the aircraft.

2.2.7 Two diplomatic pouches from the Indian High Commission, Ottawa were brought to Mirabel. After the flight arrived, one of the pouches of Category 'A' weighing 1 Kg. was given to the Flight Purser. The other Category 'B' pouch weighing 9 Kgs. was placed in an valuable container 14R.

2.2.8 No other cargo was accepted for this flight except a small package (weighing less than 1 Kg) containing medicines for cancer treatment of a patient in New Delhi. This parcel was received at 1530 Z on 21st June and was loaded in container 14R by Messrs Mega International on 22nd June, more than 24 hours after its receipt.

2.2.9 Five baggage containers, one valuables container and two empty containers were loaded in the aircraft.

2.2.10 The checked-in passengers with their hand baggage went to the departure sterile area. At the entrance to the departure sterile area security staff used X-Ray units and metal detectors to check passengers and their hand baggages.

2.2.11. At approximately 0100 Z, 23rd June, after the primary security check was completed, the passengers proceeded to boarding gate No.80. At this lcoation the secondary security check was done on passengers using hand held metal detectors. Hand baggages were also subjected to further physical and visual check by them.

2.2.12. A total of 105 passengers boarded the flight AI-182 at Mirabel Airport. It was determined that all the passengers who had checked-in, boarded the aircraft. There was no interline passenger. At Montreal there were five 'NO SHOWS' and two 'GO SHOWS'. In all 307 passengers were on board the aircraft. The flight plan and the load and trim sheet, however, indicated 303 passengers as four of the 6 infants were not included in the passenger list.

2.2.13. The seating distribution of the passengers was as given below:-

Zone/Class Total number of Seats Occupied seats Zone 'A' - First Class 16 1 Zone 'B'- Club Class 22 - Upper deck - Club class 18 7 Zone 'C' - Economy Class 112 104+ 2 Zone 'D' - Economy Class 86 84+ 1 Zone 'E' - Economy Class 123 105+ 3 377 301+ 6 (Infants)

2.2.14 The seating distribution of the 19 cabin crew members was as follows:-

Two at door L1 and two at door R1
Two at door L2 and two at door R2
Two at door L3 and one at door R3
Two at door L4 and one at door R4
One at door L5 and one at door R5
One in crew rest area, Zone 'A'
One in jump seat upper deck
One crew rest area upper deck.

2.2.15 The three suspected suit cases were not loaded on the aircraft and were detained in the baggage make-up room. After the names of the passengers to whom the suit cases had belonged had been identified the same were transferred to the decompression chamber of E1 A1 Airline where they were examined, with the aid of a Police Explosive Dog, with negative results. The suit cases were kept overnight in the said chamber and when they were opened it was found that they contained no explosive items.

2.2.16. No unclaimed baggage pertaining to the Air India flight was recovered either at Toronto or at Mirabel or Dorval Airport in Montreal.

2.2.17. The flight plan for the sector Montreal to London was filed on telephone by the Air India Flight despatch from Toronto to Dorval ATC Centre. He requested for route SHERBROOKE-COLOR-NAT XRAYBUNTY-MERLY-EXMOR-IBLEY-SAMTN-HAZEL-OCKHAM-LONDON at flight level 290 upto COLOR and flight level 330 thereafter. The reporting points on Track XRAY on that day were COLOR, 47N/50W, 49N/40W, 50N/30W, 51N/20W, 51N/15W, 51N/08W and BUNTY.

2.2.18 The aircraft took off from Montreal at 0218 Z. Its estimated time of arrival at London was 0833 Z. The CVR and the ATC tapes show that the flight was normal and quite uneventful. Suddenly at about 0714 Z, when the flight was being monitored by the Air Traffic Controller at Shannon, with the help of secondary surveillance radar, the aircraft disappeared from the radar scope. Subsequently, the ATC at Shannon got the know that the aircraft had met with an accident and its wreckage was sighted about 110 miles west south-west of Cork, Ireland.

PERSONNEL INFORMATION

2.3.1 Pilot-in-Command (Capt. H.S. Narendra)

2.3.1.1 Cap.t H.S. Narendra (age 561/2 years, date of birth 25th November, 1928) joined Air India on 1st October, 1956. He held ALTP Licence No. 247 valid upto 29th October, 1985 and FRTO No. 478 valid upto 23rd October, 1985. He was released as a Co-pilot on Boeing 707 aircraft on 21st July, 1960 and as a Commander on Boeing 707 aircraft on 17th September, 1964.

2.3.1.2 For conversion as Pilot-in-Command on Boeing 747 aircraft, Capt. Narendra had undergone ground training at Boeing Airplane Company, USA and simulator and aircraft flying training at Bombay in 1972. He completed his route checks for Pilot-in-Command endorsement between December, 72 and January, 73. He became a Commander on Boeing 747 aircraft on 14th February, 1973.

2.3.1.3 Details of Capt. Narendra's flying experience and licence renewal checks are as given below:

a. Total flying experience : 20, 379:15 hours

b. Flying experience on B-747 as
   (i) Pilot-in-Command : 6,364.50 hours
   (ii) Co-pilot : 123:45 hours

c. Day flying experience
   on B-747 aircraft : 3,980:00 hours

d. Night flying experience
   on B-747 aircraft : 2,508:35 hours

e. Flying experience during
   (i) last 6 months : 301:45 hours
   (ii) last 3 months : 159:40 hours
   (iii) last 30 days : 68:45 hours
   (iv) last 7 days : 9:00 hours

He had last flown as Pilot-in-Command on flight AI 181 (Frank- furt to Toronto) on 15th June, 1985.

f. Date of last licence
   renewal and IR check : 8 May, 1985

g. Date of last route check : 24 March, 1985

h. Date of last medical examination at CME, Delhi : 29 April, 1985

i. Date of last simulator refresher course : 19 December, 1984

j. Date of ground technical refresher course : 6/7 May, 1985

k. Date of last flight safety refresher course : 25 July, 1984

l. Rest period before operating the accident flight : 1 week

2.3.1.4 Records indicate that on 29th June, 1966, Captain Narendra was declared medically unfit for 2 months to reduce his weight by 10 Lbs. In February, 1973 he was advised to wear corrective by-focal glasses while flying. In May, 1975 he was again declared medically unfit for 3 months.

2.3.1.5 Capt. Narendra was earlier involved in the following two incidents:

(a) On 25th August, 1984, while operating flight AI-1100 from London to Delhi, there was a deviation of the aircraft by about 170 nautical miles from the track over Rahimyar Khan in Pakistan. He was given necessary INS refresher and Route checks with particular emphasis on cross checking procedure.

(b) On 6th December, 1984, while operating flight AI-124 Delhi-Bombay, the aircraft was observed approaching runway 32 at Bombay Airport when runway in use was 27. Captain Narendra was given simulator training for a series of approaches and landings and visual circuits from right hand and left hands seats for approaches and landings on runway 27 at Bombay Airport.

2.3.1.6 Captain Narendra was not involved in any accident previously.

2.3.2 Co-pilot (Capt. S.S. Bhinder)

2.3.2.1 Capt. S.S. Bhinder (age 411/2 years, date of birth 30th

November, 1943) joined Air India on 12th October, 1977. He held ALTP Licence
No. 940 valid upto 25th July, 1985 and FRTO Licence No. 2290 valid upto 2nd February, 1986.

2.3.2.2 Capt. Bhinder was released as a Co-pilot on Boeing 707 aircraft on 18th November, 1978 and as a Co-pilot on Boeing 747 aircraft on 17th May, 1980.

2.3.2.3 Details of his flying experience and licence renewal checks are as given below:

a. Total flying experience : 7,489:00 hours

b. Experience on B-747
aircraft as Co-pilot : 2,469:30 hours

c. Day flying experience
on B-747 aircraft : 1,426:15 hours

d. Night flying experience
on B-747 aircraft : 1,043:15 hours

e. Flying experience during

(i) last 6 months : 157:45 hours

(ii) last 3 months : 65:00 hours

(iii) last 30 days : 20:15 hours

(iv) last 7 days : 9:00 hours

He had last flown as Co-pilot on flight AI-181 (Frankfurt to Toronto) on 15th June, 1985).

f. Date of last licence
renewal check : 25th March, 1985

g. Date of last IR check : 23rd November, 1984

h. Date of last route check : 9 April, 1985

i. Date of last medical
examination at CME
Delhi : 14 January, 1985

j. Date of last simulator
refresher course : 16 July, 1984

k. Date of last ground technical
refresher course : 8/9 October, 1984

l. Date of last flight
safety refresher course : 3 December, 1984
m. Rest period before operating
the accident flight : 1 week.

2.3.2.4 Records indicate that Capt. Bhinder was not involved in any accident earlier.

2.3.3 Flight Engineer (Mr. D.D. Dumasia)

2.3.3.1 Flight Engineer Mr. D.D. Dumasia (age 57 1/2 years, date of birth 10th October, 1927) joined Air India on 27th December 1954. He held flight Engineer's Licence No. 37 valid upto 6th December, 1985. Mr. Dumasia was released as a Flight Engineer on Boeing 707 airecaft on 16th December, 1963 and on Boeing 747 aircraft on 6th February, 1974. He had a total flying experience of 14,885 hours out of which 5,512:35 hours were on Boeing 747 aircraft.

2.3.3.2 Last medical examination of Mr. Dumasia was completed on 1st October, 1984 at CME Delhi. He had completed simulator refresher course on 14th February, 1985, ground technical refresher course on 14/15th January, 1985 and flight safety refresher course on 13th August, 1984.

2.3.4 Cabin Crew

2.3.4.1 A total of 19 cabin crew members were on duty on Flight AI-181/182 on 23rd June, 1985. Their brief details are as given below:

Sl.No. Names Designation Flight Safety course completed on 1. Mr. S.L. Lazar Inflight Supervisor 1/2 April, 1985 2. Mr. K.M. Thakur Flight Purser 18 February, 1985 3. Mr. Inder Thakur Flight Purser 9/10 May, 1984 4. Mr. Shukla Flight Purser 23 January, 1985 5. Mr. S.P. Singh Flight Purser 15 January, 1985 6. Mr. N. Vaid Asst. Flight Purser 2/3 May, 1985 7. Mr. B.K. Sena Asst. Flight Purser 3 December, 1984 8. Mr. N. Kashipri Asst. Flight Purser 12/13 Sept., 1984 9. Mr. J.S. Dinshaw Asst. Flight Purser 17/18 Dec., 1984 10. Mr. K.K. Seth Asst. Flight Purser 11/12 February, 1985
11. Miss Raghavan Airhostess 13 July, 1984 12. Miss S. Ghatge Airhostess 10/11 April, 1985 13. Miss R. Bhasin Airhostess 11/12

February, 1985 14. Miss L. Kaj Airhostess 17/18 April, 1985 15. Miss P. Dinshaw Airhostess 17/18 Dec., 1984 16. Miss S. Lasarado Airhostess 15/16 April, 1985 17. Miss E.S. Rodricks Airhostess 10/11 June, 1985 18. Miss S. Gaonkar Airhostess 3/4 April, 1985 19. Miss R.R. Phansekar Airhostess 29/30 April, 1985   AIRCRAFT INFORMATION

2.4.1 General

2.4.1.1. Boeing 747-237B 'Kanishka' aircraft VT-EFO was manufactured by Messrs Boeing Company under Sl.No. 21473. The aircraft was acquired by Air India on 19th June, 1978. Initially, it came with the expert Certificate of Airworthiness No. E-161805. Subsequently, the Certificate of Airworthiness No. 1708 was issued by the Director General of Civil Aviation, India on 5th July, 1978. The C of A was renewed periodically and was valid upto 29th June, 1985. From the beginning of June, 1985, C of A renewal work of the aircraft was in progress. The aircraft had the Certificate of Registration No. 2179 issued by the DGCA on 5th May, 1978. The commercial flight of 'Kanishka' aircraft started on 7th July, 1978.

2.4.1.2 The aircraft was maintained by Air India following the approved maintenance schedules. It had logged 23634:49 hours and had completed 7525 cycles till the time of accident.

2.4.1.3 The aircraft was fitted with four P & W JT9D-7J engines having thrust rating of 48650 pounds. The hours and cycles logged by the engines since new till the time of accident are as given below:

Engine No.1 : P662927-7J - 29,663:26 Hrs (9422 cycles)
Engine No.2 : P695610-7J - 20,810:28 Hrs (6031 cycles)
Engine No.3 : P695602-7J - 21,992:31 Hrs (6564 cycles)
Engine No.4 : P662926-7J - 32,332:15 Hrs (11295 cycles)

2.4.1.4 All the DGCA mandatory modifications and inspections applicable to the subject aircraft had been compiled with. No major component installed on this aircraft and its engines had exceeded the stipulated life period.

2.4.1.5 The last quarter Periodic Check of the aircraft was carried out on 24th May, 1985, at 23274:53 hours and 7439 cycles. Subsequent to this check, two Check 'B' schedules were carried out. The last Check 'B' was carried out on 17th June, 1985, at 23564:14 hours and 7510 cycles and was valid for 200 flying hours.

2.4.1.6 The aircraft had flown 359:56 hours and 86 cycles since last quarter Periodic Check and 70:35 hours and 15 cycles since last Check 'B' till the time of accident.

2.4.1.7 The last Flight Release Certificate was issued on 24th May, 1985 on completion of quarter Periodic Check and was valid for 1100 hours or 150 days elapsed time whichever occurred first. After the last departure from Bombay on 21st June, 1985, the aircraft had flown for 22:34 hours till the time of crash.

2.4.1.8 Mr. Rajendra, Maintenanace Manager, Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft at Toronto on 22nd June, 1985 and no snag was observed by him. No snag was reported by the flight crew during the flight from Toronto to Montreal. Transit Check 'C' of the aircraft for the flight AI-182 was carried out at Montreal by Mr. Rajendra and three Air Canada technicians. The flight engineer also carried out his pre-flight inspection and found that the rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to Mr. P. Bayle, Air Canada technician who faired the handle and applied high speed tape. No other snag was observed during the inspection.

2.4.2 Previous Incidents and Snags

2.4.2.1 A maintenance Group was formed with representatives from Air India and Airworthiness Directorate with Mr. R.K. Paul, Senior Air Safety Officer as the Group Leader to scrutinise the maintenance documents and various defects experienced on this aircraft. The report submitted by the Group (Attachment 'B') indicates that the aircraft was involved in six incidents since the last C of A renewal, details of which are given below

(I) On 13th July, 1984 at Dubai -- flight AI-868 The aircraft returned after aborting take off due to no rise in the EPR and N1 on No.1 engine (Sl.No. 695612). The engine front and rear were checked and found OK. Slight wetness was noticed in the bleed outlets. No external oil leak was

noticed. Oil quantity was topped up. The chip detectors and oil filter were found OK. EVC Ph filter was found
OK. EVC linkage wes exercised. The engine was run up and its operation was found satisfactory. The snag was suspected to be due to lack of pressurising air at low N1.

(ii) On 18th July, 1984 at Delhi -- flight AI-105 The right hand side fuselage skin between stations 480 and 500 in line with lower portion of forward cargo door cut-out was damaged by high lift. The same was repaired at Delhi. Permanent repair was carried out at Bombay. The repairs were accomplished using guidelines given in the Boeing Structural Repair Manual.

(iii) On 12th August, 1984, at Rome -- flight AI-135 The aircraft landed with No. 2 engine (Sl.No. 662826) shut down in flight due to oil pressure and oil quantity droping. On motoring the engine, oil leak was observed from metal line between F C O C and L O P switch at the switch end. The line was found cracked which was welded and refitted. The line was subsequently replaced at Bombay.

(iv) On 24th October, 1984, at London -- flight AI-104 There was total loss of No.1 hydraulic system fluid. The fluid leak was traced to inlet pressure adapter of flap control module in the left hand body gear wheel well. Two of the four bolts holding the adaptor on the flap control module had sheared. The hydraulic pump, seal, back-up ring and case drain filter were replaced. The flap control module was replaced when the aircraft arrived at Bombay.

(v) On 14th February, 1985, at Delhi -- flight AI-164 On arrival the leading edge honey comb of the left hand aft trailing edge flap was found damaged about 18 inches in length due foreign object damage. Necessary repair was carried out at Delhi. The aft flap was replaced at Bombay.

(vi) On 28th May, 1985, at Dubai -- flight AI-103 On arrival, the left hand wing to fuselage botton fairing forward rubber seal with strip was found turn off. Temporary repair was carried out at Dubai. Permanent repair was carried out subsequently at Bombay.

2.4.2.2 The flight snags recorded in the flight report books of the aircraft during the 4 1/2 month period prior to the accident were scrutinised by the Maintenance Group and the only significant repetitive defect observed was "R2 door not going to manual". On ground checks by the aircraft maintenance engineers, the operation of the selector was, however, found normal.

2.4.2.3 Prior to operating the accident flight, the aircraft arrived at Toronto from Frankfurt. Capt. R.K. Spencer was the commander of the flight. The flight crew had reported the following three snags:

(I) HF system No. 2 had a lot of distortion

(ii) E P R L indicator unserviceable in 'Go around' mode

(iii) Hydraulic system No.1 pressure indication unserviceable (This snag was carried forward from Delhi).

2.4.2.4 The Auxiliary Power Unit (APU) was unserviceable ex-Bombay and had been released under M E L.

2.4.2.5 For rectification of the above stated snag No.1, Shri Rajendra, Air India's Maintenance Engineer at Totonto checked the connections of the transreceiver and reracked the unit. No snag was reported on this system on Toronto-Montreal sector.

2.4.2.6 Snag No. 2 was carried forward.

2.4.2.7 Regarding the third snag, Mr. Rajendra has stated that the indicator showed 4000 P S I pressure even with no pump running. He therefore, interchanged No.1 and No.3 indicators. The snag, however, persisted. He then replaced transmitter No.1 with a spare transmitter from the aircraft SE box and the snag was rectified. No rectification work was however, recorded by the AME in the Flight Report Book. No snag was reported on this system on Toronto-Montreal sector.

2.4.3 Installation of 5th Pod Engine

2.4.3.1 On 8th June, 1985, No.1 engine of Air India Boeing 747 aircraft VT-EGC operating flight AI-181 failed during take off at Toronto. The aircraft returned and the engine was replaced by a loaned engine from Air Canada. The removed engine was a P & W JT9D-7Q type (Sl. No. P702353-7Q).

2.4.3.2 Air India had planned to bring back the failed engine of VT-EGC aircraft to Bombay, as fifth pod on their flight AI-181/182 of 22/23

June, 1985 and had sent an Engineer along with the necessary kit to Toronto on 15th June, 1985. The engine borrowed from Air Canada on 8th June, 1985, was flown back to Toronto as a fifth pod engine on flight AI-181 of 22nd June, to return it to Air Canada.

2.4.3.3 Shri C.D. Kolhe, Controller of Airworthiness, Bombay examined the aspects relating to installation of the 5th Pod engine, loading of its components and certification of the related work. Shri Kolhe's report indicates that the failed engine and the associated parts were kept in the Air Canada engineering hanger at Toronto airport since June 8 when the aircraft was brought to the hanger for engine replacement. Air India requested Air Canada on 15th June, 1985, for prepairing the failed engine for installation as fifth pod engine on 22nd June. Accordingly, Air Canada's technicians undertook the preparatory work of removing the cowlings, fan blades, panels, locking of compressor, turbine rotors etc. on 17th June, 1985, and completed the work on 21st June, 1985. The fan blades (46 in number) from the failed engine were placed in 12 wooden shipping boxes provided by Air India. These boxes were then loaded in a container. The other components of the failed engine were loaded on 4 pallets.

2.4.3.4 Installation of the fith pod engine was carried out by Air Canada technicians and the individual items on the task card were certified by the individuals who had carried out the work.

2.4.3.5 Some difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fittings from the aft cargo compartment door cut-out. After removal of the fittings, the pallet could be loaded. All the removed fittings were then re-installed. Removal and installation of the fittings was certified by Mr. Rajendra.

2.4.3.6 A question arose whether removal of the door stop fittings could have caused some difficulty in flight. From the video films of the werckage it was found that the complete aft cargo door was intact and in its position except that it had come adrift slightly. The door was found latched at the bottom. The door was found lying along with the wreckage of the aft portion of the aircraft. This indicates that the door remained in position and did not cause any problem in flight. In the front cargo compartment, there were 16 containers out of which four were empty. Five containers had baggage of Delhi bound passengers. Container at Position 13L had baggage of the first class and London passengers and container at position 13R had crew baggage. The entire baggage of passengers ex-Montreal was loaded in containers at positions 12R, 21R, 22R, 23R and 24R in the front cargo compartment. Container at position 24L contained fan blades in wooden boxes and the other components of the pod engine. Valuable container was at position 14R.

2.4.3.7 In the aft cargo compartment, there were four pallets containing parts of the fifth pod engine and two containers at positions 44L and 44R containing baggage of Delhi bound passengers. The bulk cargo compartment contained passenger baggage bound for Delhi and Bombay. All the baggage and engine parts in the aft and bulk cargo compartments were loaded at Toronto.

2.4.3.8 The total weight of the fifth pod engine and its items was about 9000 kgs. As a result of carriage of the fifth pod engine, the payload of the flight was considerably reduced on London-Delhi sector.

2.4.3.9 At the time of take off from Montreal the aircraft had 104,000 kgs of fuel on board which was adequate for 08:40 hours of flying as against sector flying time of 06:15 hours. The flight plan fuel was calculated taking Paris as the alternate airport for London.

2.4.3.10 The load and trim sheet from the sector Montreal London was prepared and was duly counter-signed by the commander. The take off weight of the aircraft was 317,877 kgs which was within the maximum take off weight limit of 334,500 kgs. The estimated landing weight of the aircraft was 237,177 kgs which was also within the maximum landing weight limit of 256,279 kgs. The centre of gravity of the aircraft was at 21.3 percent of MAC at take off and the estimated C G position at the time of landing at London was 25.8 percent of MAC which was within the limits.

2.4.3.11 The load and trim sheet and the flight plan of the aircraft indicated that there was 301+2 passengers on board the aircraft whereas there were actually 301+6 passengers on board. The error occured because four of the six infants were not taken into account.

2.4.4 Corrosion Control Measures

2.4.4.1 Boeing Company have recommended various measure to control corrosion on Boeing 747 aircraft through different documents such as Maintenance Planning Data Document, Corrosion Prevention Manual and Service Bulletins. Compliance of these measures on Air India fleet is accomplished as follows:

(I) Support structure under galleys and lavatories

Boeing Company have recommended repeat inspections of under galley/ toilet structure at intervals of 12000 hours. However, in order to detect corrosion at an early stage, these inspections are carried out by Air India at intervals not exceeding 9000 hours.

(ii) Fuselage Lower Bilge Area:

Boeing Company have recommended modifications to provide improved drainage systems by incorporation of various Service Bulletins. All the relevant modification have been completed by Air India on the affected aircraft. In addition to completion of these modifications, repeat inspection of lower bilge area is being carried out to meet the requirements of Boeing Service Bulletins.

(iii) Canted Pressure Deck:

In order to prevent water accomulation and consequent corrosion in the area, Boeing Company have issued SBs 51-2015, 51-2026 and 51-2032. Air India have incorporated Service Bulletins 51-2015, and 51-2032 on all their affected airplanes SB 51-2026 is being complied progressively.

(iv) Cargo Compartments:

Inspection of all the cargo compartment interior structures for corrosion and cracks is being accomplished periodically by Air India after removal of linings and insulation blankets.

(v) Aft Pressure Bulkhead:

During every equalised Periodic Check routine, the aft surface of aft pressure bulkhead is being visually inspected for corrosion condition and security of attachements. The forward surface of the pressure bulkhead, which is covered by aft toilets, is inspected after removal of toilets at intervals not exceeding 9000 hours although the recommended interval by Boeing Company is 12000 hours.

2.4.4.2 Air India has stated that in addition to the above specific measures, aircraft structure particularly the areas below toilets, galleys, cargo compartments, outflow valve area etc. which are prone to corrosion, are inspected for corrosion, cleaned and protected during every equalised Periodic Check. Air India have further stated that no serious corrosion problem has been experienced by them so far on their fleet.

2.4.5 Supplemental Structural Inspection Programme

2.4.5.1 In the case of airplanes which have completed 10,000 flight cycles as on June 30, 1983, Federal Aviation Administration (FAA) U S A and Boeing Company had recommended additional structural inspections known as Supplemental Structural Inspection Programme. In the Air India fleet, the first three 747 aircraft, namely, VT-EBE, VT-EBN and VT-EBO fell in this category and are known as 'Candidate Airplanes'. The subject aircraft (VT-EFO) had completed only 7525 flight cycles at the time of the accident on 23rd June, 1985, and therefore, the Supplemental Structural Inspection Programme was not applicable to this aircraft.

2.4.6 Special Corrosion Inspection of B-747 Aircraft Fleet of Air India

2.4.6.1 In order to examine whether corrosion to the aircraft structure of Kanishka aircraft could have contributed to the accident, a group was constituted by Mr. H.S. Khola, Inspector of Accidents to carry out special corrosion Inspection of all the Boeing 747 aircraft of Air India.

The group consisted of the following members:

(a) Senior Air Safety Officer of the D.G.C.A.

(b) Senior Airworthiness Officer of the D.G.C.A.

(c) Air India's Representative.

2.4.6.2 The inspection was carried out in the following areas:

(a) Below toilets and galleys

(b) Forward and aft cargo compartments belly areas - internally and externally
(c) The forward and aft pressure bulkheads
(d) Canted pressure web area from inside the passenger cabin.
(e) Area around outflow valves
(f) MEC area inside and outside.

2.4.6.3 The inspection reports submitted by the Group show that no corrosion was noticed on the significant primary structural members of the aircraft. Surface corrosion was, however, noticed on some of the members below the toilets and galleys. The corrosion observed during the inspection was of minor nature which is normally expected on such inspection schedule. The Kanishka aircraft was subjected to Periodic Check on 24th May, 1985 at 23,274.53 hours/7,439 cycles and no significant corrosion was observed. Among the Nine 747 aircraft inspected for corrosion, 5 aircraft had logged hours more than the Kanishka aircraft. Three of the aircraft had actually logged nearly double the flying hours. Taking into consideration that the corrosion prevention measures recommended by the Boeing Company were followed by Air India and that even the high life aircraft (45,000 hours approximately) subjected to corrosion inspection at the time when Periodic Check was due i.e. 1100 hours since previous check, had no significant corrosion, it is considered unlikely that Kanishka aircraft, which had logged only 23,275 hours since new and 360 hours since last Periodic Check, had corrosion which could have contributed to the accident.

METEOROLOGICAL INFORMATION

2.5.1 A report on the Meteorological conditions prevailing en-route near the location where the aircraft crashed was provided by the Meteorological Service, Department of Communications, Dublin, Ireland. This report covers a period of one to two hours before and after the time of accident (0714 Z).

2.5.2 From the report it is seen that the surface Synoptic Situation in the vicinity of 51°N, 12.50°W at 0715 Z on 23rd June was as given below:

Surface wind : 250/15 knots

Surface visibility : 10 Kms (occasionally 4 kms in drizzle)

Surface temperature : 13°C

Cloud conditions : Cloud cover in the area was estimated to have been layered upto about FL 100 with a base of 600 feet. There is no evidence of cumulonimbus or thunderstorm activity.

Freezing Level : 700 feet.

2.5.3 With regard to Upper Air situation the report indicates that a mainly West or West North West airflow covered the area of FL 310 The Jet stream was centred at about 48°N. The estimated wind and temperature at FL 310 were 270/65 knots and -47°C. As per the report, at FL 310, 51°N 12.50°W and at 0715 Z any significant clear air turbulence was not expected.

2.5.4 Sunlight condition was prevailing at the time of accident. There were no sigmets valid for the area at that time.

AIDS TO NAVIGATION

2.6.1 The aircraft was equipped with Inertial Navigation System (INS) and was cruising normally at its assigned flight level 310 on track X-ray over Atlantic. It was under the control of Shannon Upper Area Control and was being monitored on the Secondary Surveillance Radar (SSR) located at Mount Gabreal. Till the time of accident, the aircraft was beyond the range of Shannon primary radar.

2.6.2 The aircraft entered Shannon airspace at the correct position and level and remained on the assigned track and flight level till it disappeared from the radar screen.

2.6.3. There is no evidence to indicate that AI-182 experienced any navigational problem during the flight.

COMMUNICATIONS

2.7.1 Two-way communication between the ill-fated aircraft and the ATS units of Canada and Ireland was maintained during the flight from Montreal till the time of crash. The communications were recorded on the ATC tapes. Transcripts of the relevant tapes were provided by the Canadian Aviation Safety Board and the Director of Air Traffic Services, Ireland.

2.7.2 From the Transcript of the conversations, it is observed that two-way communication between AI-182 and the various ATS units was normal. The last R/T contact with the aircraft was at 0709:58 Z when AI-182 informed Shannon UAC that it was squawking 2005. The tape transcript also shows that the aircraft did not transmit any information regarding the emergency on frequency 131.15 MHz on which it was last working with Shannon UAC or on distress frequency 121.5 MHz. Indecipheiable noise was, however, found recorded on the Shannon ATC tape just at the time of crash i.e. 0714:01 Z. Thereafter, repeated calls were made by Shannon UAC to AI-182, but there was no response.

SEARCH AND RESCUE

2.8.1 The report of the Search and Rescue Group gives the details of the Search and Rescue operations. From the report it is seen that at 0730 Z, Shannon UAC informed Marine Rescue Co-ordination centre (MRCC) shannon that AI-182, a Boeing 747 aircraft enroute Montreal-London had disappeared from the Secondary Surveillance Radar (SSR) at 0713 Z in position 51N/120W. Shannon UAC requested MRCC Shannon to take emergency section. At 0740 Z MRCC Shannon telephonically explained the situation to Valantia Coast Radio Station (CRS) and requested a PAN Broadcast urgently and to ask any vessels in area to keep sharp lookout and report to Valantia Radio. At 0746 Z Valantia Radio transmitted to all stations PAN message and above advice to ships. The transmission was repeated.

2.8.2 At 0750 Z, an Irish Naval Vessel AISLING reported on R/T to Valantia Radio that it was 54 miles from site of accident and was proceeding to the site. Valantia Radio passed on this information by Telex to MRCC Shannon. Between 0740/ 0750 Z MRCC briefed the Irish Naval Service (INS) Haulbowline, MRCC Swansea, RCC Plymouth and Irish Army Air Corps (IAAC) on the situation. At 0754 Z MRCC relayed a distress message to Shannon Aeradio via the Aeronautical Fixed Telecommunication Network (AFTN)

2.8.3 At 0803 Z Valantia Radio again transmitted the PAN message and the advice to ships. At 0840 Z Cargo vessel M W Laurentian Forest/ HBWP (Registered in PANAMA and owned by Federal Commerce of

Montreal, Canada) at position 51.09N/12.18W reported that it was 22 miles away from distress area and was proceeding there. Laurantian enquired if there were other ships in the area and was informed about position of Aisling. At 0813 Z Valantia Radio informed MRCC Shannon by telex about Laurentain Forest.

2.8.4 Between 0815/0820 Z, MRCC Shannon updated RCC plymouth and they advised that a Nimrod Rescue Aircraft would depart shortly for the area and that SEA KING helicopters were already enroute the Cork Airport initially. Edinburgh RCC advised MRCC Shannon that a Nimrod Rescue Aircraft was also being prepared at Kinloss. At 0820 Shannon Aeradio informed Valantia Radio that there was message from Shanwick Oceanic Control that aircraft were picking up ELT signal in position 51N/15W and 51N/08W and the actual position was beleived to be 51W/1250W. At 0833 Z, Valentia Radio sent message giving the above information and requesting ships in the area to report to Valentia Radio.

2.8.5 At 0842 Z, Ali Baba informed Valentia Radio that it was at position 5125.5N/0825.4W and was listening on 121.5 MHz. At 0850 Z Western Arctic informed Valentia Radio its position 5207N/1151W and that it would proceed in about 20 minutes after bringing in cable. At 0857 Z, High Seas Driller informed Valentia Radio that Vessel Kongstain could be released, ETA 51/2 to 6 hours and they would standby. At 0858 Z, Valentia Radio informed MRCC Shannon about reports from Ali Baba Western Arctic and High Seas Driller.

2.8.6 At 0905 Z, Laurentian forest reported to Valdentia Radio that it was 5 miles from SOS position 51N/12.5 W and it had not sighted anything. Between 0905/0908 Z, three more vessels viz. Atlantic Concern, MV Norman Amstel and MV Tasman reported their positions to Valentia Radio. At 0908 Z, Swansea advised MRCC Shannon that four Seaking helicopters and two Nimrod Aircraft were enroute.

2.8.7 At 0913 Z, Laurentin Forest reported to Valentia Radio that they had sighted what looked like 2 rafts about 2 miles away. At 0914 Valentia Radio informed MRCC Shannon about the report from Laurentian Forest.

2.8.8 At 0918 Z, Laurentian Forest reported to Valentia Radio that it had sighted wreckage in water at position 5101.9N/1242.5W and the liferafts were not inflated. Valentia Radio passed the message to MRCC Shannon at 0920 and also sent transmission about wreckage sighting. Lifeboats Valentia and Baltimore reported to Valentia Radio that they were proceeding to the position of wreckage.

2.8.9 At 0937 Z, Laurentian Forest reported that it had sighted 3 bodies in water. Valentia Radio informed the same to MRCC Shannon at 0940 Z. At 0945 Z, MRCC Shannon and MRCC Swansea decided that for security and operational reasons Cork Airport would be the primary operational base and ATC Cork were informed of this decision.

2.8.10 At 0953 Z, S MYROLI informed Valentia Radio that it was 80 miles north of position and had a group of 10 to 20 French vessesls and desired to know if they should proceed to site. After consulting Laurentian Forest, S MYROLI was advised that it was not necessary. Valentia Radio kept on giving Mayday relay frequently.

2.8.11 At 1045 Z, a prohibited flying area was established with a radius of 40 N Miles from the datum point from sea level to 5000 feet. Falmouth Coast Guard reqested Valentia Radio the position of all ships in the distress area and those proceeding so that each vessel could be designated to search a particular area.

2.8.12 At 1126 Z, Laurentian Forest reported Valentia Radio that it had located numerous bodies in water and Seaking helicopter was hovering there. Valantia Radio Transmitted this information to all stations.

2.8.13 At 1133 Z, Valentia Radio informed Coast Guard Falmouth the position and ETA of various ships and also of the Lifeabouts Valentia and Beltimore. At 1150 Z, RRC Plymouth requested MRCC Shannon that "Le Aisling" assume duty as "On Scene Commander Surface Unit". At 1204 Z, information was received by Valentia Radio that 8 Spannish Trawlers were proceeding to distress position of AI-182 and their ETAs were between 1630/2000 Z. At 1246 Z, Star Orion informed Valentia Radio that it would be able to refuel any vessel in medium or small quantities at the accident site. Valentia Radio informed MRCC Shannon and Falmouth about the Spanish Vessels and Star Orion.

2.8.14 Falmouth requested Valentia Radio at 1303 to advise Laurentian Forest to inform Aisling that 8 Spanish trawlers would arrive in search area between 1600 Z and 2000 Z and Aisling should deploy trawlers in conjunction with lifeboats to recover bodies as it would be easier to recover than from large vessels. Valentia Radio sent the above message.

2.8.15 Laurentian Forest informed Valentia Radio at 1307 Z that 10 bodies were on Aisling, 4 on Helo, and they had some alongside and had launched lifeboats to pick them up. Valentia Radio informed the same to MRCC Shannon and Falmouth. At 1338Z, MRCC Shannon requested Valentia Radio to include the following in their broadcast:
"Vessels within 100 N Miles of datum 5101.9N/1242.5W are requested to proceed to search area and contact Aisling/EIYP. Any vessels recovering bodies or wreckage are requested to retain them on board and inform MRCC Falmouth of total number of bodies recovered."

2.8.16 Valentia Radio transmitted the above message at 1340 Z to all stations and also informed MRCC Shannon. At 1503 Z Aisling informed Valentia Radio that they had recovered 56 bodies. MRCC Shannon requested Valentia Radio to advise Aisling that if they could locate "Black Box", they should drop buoy. Valentia Radio advised Aisling accordingly. At 1530 Z, on advice from MRCC Shannon, Valentia Radio asked Baltimore, Courtmaesherry and Ballycotton lifeboats to return to base. At 1633 Aisling requested Valentia Radio to inform Falmouth that they were unable to transfer bodies to Valentia Lifeboat as latter was returning to base owing to fuel shortage. At 1659, Laurentia Forest informed Valentia Radio that 66 bodies had been picked up by then. Aisling advised Valentia Radio that Valentia lifeboat was returning with four bodies.

2.8.17 At 1721 Z Falmouth requested Valentia Radio to relay following to all surface units at scene:

1. One mimrod remaining on scene overnight.
2. All other air units will be recalled at 2200 Z. One Helo remains at 15 minutes notice at Cork
3. Air Search recommences at 240400 Z.

4. All Civil surface units will be released by 2200 and may proceed on passage. Bodies should be landed at Irish Post for transfer to receiving station at Cork Airport.

5. Warship Challenger, Emer and Aisling acknowledge".

2.8.18 At 1723 Z Aisling informed Valentia Radio that they saw 3 Spanish vessels approaching and they were using Ch.16 which Aisling was using for co-ordination with RESCUE 52 and requested that Spanish Vessels be asked to stay outside 5 miles radius. Spanish Agent was told about Aisling request.

2.8.19. Valentia lifeboat informed Valentia Radio that they were heading for home (Valientia) at reduced spead of 11 knots and they had five bodies on board. At 1822 Z, Aisling requested Valentia Radio information on 'Black Box' that might help its location. Aisling was advised of ELT signal on 121.5 MHz. At 1840 Z Cork ATC Advised MRCC Shannon that a total of 64 bodies were in Cork.

2.8.20 At 1920 Z, MRCC Shannon downgraded the 'MAYDAY' Broadcast to 'PAN' (Urgency) Broadcast, Aisling informed Valentia Radio that 79 bodies had been recovered. At 1958 Z Laurentian Forest informed Valentia Radio that they were proceeding to Dublin. Valentia Radio thanked them for assistance.

2.8.21 At 2000 Z, MRCC Swansea advised MRCC Shannon that main air search would cease at 2200 Z and would recommence at 240400 Z. The overnight search would continue with one Nimrod providing air cover for the surface search by three warships. Vessels transiting the area were requested to keep a sharp look out and to report to HMS Challenger.

2.8.22 By 0300 Z on 24th June, four Seaking helicopters had deported from Cork to resume the airborne search. At that time the search area covered a six nautical mile radius of position 5059.2 N/1225.3W and the vessels Le Emer and HMS Challenger were requested to search this area. HMS Challenger was the coordinator of the surface search and Nimrod Rescue 02 was on-Scene-Commander.

2.8.23 At 0450 Z Rescue 02 reported sighting of wreckage in position 5101 M/1245 W. Between 0505 and 0543, three USAF Chinook

helicopters departed from Cork Airport to join the search. At 0556, MRCC
Swansea confirmed that there were 329 people on board the aircraft (Earlier reportes had idicated 325 people on board).

2.8.24 A continuous search was maintained throughtout the day (24th June) but only one further body and numerous pieces of wreckage were recovered. An extensive surface search was also maintained throughout the day and instructions were passed by MRCC Shannon to Valentia Radio requestiong all shipping to recover any wreckage or bodies sighted.

2.8.25 At 0900 Z, Capt. G Mc. Stay of Department of Communications advised MRCC Shannon that Aisling was bound for Cork, ETA 1300 Z and he (Capt. Mc Stay) was assuming responsibility for collection of wreckage. MRCC were also advised by Mr. Gregory of Britoil that their two vessels 'Constine' and 'Star Orion' were enroute to Foynes having picked up quantities of wreckage.

2.8.26 At 1740 Z, SRCC Plymouth advised Shannon that the Search will terminate at 242200 Z, at 1800 Z Falmouth MRCC advised MRCC Shannon to direct the Portisheal and Valentia Radios to concel Urgency Broadcast from 242000 and to release HMS Challenger and Le Aisling from the search at 242000 hours. All the aircraft were released at 24000. It was also decided that Le Emer would remain at the area. At 242003 Z, a message was transmitted to all stations on R/T and W/T that air and sea search was being terminated at 242000 Z and all the participant were thanked for their assistance.

INJURIES TO PERSONS

3.1.1 Post mortem examination was carried out by Irish Authorities at Cork. At that time Wing Commandor Dr. LR. Hill was also present. Subsequently Air Vice Marshall Kunzru also reached Cork. Both of them were members of the Medical Group which had been constituted by Mr. H.S. Khola.

3.1.2 By then 131 bodies had been recovered. None of the bodies of the flying crew were revocered. The bodies which were recovered represented 39.8 per cent of the victims. The exact seating position of passengers is not certain, because it is known if the passengers had changed their seats after the take off of the aircraft from Montreal. On the information which is available, the passengers were supposed to have been as follows:-

Passengers: Seats Occupied Bodies Available identified Zone A 16 1 0 Zone B 22 0 0 Upper Deck 18 7 0 Zone D 112 104 + 2 29 Zone D 86 84 + 1 38 Zone E 123 105 + 3 50 Sub-Total 377 301 +(6 infants) 117 Crew: Flight Deck 3 3 0 Cabin 19 19 5 Total 399 329 122

3.1.3 The Post-mortem reports were examined by Wing Commander Dr. Hill. He submitted two reports being Exhibits H-1 and H-2. He was also examined in Court as Witness No. 2. Dr. Hill who had developed a system which would indicate the severity of the accident and the injuries suffered. He used a scale from 0 to 4, with naught being no injury and 4 being a fatal lesion. Though there is some amount of subjectivity involved in the system, nevertheless categorising the injuries according to the sacle does give an overall picture of what had happened to the victims. After adding up all the injury scale for a particular body, Dr. Hill in his Report Exhibit H-1 divided the injuries as under:-

No. of victims Mild injury (0-49) total 34.4% 45% Moderate injury (50-99) 38.9% 51% Severe Injury (100-149) 25.2% 33% Catestrophic Injury (150 +) 1.5% 2 Total 100.1% 131 3.1.4 A further break up showing the overall injury score of the recovered victims is as follows:

Minor Moderate Severe Zone No. % % No. % % No. % % Total C 8 6.1 17.8 9 6.9 17.7 4 3.1 11.4 21 D 9 6.9 20 15 11.5 29.4 9 6.9 25.7 33 E 15 11.5 33.3 15 11.5 29.4 14 10.7 40 44 Unknown 13 9.9 28.9 12 9.2 23.5 8 6.1 22.9 33 Total 145 34.4 100 51 39.1 100% 35 26.8 100% 131 3.1.5 The reports submitted by Dr.Hill further indicted as follows

(a) There were 30 children recovered and they showed less overall injury. The average severity of injury increases from zone C to E and is significantly less in C than in Zones D and E.

(b) Flail pattern injuries were exhibited by eight bodies, five of these were in Zones E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

(c) There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evently distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

(d) Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 Zone D, 11 inZone E, 2 crew and 1 unknown), and 16 had little or no clothing.

(e) Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

(f) There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

(g) There is a general absence of signs indicating the wearing of lap belts.

(h) Pathological examination failed to reveal any injuries indicative of a fire or explosion.

3.1.6 In his testimony in Court, Wing Commander Dr. I.R. Hill further stated that the significance of flail injuries being suffered by some of the passengers was that it indicated that the aircraft had broken in mid-air at an altitude and that the victims had come out of the aeroplane at an altitude. He further explained that if an explosion had occurred in the cargo hold, it was possible that the bodies may not show any sign of explosion. It may here be mentioned that the forensic examination of the bodies do not disclose any evidence of an explosion. Furthermore, the seating pattern also shows that none of the bodies from Zone A or B was recovered, in fact as per the seating plan Zone B was supposed to have been unoccupied. This Zone is directly above the forward cargo compartment.

3.1.7 Dr. Hill further stated that the pattern of the accident as suggested by the injuries indicated that it was a complex affair and there were at least two phases of injuries, one in the air and the other at water impact. In answer to a specific question that if there was an explosive device in the cargo hold then could the passengers who were seated have suffered such injuries, the answer of Dr. Hill was that "it is possible". According to him, the pattern of injuries indicated that if there was an explosion in the aircraft it was more likely that the explosion had occurred in the rear cargo compartment than in the front cargo compartment. This conclusion was apparently based on the fact that, according to him, in zone E of the aircraft there were larger vertical load type injuries. Dr. Hill was also asked if he had to make any suggestions which would minimise injuries to passangers in the event of an accident. In answer, the witness made his suggestion in the following words "There are very complicated things one would have to do such as rearward facing seats; having safety belts which incorporated restraint for the upper part of the body; increasing the space between aircraft seats; incorporating shocks absorbing system within the seat and using materials which do not break easily like plastic. We would also need fuel systems which would not immediately set on fire and furnishing which would be resistant to burining, and also passengers should not carry into the aeroplanes large amount of hand bags which only get in way in the event of evacuation, and I personally feel that the carriage of large amount of alchohol both in the passengers and in the aeroplane is a hazard to flight and safety. Finally the passengers should take heed of the flight safety instructions given to them by the crew of the aeroplane".

3.1.8 Air Vice Marshal Kunzru, witness No. 10 in his report dated 14th November, 1985, Ex.A-48, gave his comments not only on the post-mortem reports but also on the statement of Wing Commander Dr. I.R. Hill. With regard to the post-mortem examination, the comment of AVM Kunzru was as follows:

"All victims have been stated in the PM reports to have died of Multiple injuries. However two of the dead, one infant and one child, are reported to have dies of Asphyxia. There is no doubt about the asphyxial death of the infant. In the case of the other child (Body No. 93) there could be doubt because the findings could also be caused due to the child undergoing tumbling or spinning with the anchor point at the ankles. Three other victims undoubtedly died of drowning. There was no evidence of significant Lap-belt injuries.

Considering rupture of the ear-drum, without injury to skull, as a criterion to indicate rapid decompression, two cases may be considered to fall in this category.

Histological examination has been carried out only in 57 bodies out of 131. Lung examination on almost all of them showed decelerative changes. Six bodies (Nos. 6,22,70,103,121 and 131) showed presence of Bone Marrow Embolism in Lung Sections. Though not of much significance in this accident, this finding does indicate survicval after a bony injury for an undefined period of time No evidence of fire burns or explosive material, other than Kerosene burns on some bodies, which I had myself seen at Cork, could be found. Kerosene burns in such acidents is a fairly common findings and is of no significance".

AVM Kunzru generally agreed with the crash injury analysis on the victims which had been furnished by Wing Commander Dr. Hill. He, however, gave the following comments with regard to hypoxia, decompression and decelerative changes:

"Hypoxia : The main Post Mortem findings in hypoxia is generalised congestion if the hypoxia is of the type described as "hypoxic hypoxia". In other causes of hypoxia of more severe degree such as "histotoxic hypoxia", "asphyxia" or "drowning" additional histological findings such as petechial haemorrhages and generalised congestion, and lung findings such as haemorrhage and extrusion of alvoolar phagocytos are seen.

Decompression : The term used by Dr. Hill is "Decompression". It is presumed that he means "Rapid/Explosive Decompression" which occurs within one Sec. and not "decompression sickness" which takes a minimum of 5 to 7 mnts to occur even at 31,000 ft. altitude and which in this case can positively be ruled out.

The Post-Mortem and histological signs of rapid Decompressions are :-

(a) Possibility of rupture of Ear drums without any injury to the skull.

*(b) Patchy Lung Haemorrhages

*(c) Emphysomatus changes

*(These occur more commonly in those cases where the individual was in the phase of breathing-in at the time of decompression.

3.1.9 If it is assumed that the aircraft suddenly broke up in Mid-Air at an altitude of 31,000 ft. the bodies will be at once exposed to hypoxia and rapid decompression and as a consequence will suffer body changes as mentioned above. As the aircraft/occupants start descending, they will be exposed to increasing amounts of Oxygen and as soon as ;they come down below 15,000 ft. and then below 10,000 ft. the effect of hypoxia rapidly diminishes. Finally, the aircraft/individuals come down and hit the ground/water with a very heavy impact, thus submitting the individuals to extremely severe G-loads of decelarative type.

Decelerative Changes : Decelerative impact brings about well established changes in the lungs besides many other associated injuries. It is relevant to note the decelerative lung changes which are :-

(a) Patchy haemorrhages in Lung.

(b) Marked Emphysomatus Changes.

(c) Extrusion of alvoolar Phagocytes

(d) Desqummation of bronchcolar epitherium.

"Comparative study of the PM/histological findings of hypoxia, Decompression and Decelerative Lung injuries reveal that they are more or less similar. Decelerative injury being the most severe of the three and last to occur tends to so modify the Post-Mortem and Histological findings that it becomes extremely difficult and some times impossible to isolate one from the other."

3.1.10 AVM Kunzru was, therefore, of the opinion that in this accident evidence of hypoxia/decompression (except in 2 cases) had not been confirmed or established.

3.1.11 The difference of opinion between Wing Commander Dr. hill and AVM Kunzru, with regard to evidence of hypoxia and decompression, is of no significance in the present case. What is important to note, however, is that they have agreed that the injury pattern does indicate break up of the aircraft in mid-air and that the occupants of Zone E had suffered the greatest amount of injuries as compared to the occupants of the other zones.

MAPPING, WRECKAGE DISTRIBUTION AND SALVAGE

3.2.1 Introduction

3.2.1.1 Oceanographic charts indicated that the depth of sea in the crash area was about 6700 feet and the site appeared to be a flat sea bed, without any valleys or hills. The immediate necessity after rescuing/ searching crash victims, was to locate and recover the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR). The operation was unique of its kind and had never been undertaken earlier in the world at this depth of the sea. It required an equipment which could home on the transmitted signals from the underwater locater acoustic beacons fitted on DFDR/ CVR, identify the units, clear them from attachments/wreckages, grab them and bring them to the surface.

3.2.1.2 The pressure exerted by the water at 6700 feet below mean sea level is extremely high and the temperature is very low. No light penetrates to that depth and it is pitch dark. Scarab I fitted on French Ship "Leon Thevenin" which had undertaken the challenging job of locating DFDR and CVR, and recovering the same, was not designed to operate at 6700 feet depth. Its maximum design operating depth was only 6000 feet. However, it was decided to exceed the design operating depth for this emergency operation.

3.2.1.3 By using the preliminary information of probable area of location OF CVR and DFDR as indicated by ship 'Gardline Locator', the Scarab I was Lowered in the sea to locate and recover these units which it accomplished on 10.7.85 and 11.7.85 respectively.

3.2.1.4 Prior to recovery of DFDR/CVR by the ship 'Leon Thevenin', sufficient spade work was done by the ship 'Gardline Locator' (A ship provided by Accident Investigation Branch, U.K.) and 'Le Aoife' (an Irish Naval Ship). The survey of the crash area, carried out with the help of side-scan sonars fitted on these ships, had indicated a general distribution of the wreckage and a rough idea about the sizes of the parts. Each part of the wreckage was called a target. The method used for survey was triangulation with multiple passes through the crash site.

3.2.1.5 Next phase was the task of :

(a) Locating hundreds of pieces of wreckage by the combined use of sonar and video monitors.

(b) Video and still photography of the pieces of wreckage.

(c) Plotting the distribution of the wreckage.

All this was to be carried out under the directions of the Court.

3.2.2 Scarab

3.2.2.1 The means (vehicles/equipment) proposed to be used in the locating, mapping and video photography of the wreckage were the CCGS John Cabot and SCARAB II.

3.2.2.2 The John Cabot is an ice breaker of the Canadian Coast Guard. Since utilisation as an ice breaker is seasonal, the John Cabot is also equipped for submarine cable laying. In order to enlarge its capabilities in this regard, the John Cabot is equipped to have on its deck the Scarab and to operate it. Thus the John Cabot can be used for repair of submarine cables. The John Cabot has complete facilities for operation, maintenance and repair of the Scarab. This includes a Control Hut, a Test Room, Workshop, Stores etc. The John Cabot has considerable experience in work on deep sea bed.

3.2.2.3 The SCARAB II is a submersible craft assisting repair and burial of cables. As will be clear from the following details, the Scarab is not ipso facto a submarine. It is a total system for carrying out its complex functions.

3.2.2.4 The SCARAB II is a state-of-the-art system designed and built for tethered unmanned work at ocean depths of upto 6000 feet. Scarab's standard equipment are :

Two rugged manipulators.

A complete optical suite.

Six thrusters of 5 hp each.

CTFM Sonar.

Navigation System.
3.2.2.5 The manipulators have a choice of grippers/claws/cutters etc. of any required description and size. The Scarab has three TV cameras mounted on separate pan/tilt mechanism to allow real time observation and video tape documentation. A 35 mm still camera was also installed and used in the present work. There was a choice of quartz-iodide flood lights to provide illumination.
3.2.2.6 The location and control of the Scarab is accomplished through a phased array navigation system.
3.2.2.7 The Scarab was equipped with a 360° high resolution Sonar with a range of 1000 meters. The Sonar was also capable of interrogating and detecting 37 KHz and 27 KHz pingers. It can function independently of the ship's facilities and is equipped with power generators and semiautomatic handling equipment.
3.2.2.8 The John Cabot can salvage items, but it is not a salvage ship as it does not have the specialised high capacity cranes, derricks etc. required for salvage of large objects. Further, it does not have deck space for keeping large salvaged items like the wings, fuselage or tail surfaces of an aircraft as large as a 747. The John Cabot was, therefore, adequate and fully satisfactory for the work envisaged in this phase of the programme, as salvage of large items was not planned in this phase. The task was, as mentioned earlier, locating, mapping and photography of the hundreds of pieces of wreckage. (The salvage work was part of the next phase of the programme).
3.2.3 Control and Monitoring of Operations
3.2.3.1 It was realised that the operation proposed would pose problems of control, monitoring and logistics.
3.2.3.2 Consider : A ship operating on the high seas in international waters on the task of locating, mapping and video photographing the hundreds of pieces of wreckage. The state of art system for Sonar location and photography (Scarab) used by the ship for handling this task. The group located on shore in charge of the operations. Finally, the Court in Delhi was in overall charge of the operatins.
3.2.3.3 It was realised that a proper line of control and

communication was essential if the operations were to be smooth and successful.

3.2.3.4 Therefore it was decided that the following would be the chain of command :

Court Investigating the Accident
(Mr. Justice B.N. Kripal)
Control Centre at Cork
(Court's representative)
CCGS John Cabot
(Commanding Officer)
Scarab
(Project Manager)

3.2.3.5 Because of the multiplicity of agencies involved in the operations, the need was felt for a proper delineation of power at all levels. It was, therefore, decided that :

a. Overall responsibility for the operations would rest with the Indian authority viz. the Court. This would cover the identification and definition of assignment of the overall tasks, laying down of the priorities, overall control of the coverage of the operation and, finally, the time schedule for the operation.

b. Decisions taken at the Control Centre, flowing from the above, were to be taken solely by the Court's representative. The experts from CASB, NTSB and Boeing were free to give their views and recommendations, but the final decisions were to be left to the Court's representative. Examples of such matters are : Track of the survey, areas to be covered by John Cabot, assignment of priorities for specific tasks, amount of time to be devoted to any piece of wreckage, whether any item of wreckage is to be picked up, etc.

c. Operation Control of John Cabot would be in the hands of the Canadian Coast Guard Officer in the Control Centre, who would co-ordinate with the Commanding Officer of John Cabot. This would cover decision on feasibility or otherwise of operations under adverse weather conditions, manner of covering the area, method of retrieving any wreckage, etc.

d. Decisions relating to the Scarab (i.e. whether the weather was suitable for Scarab operations, whether the size, weight etc. of an item would permit its being picked up by Scarab, etc.) would be left to the Scarab Project Manager on Board John Cabot.

3.2.3.6 It might appear at first sight that in the above system excessive power was delegated at certain levels to the detriment of overall control. Any such impression would not be correct. In actual fact, because of proper delegation of responsibility and power at different levels, the operations were carried out with extraordinary efficiency, smoothness and coordination, In this connection, it is relevant to point out that the operations were not a uni-disciplinary one. The operation (aircraft accident investigation) was totally dependent on experts from other disciplines, like naval (coast guard) operations, deep sea photograph, salvage from sea bed etc. It was therefore, decided that for smooth and efficient operations, adequate power and responsibility should be delegated at all levels, particularly to specialists engaged in the different areas of work as above.

3.2.3.7 It was also considered that adequate communication was a sine qua non for smooth operation. Therefore, the following communication facilities were established :

Control Centre at Cork Airport

Telex

Telephones (2)

3.2.3.8 The ship John Cabot had both telex and telephone facility. These links were through satellite (IN MARSAT). The Control Centre was in continuous communication contact with John Cabot through telex and telephones. In order to establish a reliable and satisfactory line of communication it was decided that instructions or communication from Control Centre to the Indian experts on John Cabot would follow the path as under :

Control Centre

Court's representative --- Canadian Coast Guard Officer

John Cabot

Indian experts --- Commanding Officer

3.2.3.9 It was felt that this would eliminate any possibility of inconsistent or contradictory orders/messages going to John Cabot.

3.2.3.10 With a view to have an ordered system of communications between the control centre and John Cabot (which is essential for proper control and monitoring of the operations), it was decided that John Cabot would sent to the Control Centre daily Situation Reports (SITREPS) at specified times viz. 0800 hrs, 1200 hrs, 1600 hrs and 2000 hrs. This however did not preclude the despatch of telexes by both Control Centre and John Cabot at any other time.

3.2.3.11 In order to inform all agencies of the above system of Control and Communication a number of meetings were held. These were on 12.8.85 and 3.9.85 on board John Cabot and on a number of occasions at the Control Centre. The purpose of these meetings was not only to inform all concerned about the specific task, the programme and the line of control and communication but also to sort out differences and to understand the technical and operational difficulties faced by the personnel on the spot and to find a way out.

3.2.4 Daily Monitoring of Progress

3.2.4.1 It may be relevant to point out here that search, location and video photography work was to be carried out round the clock. Thus a considerable volume of data would be coming into Control Centre. This required regular, almost hourly, monitoring, study and analysis for (a) proper understanding of the data collected and (b) advising John Cabot of any changes in its programme, such as additional photography on an item etc. For this purpose (i) SITREPS were filed in the Control Centre (ii) all data (description, latitude and longitude) obtained on every target was tabulated and the cumulative list updated daily.

3.2.4.2 The location of the targets was plotted on charts every 4 hours. This was in addition to the plotting of targets carried out on John Cabot.

3.2.4.3 Every day (including holidays and week ends) all the officers posted at Control Centre assembled at about 0900 hrs. They studied the SITREPS received at 0800 hrs and any other telexes received from John

Cabot in the night. The lists of targets were updated and the new targets plotted on the charts. John Cabot generally also sent brief remarks such as description, nature of failure/damage, dimensions etc. Discussions were held on the significance of the targets and their implications. Instructions if any to be telexed to John Cabot were also discussed. Similarly SITREPS received at 1200 hrs and 1600 hrs were studied.

3.2.5 Monitoring at Cork

3.2.5.1 The Scarab provided video tapes and still photographs. In the initial stages (upto 9.8.1985) the John Cabot was operating in peripheral areas and therefore few targets were found. Hence the output of videotapes was small. In fact upto 9.8.85, only about 10 targets were found and only 3 video tapes were used up. But later, when John Cabot came close to and into the crucial areas, video tapes were recorded at a fast rate. Further, still photography facility on the Scrab was activated at about this time. Therefore, arrangements were made periodically to obtain the video tapes and films from John Cabot. Video tapes and still photographs (these required to be processed) were transported from John Cabot to Cork Control Centre.

3.2.5.2 About 50 video tapes and nearly 3000 still photographs (positives and transparencies) provided the visual information on the targets.

Arrangements had to be made at Cork for such viewing and study of the video tapes and still photographs. Video equipment (TV monitor plus VCR) suitable for viewing the video tapes had to be arranged.

3.2.5.3 The still photography used special professional quality colour film (35 mm), each roll having 800 frames. The film was diapositive. These had to be developed and transparencies obtained from them. Thereafter negatives and prints had to be made. Special equipment for viewing the transparencies had to be provided for continuous work. The video tapes, transparencies and prints provided the principal means of monitoring of the results of the operation.

3.2.6 Operations

3.2.6.1 The Charts prepared by 'Gardline Locator' were on a different type of grid system, and had to be translated into LAT-LONG system, for use by John Cabot. For the convenience of search/mapping operation the search area was divided into 4 blocks viz. Block 1, Block 2, Block 3 and Block 4.

3.2.6.2 The navigation system used by John Cabot is PULSE-8 system. This system needs the transponders to be placed on the sea bed. These transponders help in getting the correct fix of a target and in obtaining relative positions of the targets on the sea bed which is highly useful for revisit for the purpose of rephotography or recovery. Initially 4 transponders were placed, and subsequently the number was increased as the search operation was continued. The strategic locations for placing the transponders was decided by considering :

(a) frequencies of relative transponders,

(b) distances required between relative transponders,

(c) wreckage distribution suggested by side scan sonar plots of Eithena and Garline Locator, and

(d) size of search area.

These transponders were calibrated to match the navigation system of the ship.

3.2.6.3 In order to obtain the maximum information from search, it was decided that the Scarab search paths should be as follows :

(a) Normally the search paths should be east to west, or west to east within the individual blocks.

(b) The pattern of search should be a parallel search method.

(c) Distances between the parallel paths to be 1,200 feet (i.e. 2 cable widths), for effective use of sonar fitted on the Scarab.

(d) If Scarab deviates from its planned path for photography or recovery, it should return to its planned path for further search.

(e) In each block, the search was to be made, at least 1/2 mile (North or South) beyond the last target sighted, so as to ensure no target is missed out from the given block.

3.2.6.4 However, when there was a need to modify the search pattern, due to wreckage distribution in particular areas, the following changes were made:

(a) Expanding box type search pattern was used in Block 1.

(b) Some North to South and South to North passes were made in Block 3.
(c) In Block 3 northern end, the distances between the search passes was reduced to 600 feet i.e. 1 cable width.
However, these deviations were made basically to improve the reliability of search in specific areas, as demanded by peculiar distribution of aircraft wreckage.
3.2.6.5 To facilitate identification of the wreckage located by Scarab it was necessary to position aircraft maintenance personnel on board the ship. As the aircraft structure was badly torn, mutilated and distorted, serious difficulty was anticipated in identification of small pieces of structure. It was therefore essential that these maintenance personnel were provided with aircraft photographs, manufacturing drawings, parts catalogue, wiring diagram manuals and maintenance manuals. Since carriage of such voluminous literature was not praticable, 3M micro film reader printer
machines with micro film cassettes of the above literature were produced and installed on the ship. In case of difficulty of locating any particular information, the engineers were advised to contact Cork Search Centre by telex or telephone who, in turn, could seek the desired information from the manufacturers.
3.2.7 Wreckage Distribution
3.2.7.1 The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling at the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled. Although badly damaged, sections 41, 42 and

44, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been mapped or photographed. Section 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the western most identified aircraft component located at lat 51°02.90'N and long 12°50.1'N. The wreckage extended in a line about 110 degrees to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern. A third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southwest orientation. One of the operating engines was displaced 0.5 nautical mile to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components

and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

3.2.7.2 Details of the various targets which were identified by the Structures Group is contained in Appendix 1 of this Report.

3.2.8 The Break up Pattern

3.2.8.1 The forward fuselage section of the aircraft was found inverted and badly broken into many pieces, the major pieces being :

(I) Section of fuselage right side below cockpit windows containing part of the name 'Kanishka' (in Hindi) and 3 passenger windows (Target No. 192)

(ii) Portion of upper skin between B S 360 and B S 520 below window belt right side, up and over crown. This portion includes the crew door and last letter of the "Air India" (in Hindi) logo (Target No.

192).
(iii) Section of fuselage between B S 510 to B S 700, including the passenger window belt right side, up and over crown to include upper deck windows left side (Target No. 218).
(iv) Section of fuselage between B S 720 to B S 840 including left side passenger window belt, up and over crown to right side passenger window belt. Forward and upper edges of L H No.2 door cutout can be seen (Target No. 193).
(v) Large section of fuselage between B S 1000 to B S 1460 including left side passenger window belt, up and over crown to right side passenger window belt. This section was found lying on its right side (Target No. 137).
(vi) The lower portion of the fuselage skin/frame between the nose and B S 1000 was damaged past recognition except for a small portion with the forwarded cargo door (Target No.204) and another portion containing the aft access door cutout at B S 810 (Target No. 362).
3.2.8.2 The aft fuselage was found in the following major pieces :
(I) Section of RH fuselage skin between B S 1640 and B S 1940 below the window belt up to the crown (Target No. 321).
(ii) The RH fuselage bottom skin between B S 1820 (forward edge of C2 door) and B S 2060 and between two stringers above the door cutout to just below stringer 46 lap joint (Target No. 40).
(iii) The lower fuselage skin with stringers between B S 1480 and B S 1846 about 100 inches wide approximately (Target No. 7).
(iv) The LH fuselage skin panel between B S 1740 and B S 1880 about 110 inches wide (Target No. 11).
(v) The LH fuselage skin between B S 1460 and B S 1800 width 80 inches including No. 4L door and passenger windows (Target No. 28).
(vi) The RH fuselage skin between B S 1660 and B S 1920, from below window belt up to the crown including the 4R door cutout (Target No. 321).
(vii) A fuselage lower skin panel (containing out flow valve) between B S 2120 and B S 2240 and 120 inches wide (Target No. 320).
(viii) A fuselage LH skin panel (containing 5 windows with "T -"

part of registration) between B S 1980and B S 2080 between stringers 19L and 24L (Target No. 369 and 26).

(ix) A fuselage LH skin panel between B S 1460 and B S 1800 with 8 stringers below the bottom of the door and 3 stringers above the top of the door (Target No. 28).

3.2.8.3 The tail portion of the fuselage was found in the following pieces:

(I) The lower fuselage skin between B S 2412 and B S 2598 about 20 stringers wide (Target No. 371).

(ii) The vertical fin with rudders attached was lying on the ground by itself with a portion of B S 2517 frame. This includes a small portion of the aft pressure bulkhead (Target No.37).

(iii) The horizontal tail with elevators attached was lying on ocean floor with the jack screw and drive motor attached (Target No. 31).

(iv) The fuselage tail cone aft of B S 2669 was found basically intact and lying separately (Target No. 27).

3.2.9 Extent of Damage

Photographic and Video Interpretation of Wreckage

Photographic Interpretation

3.2.9.1 All wreckage sighted was recorded on video tapes and all major items were recorded on 35 mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage pattern. For example, the sine wave bending of target 7 appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into acount.

3.2.9.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

3.2.9.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gears were in the 'up' position at the time of impact.

3.2.9.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

3.2.9.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

3.2.9.6 Section 42

Portions of Section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers. All cargo doors were found intact and attached to the fuselage structure, except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different from that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back on to the sea bed. An attempt to relocate the door was unsuccessful.

3.2.9.7 Section 44

Section 44 containing the aircraft structure between B S 1000 and B S 1480 including that area where the fuselage and wings were mated was located and identified. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gears were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

3.2.9.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northern most area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

3.2.9.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of B S 1480 and, for purposes of this report, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

3.2.9.10 The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were positively identified (targets 35, 37, 73 and 296). Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognisable as having come from a specific area of the aircraft.

3.2.9.11 Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from B S 1600 to B S 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

3.2.9.12 The tail cone and the auxillary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

3.2.9.13 A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure.

3.2.9.14 The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

3.2.9.15 The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates° to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabiliser was missing and the auxilliary spar was exposed. There was localized damage to the right-hand root of the loading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

3.2.9.16 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from section 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42 and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat belts were not fastened.

3.2.10 Salvage Operations

3.2.10.1 During recovery operation the video tapes as well as photographs of the wreckage to be recovered, were supplied to the personnel on board the ship for facilitating identification and recovery of correct targets.

3.2.10.2 Whenever any component/part of the aircraft wreckage was salvaged it was essential to immediately subject the same to inspection and to identify the damage sustained during recovery operation. In order to oversee this critical operation, the Court deputed one of its Assessors, Dr. V. Ramachandran, to be on board the ships. Under his supervision, the components/parts were thoroughly washed with fresh water, dried and treated with corrosion inhibiting compounds. A detailed inspection was thereafter carried out, observations recorded and the targets were appropriately labelled and their numbers were painted thereon. A laboratory microscope was taken on board by Dr Ramachandran. With that, fragments of significance were segregated for further investigation.

Indeed some of these fragments did give important clues.

3.2.10.3 All the investigating personnel on board the ship were provided with leather gloves, fisherman's shoes, raincoat, life floating suits, writing and labelling material, camera with coloured films, etc. Sufficient number of "body bags" were positioned on each ship to cater for the eventuality of recovery of bodies with the wreckage. This precaution helped when a body did come along with wreckage on 25.10.1985.

3.2.10.4 The ship John Cabot completed the operation of locating, mapping and photography of the wreckage and returned to Cork on 1.10.85 at 2020 hours. The next phase of operation was to recover the significant wreckage parts which would be useful for deciding the cause of the crash.

3.2.10.5 Subsequent to the accident to Japan Airlines Boeing 747 aircraft, suspected to have been caused by failure of the repair to the rear pressure bulkhead, NTSB and FAA decided to fund the U.S. Navy for a two week operation over the seas for recovery of significant pieces of wreckage. For this purpose, U.S. Navy appointed Commander J.R. Buckingham, a deep sea salvage expert, to head the recovery operation. An offshore supply vessel M.V. Kreuzturm, of Canada was hired by U.S. Navy to recover the wreckage with the help of Scarab on John Cabot. One nylon lift line together with winch and ram were installed on the ship prior to its sailing to Cork where it arrived on 4th October, 1985. One crane was installed on the ship Kreuzturm in Cork.

3.2.10.6 One inch dia Kevlar lines coated with black plastic for abrasion resistance and braided with Dacron lining were used by John Cabot as primary lift lines.

3.2.10.7 The structure group after studying the photographic data, had formulated a list of 32 targets for recovery on 3.10.85. A systemwise priority list proposed by the Court of Inquiry was received through Dr V. Ramachandran on 4.10.85. Using these two lists, and taking into account the operating restrictions imposed by two ship operation, a final list of targets was prepared for recovery by the ships, assigning a priority number to each target. However, as the recovery operation progressed, changes in priority list were made to achieve optimum utilisation of the ships.

3.2.10.8 A meeting was held at 1400 hrs. on 4.10.85 on board CCGS John Cabot to establish/clarify the priorities for the wreckage recovery operation and coordination between John Cabot, Kreuzturm and Cork Search Centre. All the personnel involved in the recovery operation were shown the slides and photographs of the targets which were chosen for recovery on priority basis. The method and procedure of the recovery operation was discussed in detail and finalised. Another meeting was convened on 6.10.85 to clarify the doubts and to present the picture albums containing various photographs of targets to be recovered. The mode of attaching grippers/grabbers to the targets at strong points was clarified. A serialised list of priorities was prepared based on the mode of operation indicated by the the crew of John Cabot and Kreuzturm. Dr Ramachandran was given the authority to make on-the-spot decisions during the salvage operations.

3.2.10.9 A detail log of the activities of the ships John Cabot and Kreuzturm which started the recovery operation of 10.10.85, reveals the following :

(a) The Scarab working independently recovered the following

(1) Basket at target 192 containing copilot's chair, 2 suitcases and radar antenna (12.10.85)

(2) Target 8 - Lower fuselage skin of aft cargo compartment. (11.10.85).

(3) Target 245 - Forward belly skin just aft of radome (16.10.85).

(4) Target 350 - Economy class seats and carpet (23.10.85).

(5) Target 296 - Piece of aft pressure bulkhead.

(b) The Scarab after attaching the grippers, bridal cable and lift line to the targets buoyed off the same to Kreuzturm which recovered the following targets :

(1) Target 362/396 - Forward cargo fuselage skin from station 700 to 840 and STR 41L to 43R. (16.10.85).

(2) Target 193 - Fueselage skin from station 720 to 860 and passenger

door 2L (17.10.85)
(3) Target 223 - Nose landing gear pressure deck web and stiffeners, container pieces (staion 260-340)(19.10.85).
(4) Target 181 - Wing skin with forward cargo compartment SLIPPED OFF WITH GRIPPERS (21.10.85) AND WAS LOST.
(5) Target 399/358 - Fuselage skin from station 780 to 940 and STR 7R to 35R with 2R door (25.10.85). A body entrapped in target 399/358 was recovered. Another body which came upto surface with the wreckage fell
off into sea and was lost while hauling the wreckage on board. The recovered body was identified as of Dr. Mathew Alexander, a Canadian passenger and was brought to Cork by Fisherman's vessel "Orion" at 0130 hrs. on 28.10.85 and was sent for Post Mortem etc.
(6) Target 7 - Aft cargo compartment fuselage skin from station 1480 to 1860 (26.10.85).
(7) Target 47/50 - Aft cargo floor structure with roller tracks, frames, latch etc. from station 1600 to 1760 (27.10.85).
(8) Target 117 - Three rows of coach class seats with passenger cabin floor boards, broken floor beam (28.10.85).
(9) Target 35 - Aft Pressure Bulkhead piece (30.10.85).

3.2.10.10 The Scarab experienced malfunctions with its arms, Sonar equipment, multiplex system, junction box, microprocessor unit, etc. off and on during the above period of operation. Fouling of lift line with umbilical cord was also experienced in the early stages of operation. Since the assigned recovery by Kreuzturm was over by 30.10.85, and as the Scarab became unserviceable due to breakdown of its power suppluy, the OSV MV Kreuzturm was directed to return to Cork to off-load the recovered wreckage and its operation was terminated, (Indian Government had funded the cost of operation of M.V. Kreuzturm from 21.10.85 onwards).

3.2.10.11 Since the Scrab continued to remain unserviceable, the ship John Cabot was called back to Cork. It anchored in Cork at 1100 hrs. on 5.11.85. All the wreckage on board the ship was transported to the boat yard, in the afternoon.

3.2.10.12 After detailed macro photography of the recovered wreckage, the experts group mentioned in section 1.5.16 prepared a detailed factual report after carefully inspecting each of the targets recovered. It was decided to send the wreckage to Bombay for which necessary crates were then prepared and the large pieces of wreckage were cut along the lines indicated by the experts group to facilitate their packing.

3.2.10.13 RCMP investigators carried out a close visual and microscopic examination of the fragments recovered with the wreckage, suitcases, seats and cushions, etc. For further laboratory analysis. Dr A.D. Beveridge collected a few samples.

3.2.10.14 The Scarab appeared to be serviceable on 19.11.85 and the ship John Cabot sailed for completion of recovery of left over targets, on 20.11.85. However, the serviceability of Scarab proved elusive, it became inoperable on 21.11.85 and the ship returned to Cork at 1700 hrs on 25.11.85.

3.2.10.15 Efforts were made to repair Scarab so that the ship John Cabot could sail again in order to salvage as many pieces as possible. It was fortunate that the weather had not deteriorated. Some of the important but small pieces which had to be recovered had been placed in a basket at the bottom of the ocean. The ship sailed out again after Scarab had been repared. The basket was sought to be lifted, but, unfortunately, when it reached near the surface of the sea it overturned and the contents of the basket spilled and were never traced again.

3.2.10.16 At this juncture it was decided that the salvage operations should be terminated. The ship returned and sailed for home in the first week of December 1985.

3.2.11 Examination of Wreckage

3.2.11.1 Floating Wreckage

Soon after the accident, a number of light weight parts of the aircraft were found floating over a wide area at the crash site. These were picked up by the ships engaged in rescue operations and were brought to Cork where they were kept in the boat yard. The floating wreckage recovery continued for four days i.e. upto 26th June.

3.2.11.2 Some of the wreckage items were subsequently washed to the west coast of Ireland. These were picked up by the Irish Police and were brought to Cork. Some wreckage items were taken by a ship to Halifax, Canada. These were flown to Cork by the Canadian Aviation Safety Board. With the assitance of Air India engineers, the wreckage items were
identified, labelled, photographed and laid out in the boat yard hangar for examination.
3.2.11.3 The wreckage was initially examined at Cork by the Structures, Power Plant and Systems Group. It was subsequently transported to Bombay for further examination. A few wreckage items which were taken by the Spanish trawlers to Madrid were also transported to Bombay. Some wreckage items had washed to the west coast of England. These were collected by the Accident Investigation Branch of UK and were transported to Cork and then to Bombay.
3.2.11.4 The floating wreckage recovered constituted approximately 3 to 5 per cent of the aircraft structure. The major items of the wreckage recovered were :
Various leading edge skin panels of LH nd RH wing, LH wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canon fairings aft end pieces, landing gear wheel wall doors, pieces of elevator and aileron, toilet doors, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggages, suitcases etc. and three empty oxygen bottles.
3.2.11.5 The Structures Group which had been constituted by the Court examined the floating wreckage and submitted its report. From the report the following significant information about the damage to major items of the floating wreckage is noted :
(I) VT-EFO aircraft was carrying a -7Q engine on 5th pod and a -7Q 5th pod kit in the aft cargo compartment. It had therefore, in all 14 engine fan cowls (eight working engine fan cowls plus two 5th pod engine fan cowls plus two -7T engine kit fan cowls in the aft cargo compartment plus two -7Q engine fan cowls in the aft cargo compartment). Out of these 14 fan cowls, 9 cowls (6 of working engines

plus 2 of -7J kit plus one of 7Q kit) and two additional pieces of fan cowls were found. Five of the fan cowls of working engines show folding damage lines at approximately 3 O'Clock and 9 O'Clock positions. The number 3 engine inboard fan cowl has severe impact damage on its leading edge and has small inward to outward puncture holes (not penetrating through outer skin) in the lower centre region. The two fan cowls of -7J 5th pod kit stowed in the aft cargo compartment exhibit severe damage. One of these cowls is broken in two pieces. One of the pieces is cut at one corner in an arc of about 20 inches diameter and its external skin is pealed back. The external surfaces of all the three pieces have considereable scratches, tears and holes from outside to inside. None of the punctures penetrates the inner skin. Some punctures are also present from inside to outside but none of these penetrates the outer skin.

(ii) Out of the 12 spoilers, seven (number 2, 3, 5, 7, 8, 9 and 12) have been retrieved. Of these, six have their actuators attached to them in fully retracted position. Six spoilers have splits in their lower skin with split edges curled into the cores of honeycomb. Number 8 spoiler (located just inboard of number 3 engine) has a concentrated local impact damage on front spar and trailing edge beam from forward to aft and up direction over a span of 2 feet starting from outboard of spoiler actuator.

(iii) The left hand wing tip assembly with a part of H F Antenna was retrieved. No burning/discolouration marks around lightning arrester of H F system were noticed. The rib inboard of the lightning arrester was found intact. There were no burn marks anywhere on the panel.

(iv) The right hand wing leading edge top panel inboard of number 3 engine with a position of kruger flap frame along with bull nose attached was recovered. The bull nose was found crushed from top in the area just below the stay rod and the lower surface of stay rod has scratch marks from front to rear.

(v) The right hand wing root leading edge (inboard of W S 268.81) shows an impact damage at the leading edge. Bottom skin and internal structure are torn away. The leading edge skin is caved in over a span of about 3 feet and shows signs of heavy body impact in air. The impact damage shows signs of downward and backward movement of the impacting body.

(vi) A 3' x 2' piece of right hand inboard trailing edge fore flap with accordian seal was recovered. The inboard 8" portion of leading edge was found damaged by impact of an object going from lower forward to upper aft.

(vii) All the floor panels recovered from upper deck and main cabin indicate that these were detached from their attachments in an upward direction from all sides.

(viii) One main deck blow out door located between B S 2040 and 2140 left hand side was available. Out of its four metal clips, one clip was broken off with 2 nylon rivet heads sheared.

(ix) The cockpit entry door and the side bulkhead panel were found fairly intact but had come out of their attachment.

(x) Twelve toilet doors, out of a total of 16, were available and were found fairly intact, but had come out of their attachments.

(xi) The available cabin interior panels and overhead bins of the main deck and upper deck have only minor damage.

(xii) The woodent boxes which contained the fan blades of 5th pod engine and were loaded in container at position 24L in the forward cargo compartment were found broken apart with no burn marks.

3.2.11.6 Wreckage Salvaged from Sea

The wreckage salvaged from the sea was visually examined at Cork by the Committee of Experts as mentioned in section 1.5.16 and the observations thereon recorded. Subsequently detailed metallurgical examination was carried out at the Bhabha Atomic Research Centre, Bombay by

Dr. M.K. Asundi and Dr. G.E. Prasad of B.A.R.C., Mr. S. Radhakrishnan and Dr. R.V. Krishnan of National Aeronautical Laboratory and Mr. B.K. Athawale of the Explosives Research and Development Laboratory, under the guidance of Dr. V. Ramachandran. During this examination, representatives of CASB, CP Air and Boeing were present in the first week. These represntatives left Bombay while the metallurgical examination was being carried out. The metallurgical examination was continued and the aforesaid group submitted the metallurgical report to the Court in December, 1985.

3.2.11.7 Although all the recovered wreckage was examined, only those items exhibiting characteristics which provide some evidence as to what may have happened to the aircraft during its final moments of flight are discussed herein below :

3.2.11.8 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from B S 1480 to 1850 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear and the torn edge was buckled in waves, like the trace of a sine wave. One the right side, between the one quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at B S 1480. The skin tear located at about B S 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distored and elongated.

3.2.11.9 This panel was examined by the committee of experts at BARC and according to their report the keel beam trunnion fitting beneath the outer chord of the station 1480 bulkhead had fractured at the aft set of bolt holes. The fracture surface of the right side of the trunnion fitting was clean. As per the report, it was typical of overload failure in tension. The fracture surface of the left side of the trunnion fitting was covered with corrosion products, especially, at one corner, due to sea water. After cleaning this area by the recommended techniques, scanning electron microscopy revealed morphology of overload fracture consisting of dimples. Away from this corner also the fracture was similar as being due to overload. There was no evidence of there having been any fatigue failure.

3.2.11.10 At B.A.R.C., a sample was cut from the corroded corner of the failed left side trunnion fitting and metallographic examination was carried out on the same. The said examination showed on a face perpendicular to the corroded fracture surface, pits due to corrosion by sea water. The basic microstructure was however free from intergranular cracking. It was thus concluded by the experts that the material in the region corroded by sea water had not suffered stress corrosion cracking which generally manifests as intergranular cracking.

3.2.11.11 A piece of the trunnion fitting was cut and the hardness and electrical conductivity values were measured by the said experts. As per their report, the electrical conductivity values were within the specified limits.

3.2.11.12 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from B S 1860 to 1960 and from stringer 46L to 46R. The forward end of target 8 matched with the aft end of Target 7. A region of fracture along the rivet holes near stringer 46L was marked for SEM examination. SEM examination after cleaning revealed that the fracture was characterised by dimples along its length, including areas adjacent to the edges of the rivet holes. These features are consistent with an overload mode of failure.

3.2.11.13 According to the metallurgical report, there was no evidence of fatigue failure on this target.

3.2.11.14 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 O'Clock position, the piece from 12 to 1 O'Clock position had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 O'Clock position the outer edge showed sinusoidal buckling, and the edge sector at 9 O'Clock position was partially collapsed and its edge was turned under. Samples taken for optical stereo microscope and SEM examination revealed that the fracture characteristics were consistent with an ovrload mode of failure.

3.2.11.15 According to the metallurgical report, there was no evidence of fatigue or any other mode of failure.

3.2.11.16 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occuped the 7 to 9 O'Clock position. Optical and SEM examination were undertaken on this item.

3.2.11.17 The fracture alont the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

3.2.11.18 Representative fracture samples were cut from the left-hand side and circumferential fracture edges of the fracture surfaces. Optial and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

3.2.11.19 Target 47 - Aft Cargo Floor Structure

This portion of the aft cargo compartment was located between B S 1600 and B S 1760. No significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

3.2.11.20 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between B S 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

3.2.11.21 In the metallurgical report it is stated that on an examination of this target it was also found that on the underside of this floor near the forward end, a number of dents and impact marks were observed. This region appeared to have suffered shrapnel penetration. This area was radiographed but no metallic fragment was detected.

3.2.11.22 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segement was located between B S 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

3.2.11.23 Target 399 - Fuselage around 2R Door

This target is shown in Fig. 399-1. A detailed description is given below :

TARGET 399 Fuselage Station 780 to 940 in the longitudinal direction and stringer 7R down to stringer 35R circumferentially.

This piece contained five window frames, one in the 2R passenger entry door. Three of the window frames, including the door window frame, still contained window panes. Little overall deformation was found in the stringers and skin above the door. The structure did contain a significant amount of damage and fractures in the skin and stringers beneath the window level. In the area beneath the level of the windows, the original convex outward shape of the surface had been deformed into an inward concave shape. Further inward concavity was found in the skin between many of the stringers below stringer 28R. The skin at the forward edge of the piece was folded outward and back between stringers 25R and 30R. Over most of the remaining edges of the piece a relatively small amount of overall deformation was noted in the skin adjacent to the edge separations. Twelve holes or damage areas were numbered and are further described.

No.1 : Hole, 5 inches by 9 inches with two large flaps and one smaller curl, all folded outward. Reversing slant fractures, small area missing.

No.2 : Hole, 2 inches by 3/4 inch, one flap folded outward, reversing slant fractures, one curled sliver, no missing metal.

No.3 : Triangular shaped hole about 2 inches on each side. One flap, folding inward, with one area with a serrated edge. No missing metal, extensive cracking away from corners of the hole, reversing slant fracture.

No.4 : Tear area, 8 inches overall, with deformation inward in the centre of the area. Reversing slant fracture.

No.5 : Fracture area with two legs measuring 14 inches and about 24 inches. Small triangular shaped piece missing from a position slightly above stringer 27R. Inward fold noted near the joint of the legs. An area of 45° scuff marks extend onto this fold.

No.6 : Hole about 2.5 inches by 3 inches with a flap folded outward, reversing slant fracture. Approximately half the metal from the hole is missing.

No.7 : Hole about 3 inches by 1 inch, all metal from the hole is missing. Fracture edges are deformed outward.

No.8 : Forward edge of the skin is deformed into an "S" shaped flap. Three inward curls noted on an edge.

No.9 : Inwardly deformed flap of metal between stringers 11R and 12R at a frame splice separation. No evidence of an impact on the outside surface.

No.10 : Door lower sill fractured and deformed downward at the aft edge of the door.

No.11 : Frame 860 missing above stringer 14R. Upper auxilliary frame of the door has its inner chord and web missing at station 860. A 10 inch piece of stringer 12R is missing aft of station 860.

No.12 : Attached piece of floor panel (beneath door) has one half of a seat track attached. The floor panel is perforated and the lower surface skin is torn.

3.2.11.24 Much of the damage on this target was on the skin and stringers beneath the window level, i.e., on the starboard side of the front cargo hold. The inside and outside surface of the skin in this region are shown in Fig. 399-2 and 399-3 respectively. There were 12 holes or damaged areas on the skin as described above, generally with petals bending outwards. The curl on a flap around hole no.1 shown in Figh 399-4 has one full turn.

This curl is in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.

3.2.11.25 When this target was recovered from the sea, along with it came a large number, a few hundreds, of tiny fragments and medium size pieces, All of the fragmets were recovered from the area below the passenger entry door 2R. One of the medium size pieces recovered with this target was a floor stantion, about 35 inches long, shown in Fig. 399-5. It is a square tube. It had the mark station 880 painted on its inner face, i.e. facing the centre line of the cargo hold. The part number printed on this station is 69B06115 12 and the assembly number is ASSY 65B06115-942 E3664 1/31/78*. It was confirmed that this stantion belongs to the starboard side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the station. Fig. 399-6 is a print from the radiograph of this station. The inward curling can be seen clearly in this figure. Curling of the metal in this manner is a shock wave effect.

3.2.11.26 A piece near the fracture edge of this stantion was cut, and examined metallographically. Fig. 399-7 and 399-8 show the micro-structure of this piece. Twins are seen in the grains close to the fracture edge. The normal microstructure of the stantion material is free from twins as shown in Fig. 399-9.

3.2.11.27 Fig. 399-10 shows a collection of small fragments recovered along with target 399. There were some curved fragments with small radius of curvature (A). Reverse slant fracture (B) was noticed in some of the skin pieces. A piece 3/4" x 1/2" and 3/16" thick was found to have three blunt spikes at the edge (C). This piece was metallographicaly polished on the longitudinal edge. The microstructre of the piece is shown in Fig. 399-11. It may be seen that the grains in this fragment also contain a large number of twins.

3.2.11.28 Target 362/396 Forward Cargo Skin

This piece indluded the station 815 electronic access door, portions of seven longitudinal stringers to the left of bottom centre and five longitudinal stringers to the right of bottom centre. The original shape of the piece (convex in the circumferential direction) had been deformed to a concave inward overall shape. Multiple separations were found in the skin as well as in the underlying stringers. Further inward concavity was found in the skin between most of the stringers.

3.2.11.29 The two sides of this piece are shown in Fig. 362-1 and 362-2. This piece has 25 holes or damaged areas in most of which there are multiple petals curling outwards. These holes are numbered 1 to 3, 4a, 4b, 4c and 5 to 23. These are described below. Unless otherwise noted, holes did not have any material missing :

No.1 : Hole with a large flap of skin, reversing slant fracture.

No.2 : Hole with multiple curls, reverse slant fracture.

No.3 : Hole with multiple flaps and curls, reversing slant fracture, one area of spikes (ragged sawtooth)

No.4A : One large flap, reverse slant fracture, one area of spikes.

No.4B : Hole with two flaps.

No.4C : Hole with two flaps, one area of spikes

No.5 : HOle with two flaps.

No.6 : Braching tear from the left side of the piece, reversing slant fracture.

No.7 : Hole, with one flap, one curl and one area of spikes.

No.8 : Very large tear from the left side of the piece with multiple flaps and curls, reversing slant fracture and at least two areas of spikes.

No.9 : Hole with multiple flaps, one curl.

No. 10 : 2.5 inch tear

No.11 : One flap

No. 12 : Grip hole, plus a curl with spikes on both sides of the curl.

No.13 : "U" shaped notch with gouge marks in the inboard/outboard direction. Three curls are nearby with one are of spikes. Gouges found on a nearby stringer and on a nearby flap.

No. 14 : Nearly circular hole, 0.3 inch to 0.4 inch in diameter. Small metal lipping on outside surface of the skin. Most of the metal from the hole is missing.

No. 15 : Hole in the skin beneath the first stringer to the left of centre bottom. Small piece missing.

No. 16 : Hole in the stringer above hole No. 15. Most of the metal from this hole is missing.

No. 17 : Hole through the second stringer to the left of centre bottom, 0.4 inch in diameter. The hole encompassed a rivet which attached the stringer to the outer skin. Small pieces of metal missing.

No. 18 : Hole at the aft end of the piece between the third and fourth stringers to the left of centre bottom. The hole consisted of a circular portion (0.4 inch diameter), plus a folded lip extending away from the hole. The metal from the circular area was missing.

No. 19 : Hole with metal folded from the outside to the inside, about 0.6 inch by 1.5 inch. Flap adjacent to the hole contained a heavy gouge mark on the outside surface of the skin.

No. 20 : Hole containing a piece of extruded angle.

No. 21 : Hole containing a piece of extruded angle.

No. 22 : Hole with one flap.

No. 23 : Hole about 0.3 inch in diameter, with tears away from the hole. Small piece missing.

3.2.11.30 Fig. 362-3 to 362-7 show a few of these holes. There were also cracks or tears around some of the holes. The curls around some of the holes had nearly one full turn. In the large tear between body stations 700 and 740 and stringers between 41L and 45L, there were many pronounced curls as shown in Fig. 362-8. On the edges of the petals around several holes, reverse slant fracture was seen at a number of places. This slant fracture is at an angle of about 45° to the skin surface, the fracture continuing in the same general direction but with the slope of the slant fracture reversing frequently.

3.2.11.31 Sharp spikes were observed at the edges of the holes or at the edges of the petals around the holes No. 3, 4A, 4C, 7, 8 (at two locations), 12, 13 and 16. Some of the spikes are shown in Fig. 362-9 to 362-12. One of the holes, No. 14, on the skin was nearly elliptical with metal completely missing, as shown in Fig. 362-13. On the inside surface of the skin, paint surrounding this hole was missing. Hole No. 16 was through the hat section stringer, as shown in Fig. 362-14. In this, most of the metal was missing. On the inside of the hat section, the fracture edge of this hole had spikes, as shown in Fig. 362-15. Hole No. 17 was through the stringer and the skin, as shown in 362-16.

3.2.11.32 Through holes No. 20 and 21, extruded angles were found stuck inside, as shown in Fig. 362-17 and 362-18 respectively. In the petal around hole No. 20, there was an impact mark by hit from the angle as seen in Fig. 362-19 photographed after removing the angle. Such a mark was not present in the petals around other holes.

3.2.11.33 On the skin adjacent to hole No. 13 gouge marks were noticed, Fig. 362-20. These marks were on the inside surface of the skin. To check whether these could be due to rubbing by the bridal cable of Scarab during the recovery operations, a sample of bridal cable was obtained from "John Cabot" and gouge marks were produced by pressing this cable against an aluminium sheet. The gouge marks thus produced, as shown in Fig. 362-21, appear to be different from those observed near hole No. 13.

3.2.11.34 A piece surrounding hole No. 14 was cut out and examined in a Jeol 840 scanning electron microscope at the Naval Chemical and Metallurgical Laboratory, Bombay. Fig. 362-22 and 362-23 are the scanning electron micrographs showing the inside surface and outside surface of the skin around this hole. Flow of metal from inside to outside can be seen from these figures. Energy dispersive x-ray analysis was carried out on the edges of this hole. Only the elements present in this alloy and sea water residue were detected.

3.2.11.35 A portion of the skin containing part of hole No. 14 was cut, polished on the thickness side of the skin and examined in a metallurgical microscope. Fig. 362-24 shows the microstructure of this region. The flow of metal along the edge of the hole can be seen from the shape of the deformed grains near the hole. This can be compared with the bulk of the grains shown in Fig. 362-25, away from the hole. In addition, in Fig. 362-24, a series of twin bands can be seen in some of the grains near the hole. Fig. 362-26 shows these bands at a higher magnification. Normal deformation rates at various temperatures do not produce such twinning in aluminium or its alloys. It may be noted that this microstructural feature is absent in the microstructure of the skin, away from hole No. 14, Fig. 362-25.

3.2.11.36 Metallography was also carried out on a petal around hole No.7 and on a curl with spikes around hole No. 12. The microstructures indicate twins, however they could not be recorded due to their poor contrast.

3.2.11.37 Small pieces containing the spikes around holes No. 12 and 16 were cut and energy dispersive x-ray chemical analysis on the region of spikes in both was carried out in the Jeol 840 SEM. Only elements present in the alloys and sea water residue were detected.

3.2.11.38 A number of small fragments were found along with the forward cargo skin in target 362. Amongst them was a piece from the web of a roller tray. This has pronounced curling of the edges towards the drive wheel, Fig. 362-27.

3.2.11.39 Another small fragment was found from the above target. This piece, identified as specimen No. 12 in box No. 1, target 362, has a number of spikes along the edge. A scanning electron micrograph of the spikes is shown in Fig. 362-28. The sides of the spikes on SEM examination revealed elongated dimples as shown in Fig. 362-29, characteristic of shear mode of fracture. Metallography was carried out on the thickness side of this specimen. Fig. 362-30 and 362-31 show the microstructure near the apex of the spike and at the root of the spike respectively. Extensive twinning can be seen in these regions of the spikes.

3.2.11.40 Another fragment recovered with target 362 and identified as specimen No. 8 in box No. 1, also showed extensive twinning. The microstructure is recorded in Fig. 362-32.

3.2.11.41 Reference has also to be made to two other reports concerning wreckage.

3.2.11.42 The floating wreckage recovered was initially examined at Cork. On 25th June, Mr. Eric Newton a retired investigator of AIB, UK, was requested to examine the floating wreckage recovered and other materials with specific reference to the possibility of explosive sabotage having taken place. Mr. Newton examined the floating wreckage, passenger clothings and the other materials recovered from the crash victims The findings of Mr. Newton on the material available at that time are summarised below:

a. Taking the scatter of the wreckage and bodies into consideration and the condition of the limited wreckage recovered indicates that the aircraft had broken up in flight before impact with the sea.

b. Detailed examination of the structural wreckage recovered did not reveal any evidence of collision with another aircraft. Nothing was found suggestive of an external missile attack.

c. There was no evidence of fire internal or external.

d. There was no evidence of lightning strike.

e. Examination of all available structural parts recovered, did not reveal any evidence of significant corrosion, metal fatigue or other material defects. All fractures and failures were consistent with overstressing material and crash impact forces

f. Examination of clothing from the bodies did not show any explosive fractures or any signs of burning. The seat cushions and head cushions also did not show any explosive characteristics.

g. The damage to the suitcases (14 large and 29 small) which were examined was due to impact crash forces. The presence of 14 large suitcases could, however, indicate that one of the baggage containers had been broken to permit these suitcases to escape.

h. A number of lavatory doors and structure also did not show any damage consistent with explosion. The flight deck door showed no explosion damage inside or outside.

i The circumstatnial evidence strongly suggests a sudden and unexpected disaster occurred in flight.

j. There was no significant fire or explosion in the flight deck, first and tourist passenger cabin including several lavatories and the rear bulk cargo hold.

3.2.11.43 The other report dated 30th November, 1985 is of Mr. V.J. Clancy. Mr. Clancey had examined the wreckage and had also taken part, though only for a few days, in the metallurgical examination which was being conducted at BARC, Bombay.

3.2.11.44 Mr. Clancey examined practically all the items of wreckage which had been brought to BARC and in his report he has dealt with all of them. His report contained a description of the recovered items and also his comments thereon.

3.2.11.45 With regard to the aforesaid target 362, he observed that there were about 20 holes in it clearly resulting from penetrations from inside.

3.2.11.46 He further stated that:

"In addition to the fact that perforation was from inside there are certain features which suggest that they were made by high velocity fragments such as are produced by an explosion. These features are:

(a) Presence of toothed or spiked edges at some parts of the metal which had petalled out from the perforations.

"Tardif and Sterling (Canadian Aeronautics and Space Journal, 1969, 16, 1, 19-27) obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.

(b) Presence of marked curling, in some cases of more than 360°, of some of the petals.

Tradif and Sterling stated that such curling was a feature of explosively produced fragments.

(c) The virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal.

(d) The virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object. This suggested that the production of at least many of the perforations were separate independent events.

(e) One perforation (identified as No. 14) resembles a "bullet hole", that is cleanly punched out - a type of hole usually associated with a high velocity missile.

"There is evidence that the forward part of this item had been folded back inwards along the line of station 760 and then bent back again along a line slightly forward of this station.

"Such folding, may be violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.

"One hole identified as No. 13, was almost certainly caused by a slipping wire rope used as a sling.

"Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken by me of this area and are being examined by R.A.R.D.E. for evidence of fire or explosives".

3.2.11.47 There were several hundred small fragments which were recovered from the same general area as Target 362. While dealing with these Mr. Clancey observed that the production of a large number of small fragments is generally regarded as indicative of an explosion. One piece out of this was isolated, which was about one inch square of sheet alloy, and it was noted by Mr. Clancey that this piece had characteristic spikes on one edge similar to those described by Tardif and Sterling. (This piece is the same as shown in Fig. 362-28).

3.2.11.48 Mr. Clancey also examined a few suit cases which had been recovered. One particular suit case to which reference was made by him was of red plastic material with blue lining. With regard to this he stated that the damaged lining, severely tattered, resembles that of one found after an explosion in an aircraft in Angola. In that case microscopic examination showed definite evidence of damage by an explosion.

3.2.11.49 The later part of the report of Mr. Clancey contained his opinion. With regard to Target 362 his opinion was as follows:

"The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

"Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

"A more detailed study, metallurgical and fractographic, is required.

"The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

"The single "bullet hole", No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

"If the forward part of this item was forcefully and rapidly folded back to impact on the other part it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility".

3.2.11.50 The opinion of Mr. Clancey about the small fragments was as follows:

"The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.

"The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

3.2.11.51 It appeared to the Court that the report of Mr. Clancey required certain clarifications. It was suggested to Boeing Commercial Airplane Company by the Court that Mr. Clancey should appear as a witness. The Court received a message to the effect that Mr. Clancey felt that he could not add anything useful to his report.

3.2.11.52 A close examination of the report of Mr. Clancey shows that the opinion expressed by him in the later part of the report is at considerable variance with the observations contained in the earlier part of the report. Particularly with regard to Target 362 and the small fragments, Mr. Clancey has stated in his observations that there was strong evidence of explosion. In his opinion, however, he has stated that more detailed study is required. It is interesting to note that though Mr. Clancey has referred to the opinion of Tardif and Sterling, he has not chosen to contradict the conclusions arrived by them. Mr. Clancey has also not stated as to what could possibly have caused the special features

which were noted on Target 362.
3.2.11.53 We find the metallurgical report inspires more confidence. Not only is reference and reliance made in the report to other expert opinions contained in various articles written by experts all over the world, certain explosion experiments were also carried out by the experts which led them to the same conclusion.
3.2.11.54 The particulars of the experiments so carried out and the results obtained therefrom have been stated in their report as follows:
EXPLOSION EXPERIMENTS
"To determine the damage by high velocity fragments or shock waves on a structure similar to the one in aircraft cargo hold, the following experiments were conducted on November 30 and December 1, 1985 at the Explosives Research and Development Laboratory, Pune, using plastic explosive (PEKI) and different mixtures of plastic explosive and TNT. The explosive was kept in a box made of sheet metal of 6" x 6" x 6" of 1/16" thickness. This box was kept inside another box made of sheet metal 2' x 2' x 2' of .04 or .06" thickness. The boxes were made of 2024 aluminium alloy sheets used for aircraft skin. To the inner surface of the outer box, hat section stringers similar to those used in the aircraft were riveted. The quantity of explosive used in the inner box was varied from 60 g to 100 g. The explosive was detonated with an electrical detonator. After the explosions the fragments and the panels were collected and examined.
"Experiments were also conducted to produce explosive damage on skin panels, individual hat section stringers and individual stantion tubes. In the case of stantion tubes experiments were carried out placing the explosive charge both inside and outside. The quantity of explosive used was varied from 5 g to 50 g.
"Various types of damages were recorded on all the targets. These include punched holes, petaling and curling around holes, spikes at fracture edges, curved fragments with small radius of curvature and reverse slant fracture. Fig. EXP-1 shows a collection of fragments. The features mentioned above are shown in Fig. EXP-2 to EXP-7. It may be noticed that the features produced by experimental explosion were

similar to the features observed largely in target 362 of the wreckage. The small fragments had features similar to those in the fragments from targets 362 and 399.

"Metallography was carried out in (a) a specimen surrounding a punched hole in the skin (b) a specimen surrounding a hole in the stringer, (c) a curl in the stantion and (d) spikes in a fragment. In all these cases, the grains adjacent to the area of explosive damage are having twins. Two typical microstructures are shown in Fig. EXP-8 and EXP-9. Away from these areas the microstructure is normal. Thus it is confirmed that twinning in the microstructure of these structural members is a unique feature of explosive fracture, not produced by any other measns known so far."

3.2.11.55 The findings in the said metallurgical report are also strengthened by the observations of Eric Newton in the article "Investigating Explosive Sabotage in Aircraft" published in the International Journal of Aviation Safety, March 1985, p. 43. Mr. Newton is an acknowledged authority in the detection of explosive sabotage in aircraft. The conclusions contained in the article are based on his review of incidents of explosion between 1946 and 1984 which were known to him. Some of the conclusions arrived at by him which were relevant in the present case are when he states "Generally speaking, the smaller the fragment, higher the velocity of the detonation. Minute fragmentation is indicative of high explosive having been used, and provides clues to the focal point or region of the explosion. The mode of break up of the aircraft itself and its sequence of failure is usually very complicated and quite without the logic dictated by normal aerodynamic overstressing".

3.2.11.56 Mr. Newton has also observed that curling, cork-screwing, and saw tooth edges may also be indicative of an explosion though such fractures by themselves may not be conclusive evidence that an explosion was involved. Firmer evidence, according to him, was of fusing of metal, scorching, pitting and blast effect. He further states that "Perhaps the most conclusive material evidence to be found on metal specimens is cratering, very often in groups, often minute and numerous".

3.2.11.57 Mr. Newton also refers to the positive explosive signatures which remain on a detonation in an aircraft. These positive singatures, according to him, are as follows:

"(a) The formation of distinctive surface effects such as pitting or very small craters formed in metal surfaces, caused by extremely high velocity impacts from small particles of explosive material. Such craters, when viewed under the microscope, have raised and rolled over edges and often have explosive residue in the bottom of the crater.

"(b) Small fragments of metal, some less than 1 mm in diameter, which, under the scanning electron microscope, reveal features such as rolled edges, hot gas washing (orange peel effect, surface melting and pitting and general evidence of heat; such features have been proved and observed following explosive experiments with known explosives). Supporting strong evidence would be if such fragments (normally found embedded in structures, furnishing or suitcases) were found embedded in a body where evidence of burning of tissue is present at the puncture entry and where the fragment came to rest.

"(c) As well as surface effects on metal fragments produced by explosives there are deformation mechanisms which are peculiar to high rates of strain at normal temperature. At normal rates of strain metals deform by usual mechanism associated with dislocation movement. However, because this process in an explosion is thermally activated at very high rates of strain, there is insufficient time for the normal process to occur. In some metals such as copper, iron and steel, deformation in the crystals of the metal takes place by 'twinning', that is to say by parallel lines or cracks cutting across the crystal. Such a phenomenon can occur only if the specimen has been subjected to extreme shock wave loading at velocities in the order of 8000 m/sec. Such specimens, usually distorted must be selected with care, prepared in a metallurgical laboratory, polished, mounted
and microscopically examined. Where such twinning of the crystals is found it establishes (a) that the specimen was close to the seat of the explosion and (b) that a military type explosive had been used with a

detonating velocity of 8000 m/sec or more. Twinning is rarely produced when shock impact loadings are below 8000 m/sec.
"The above features, singly or combined, are considered to be proof positive evidence of a detonation of a high explosive; they could not be produced in any other way."
3.2.11.58 The metallurgical report indicates that the microscopic examination (conducted by them) discloses such features being present which had been described as positive signatures of the detonation of an explosive device in an aircraft by Mr. Newton. Furthermore, twinning effect has also been noticed at a number of places - around holes and in fragments. These have been categorised by Mr. Newton as positive signature of an explosion.
3.2.11.59 In the primary zone of explosion, metallic structures disintegrate into numerous tiny fragments and usually these fragments contain the above mentioned distinct signatures of explosion. In the present case the explosive damage had occurred at an altitude of 31000 feet when the aircraft was flying over the ocean. The fragments that formed due to explosion must have been scattered over a wide area and it is impossible to locate and recover all of them from the ocean bed. Nevertheless, some of the fragments which were recovered along with the targets 362 and 399 do contain signatures of explosive fracture.
3.2.11.60 From the aforesaid discussion it would, therefore, be safe to conclude that the examination of targets 362 and 399 clearly reveals that there had been a detonation of an explosive device on the Kanishka aircraft and that detonation has taken place not too far away from where these targets had been located.

FIRE

3.3.1 There is no evidence that there was any fire on board the aircraft before it met with the accident.
3.3.2 Amongst the floating wreckage, however, was found, what was later on identified as, a spares equipment box belonging to this aircraft. This box was charred on one side and partially on the bottom. The depth of charring suggested that the burning time was three to four minutes. This box contained some sand and small shellfish. The flesh

from the shelfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

FLIGHT RECORDERS

3.4.1 Recovery of Flight Recorders

3.4.1.1 Recovery of the flight recorders was a very difficult and challenging job. At the site of accident, depth of water is about 6700 feet. The job involved fixing the location of recorders and then retrieving them. For this purpose three ships viz. Guardline Locator (a ship provided by Accident Investigation Branch of U.K.), Le Aoife (an Irish Naval Ship) and Leon Thevenin (a French Cable laying ship, charterd by the Government of India) were utilised. Guardline Locator and Le Aoife were solely for fixing the positions of recorders and also had the capability to lift the recorders with the help of its scarab.

3.4.1.2 Both the Cockpit Voice Recorder and the Digital Flight Data Recorder were fitted with Dukane Underwater Acoustic Beacons (Pingers) which enabled establishing the location of flight recorders under water. The Beacons are designed to provide a signal at 37.5 ñ 1 Khz frequency that can be heard for approximately 2 miles in any direction for 30 days after water entry. Its high strength case permits operation in water depth to 20,000 feet. Its pulse repetition rate is not less than 0.9 pulse per second.

3.4.1.3 On 4th July, 1985, Guardline Locator reported strong possibility of two separate sound sources of frequencies between 39 KHz and 42 KHz. On 5th July, Guardline Locator gave coordinates of an area, which it believed contained the pinger. Guardline Locator later reported that using a Dukane Hand Locator, it had located pinger (2) at 5102.6N, 1248.6W. Leon Thevenin then concentrated its search in this area for retrieving the recorders.

3.4.1.4 In response to a query, Messrs Dukane Corporation advised that Pinger transducer is made of ceramic and if cracked during impact, its frequency could be elevated. The pulse rate should, however, be uneffected. Keeping this in mind, the Leon Thevenin increased its Sonar Band one upper frequency limit from 40 KHz to 45 KHz.

3.4.1.5 On 9th July at about 2300 hours the Scarab of Leon Thevenin located the Cockpit Voice Recorder at 5102.67N, 1248.93W and the recorder was brought on the deck at 0747 hrs on 10th July. The CVR was kept in a drum filled with water. The scarab was again lowered on 10th July in the same area and at about 2130 hours faint signals were picked up on Sonar. By about 2200 hours the signals became louder and the pulse rate frequency was calculated to be 72 transmissions per minute. At about 2230 hours the DFDR was also located at 5103.10N, 1249.59W and it was brought on deck at 0245 Z on 11th July.

3.4.1.6 The DFDR was also placed alongside the CVR in the drum filled with water. Leon Thevenin was then advised to return to Cork with the Flight Recorders. Leon Thevenin reached Cork on the morning of 12th July and the flight recorders were placed in two specially fabricated water tight steel containers filled with water. The recorders were then carried to Bombay on the same day by Mr. Satendra Singh, Reginal Controller of Air Safety, Bombay, accompanied by Mr. Vishwanath of Air India for preparing read-outs and transcript of the recorders. Necessary precautions were taken to ensure that the data recorded was not affected during transportation to Bombay.

3.4.1.7 Both the recorders reached Bombay on the morning of 13th July and were kept in the office of the Regional Controller of Air Safety under Armed Police Guard.

3.4.2 Description of Flight Recorders

3.4.2.1 Kanishka was equipped with a Fairchild A-100 Cockpit Voice Recorder Serial No. 5809 and a Lockheed 209E Digital Flight Data Recorder Serial No. 1282. These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the rear pressure bulkhead.

3.4.2.2 The CVR records all crew communications and sounds in the cockpit on a continuous tape loop which has a tape speed of 1-7/8 inches per second. The Recorder has two heads, one head which erases the previous recording and the second which records the current information and thus the last 30 minutes of recorded signals are retained, the previous being automatically erased. It continuously records convervations/sounds from 4 different sources on the following four

separate channels:
Channel 1 : Radio channel of pilot
Channel 2 : Radio channel of flight engineer
Channel 3 : Cockpit Area Mike
Channel 4: Radio channel of co-pilot.

3.4.2.3 The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor. Adjacent to this unit was a Lockheed Model 280 Quick Access Recorder that recorded the same serial digital signals on to a 50 hour cassette.

3.4.2.4 The DFDR records 52 basic parameters on a magnetic tape. The tape preserves records of the last 25 hours. The serial digital signal has a bit rate of 768 bits per second and is recorded at a tape speed of 0.37 inches per second.

3.4.3 Examination of Flight Recorders and Tapes

3.4.3.1 General

The recorders brought to Bombay from Cork were opened on 16th July, 1985 at the Air India's Facilities in Bombay in the presence of the Court and Assessors. A team of foreign experts including one each representatives from both the Recorder Manufacturers, three from National Transportation Safety Board, one from Canadian Aviation Safety Board and one from NRC Flight Recorder Playback Centre, Canada were present when the tapes were taken out of the recorders. Apart from them, representatives of the Government of India and Air India were also present.

3.4.3.2 Cockpit Voice Recorder

When the unit was removed from its shipping and storage container, some mechanical damage was immediately evident. The top of the cover had been deformed inwards, probably due to initial external
strong attachments for the horizontally mounted Underwater Acoustic Beacon. The plate had torn away from the light structure behind it. The cause of the damage was not obvious. The light outer cover was removed by cutting it open with hand shears and pliers.

3.4.3.3 When the armoured and insulated containment was opened, the tape transport was found to be in relatively good condition and the tape physically undamaged. Eighteen inches of the tape was pulled from the centre of the tape stack and the tape cut near the stack well clear of the end of recording. The tape was then removed from the recorder, transferred to standard tape reels, laboriously cleaned several times with distilled water and dried with lint free absorbent material.

3.4.3.4 Digital Flight Data Recorder

When the recorder was removed from its shipping and storage container, it was noted that there was very little external damage. A cover on the rear section was removed and it was observed that, when viewed from the front of the recorder, the right hand edges of the four rearmost printed circuit cards were displaced towards the front of the recorder. The left hand edges were restrained by plug-in connectors to the boards. The rearmost card, that controls track selection on the tape, and the one in front of it, had bowed along the right-hand edges and popped out of their plastic guides in the top and bottom of the recorder. Deflection of the other two cards had occurred following failure of the attachments of the right hand ends of the plastic guides to the chassis. The damage could have been caused by a high lontitudinal decelaration, as would occur if the front face of the recorder impacted the water.

3.4.3.5 When the tape deck was opened, it was found that the tape was intact but had become dislodged from the last tape guide when the tape was moving in the direction of the odd-numbered tracks and had also jumped out of the adjacent end-of-tape sensor. One edge of the tape had been streteched in this area. The drive belt to the tape transport was still in its correct position. The tape was stuck to the third tape guide in the odd-numbered track direction and suffered some damage when it was finally detached from it. This was repeaired with a splicing tape.

3.4.3.6 The location of the record heads was marked on the back of the tape with a waterproof felt pen. It was noted that there was slightly more tape on the supply reel for the odd tracks than on the other reel. The tape reels and tape were removed from the recorder, keeping the tape wet with distilled water, and the tape transferred to the standard reels for meticulous cleaning. During the cleaning process, it was found that the edge of the tape had also been stretched locally 336 inches down- stream from the splice repair in the odd track direction. The tape was dried by patting it with absorbent lint-free material before loading it into a serviceable recorder as this was the only means by which it could be replayed at the Air India base.

3.4.3.7 The circuit card controlling track selection was removed from the accident recorder and the status of the latching relays checked to determine the last track on which recording was being made. It was found that the relay states indicated Track 1, but since this requires all relays to be set in the same condition, it was considered possible that they had been mechanically set on water impact. The card was subsequently inserted to another recorder and the Track 1 setting confirmed on a test bench.

3.4.3.8 When a change in track selection was attempted, it was found that the relays would not switch, probably due to the effects of salt water corrosion or high water pressure. It was decided that Track 1 would be considered as the most likely one to contain the accident data with the possibility that it could have occurred on any of the other tracks. When the data was recored, the accident information was found some distance past the mid-point of Track 1.

3.4.4. Recovery of Information

3.4.4.1 Cockpit Voice Recorder Tape

The spool was removed from the CVR and was washed with distilled water, dried and loaded on to another spool. The cleaned and dried tape was taken to the Bhabha Atomic Research Centre (BARC), and a copy of the tape was prepared which was used for preparing transcript and carrying out further analysis. The transcript of the CVR conversation is given in Appendix 2.

3.4.4.2 Shannon Air Traffic Control Tape

A copy of this tape that contains all radio communications between the aircraft and Shannon was provided to the Indian Authorities by the Air Traffic Control Authorities, Shannon. The recording also included the short series of unusual sounds that occurred about the time of the accident.

3.4.4.3 When the CVR and the ATC tapes were played it was found that some adjustment in speed was necessary so as to synchronize the two. This adjustment was independently carried out by different experts who analysed the CVR tapes.

3.4.4.4 Digitial Flight Data Recorder Tape

The Lockheed representative had brought a Lockheed Model 235 Copy Recorder from his plant. This unit copies all the 25 hours of data from the recorder by running it at high speed for only two passes of the tape, an operation lasting only 16 minutes. A copy tape was made by this procedure before embarking on the standard Air India recovery procedure to serve as a back-up tape in the event of physical damage to the original tape in subsequent playback.

3.4.4.5 Air India playback equipment for the DFDR required that the tape be re-installed in another DFDR in which it was driven at high speed. In the standard playback procedure, the tape was first run to the beginning of Track 1 through 6 sequentially on to a computer tape followed by a repeat of Track 1. The computer tape was then taken to Air India's main computing facility where selected information was printed out in engineering units.

3.4.4.6 The first printouts showed that the accident was recorded on Track 1, as indicated by the latching relays, and suggested a rather abrupt end to the recording. There was a loss in bit synchronization in word 26 of the last Subframe 3 of data that was followed by a normal Subframe 4. Prior to the loss in bit synchronization, all measurements appeared normal. Plans were made to borrow the high speed oscillograph recorder previously used to studythe final CVR signals from BARC to examine the end of the recorded serial digital signal in detail.

3.4.4.7 Meanwhile, the critical section of the tape and the heads of the playback recorder were re-cleaned and a second transfer of data on to the computer tape was made. Printouts from this computer tape showed no significant difference from the first one.

3.4.4.8 The recorder was then opened and the tape positioned about

1.5 inches before the final resting place of the tape that was clearly indicated by head imprints on the magnetic oxide coating side. A high speed oscillograph record of a few seconds of data was made and visually decoded. It was found that the recorded GMT was 21 hr 16 min. This time corresponded to 15 min or about 333 inches of the tape after start of the oldest recording downstream of the accident.

3.4.4.9 The tape was then re-positioned using a Lockheed analogue playback unit, that had a display of the recorded time and a stopwatch was used to locate the accident timing. Two oscillograph copies of the end of the serial digital data were made, the second one having more data preceding the end. Visual reading of the traces confirmed that recording became erratic and irrecoverable at the end of Word 26 in Subframe 3 at the recorded time of 07 h : 14m : 35s. The erratic signal continued for about 0.27 inches of the tape before switching back to the data recorded 25 hours earlier.

3.4.4.10 Examination of the printouts confirmed a suspicion that the complete Subframe 4 of data following the partial Subframe 3, was data from 32 seconds earlier that had not been cleared from the data buffer in the computer and that Word 26 of the Subframe 3 was the last normal measurement provided by the recorder.

3.4.4.11 The end of recording occurred at the point on the tape at which some damage had been observed during the cleaning process. It was apparent that, after the end of the recording, the tape had run on for 336 inches before finally coming to rest.

3.4.4.12 A copy tape of the DFDR tape was made at Bombay and taken to Ottawa. Data from the accident flight, the preceeding Toronto-to-Montreal flight and part of the cruise conditions of the earlier flight to Toronto were transcribed on to the computer tape. The tape was edited to minimize errors and converted to engineering units using standards calibration. Time histories of all parameters for periods of interest were plotted. In addition, chart records were made of all parameters in raw data form for the total duration of the last lap of the flight.

3.4.4.13 The DFDR read out shows that the aircraft was cruising at an altitude of 31,000 ft. and a computed air speed of 296 knots till it suddenly stopped recording at 07:14:35 GMT recorded time.

3.4.5 Reports received by the Court

3.4.5.1 The CVR was taken to B.A.R.C. This tape was played by the CVR group a number of times and hard copies of the time information were also prepared using an ultra violet (UV) Recorder. The group consisted of Mr. Satendra Singh, Regional Controller of Air Safety of D.G.C.A., Mr. S.N. Seshadri of BARC, Mr. Paul C. Turner of NTSB, USA, Mr. John G. Young of NTSB, USA and Mr. P. dE Niverville of CASB, Canada. On 18th July, 1985 this group made the following observations after playing the aforesaid tape (UV recording of CVR is at Fig. 1) :-

"The first visible rising signal volume was observed on channel number three the CAM channel It reaches a maximum in about 50 milliseconds. At this time noticeable disturbances are observable on the other three channels. A smaller disturbance is observable on channels 2 and 4 earlier than observable on channel 1. A major disturbance is observed to begin approx. ninety milliseconds following the initial observation on channel number 3 (CAM), on channels 1,2 and 4. Following this point at 75 milliseconds the CAM signal subsides to a lower level but much higher than observed ambient (prior to disturbance) where it remains for approximately 375 milliseconds from initiation when it ceases. Channel four goes off at the same time. Channel 1 goes off twenty five milliseconds earlier. Channel two is inconclusive and had a different pattern. All four channels exhibit a disturbance at approx. 450 milliseconds. The cockpit voice recorder power then shuts off at 650 milliseconds.

The Shannon area control centre tape made the night of the accident was examined and printed. It shows a signal was received at approximately the time the aircraft disappeared from radar. It isn't conclusive at this time that the signal originated from the accident aircraft. The signal was received in pulses for approximately five seconds."

3.4.5.2 The tape was again played on 19th July, 1985 and a further report was prepared which was signed by the aforesaid persons and Mr. B. Caiger of NRC, Canada. In this report it was stated as follows:-

"The Shannon area control centre tape was again printed at .05"/second per inch speed from approximately 22 sec. before the first broadcast from the accident aircraft at 0709.58 until Radio carrier with indecipherable modulation can be heard at 0714:01. The print contains a time encoded signal.

A similar print was made from the CVR channel 4 (Co-Pilot's) of the same audio as received on the ATC tape. Although the tape speed is different, the events when corrected for tape speed errors occur at the same time. It appears that the ATC recording contains the beginning of the aircraft breaking until power is lost to the transmitter since channel one and channel four (Capt + Co-pilot's radio) appear to contain a transmitted signal on the CVR. It is probable that the ATC signal at 0714:01 coincides with the final quarter second of CVR radio channels".

3.4.5.3 On the date i.e. 19th July, 1985, Mr. Paul Turner of NTSB also gave an additional report which is to the following effect :-

"During my observations of numerous cockpit voice recorders I have heard and observed a number of aircraft breakages due to various causes. In this case the explosive sound on the CAM channels occurs prior to any electrical disturbance observable on the selector panel signals. Electrical disturbances can generally be seen prior to audio signal when explosive sounds originate at any significant measureable distance from the microphone (15 feet) and in the area where there is significant electrical systems. It is my opinion that an explosive event occurred close to the cockpit. The CAM signal which follows the explosive event shows a very much higher noice level than cockpit ambient 85 db, indicating to me the cockpit area was penetrated and opened to the atmosphere. The selector panel signals show signatures similar to those of an aircraft breaking up and are apparantly caused by electrical systems disturbance (circuit breaker blowing, fuse switching etc.). The lack of Mayday call and apparent inadvertant signal from the cockpit crew incapacitation. The transmitter coming on due to breakup is phenomena observed previously.

This contains only my personal opinion and in no way should be considered a final determination of cause without corroborating evidence".

3.4.5.4 Copies of the tapes were also sent to some of the participants who wanted to carry out independent analysis.

3.4.5.5 With regard to DFDR the Court received reports from Dr. Caroll Roberts of NTSB and report dated 11th November of Mr. B. Caiger.

3.4.5.6 With regard to CVR the Court received reports from Mr. B. Caiger dated 11th November, 1985, report dated November, 1985 of Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K., report dated 31st August, 1985 of Mr. S.N. Seshadri of BARC, Bombay.

3.4.6 Court Observations

3.4.6.1 Digital Flight Data Recorder

The reports of Dr. Caroll Roberts and Mr. Caiger which also coincide with the report submitted by Mr. Satendra Singh disclose that the DFDR showed no evidence of abnormal values of any of the many parameters being monitored upto a point at which the recorded data signal became irregular for a fraction of a second and recording ceased. Both the DFDR and the CVR stopped at the same time.

3.4.6.2 The short period of irregular digital data that occupied only 0.27 inches of tape, most probably indicates that the recorder was subjected to a sharp angular acceleration in the left wing down sense about the aircraft longitudinal axis.

3.4.6.3 According to Mr. Caiger's report the possibility that the digital recorder was subjected to a sharp disturbance more rapid than violent motion of the aircraft lends some credence to the possibility of a detonatiaon of an explosive device in the aircraft. The other alternative, according to Mr. Caiger, which could have led to this was that the Flight Data Acquisition Unit in the main electronics bay .or its power supply were suddenly disturbed. As the Lockheed Quick Access Recorder was not recovered from the wreckage, this possibility could not be investigated further. A perusal of the DFDR print out, however, shows that whereas there was a speed limit of 290 knots (.81 Mach) of the aircraft due to carriage of the 5th pod engine, in actual fact the aircraft's speed during cruise varied from 287 to 296 knots. Mr. H.S. Khola asked the Boeing Airplane Company to examine the effect of aircraft cruising at a speed of 296 knots with a 5th pod engine installed on it. The Boeing company sent a reply, inter alia, stating as follows:

"The operating speed limit of Air India 747-237B, JT9D-7J with fifth engine pod was 290 knots indicated airspeed, with an altitude limit of 35,200 feet. Flight testing of this model airplane configuration was successfully accomplished to a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, with no adverse effects.

In the event that the operating speed placard was exceeded an increase in perceptible vibration levels would be felt. As the dive Mach number (0.92) is approached the buffet vibration would increase to level that could become objectional to the flight crew, but would not he bazardous".

3.4.6.4 It would thus be clear that if no adverse effects could have been noticed with a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, there was little likelihbood of the aircraft having been subjected to any adverse effect by reason of the speed varying from 287 to 296 knots while it was cruising at a height of about 31,000 feet.

3.4.6.5 Cockpit Voice Recorder

The Court received four reports of the CVR tape analysis. These reports were of Mr. B. Caiger, Mr. R.A. Davis, Mr. S.N. Seshadri and Mr. Paul C. Turner. Whereas the first three experts appeared and deposed in Court, Mr. Paul Turner did not come.

3.4.6.6. There were certain aspects of the report of Mr. Turner which required clarification. After the Court had failed to secure his presence, it sent a questionnaire to Mr. Turner for his answers thereto. It is indeed unfortunate that till now no reply has been received. It is in this background that the report dated 13th November, 1985 of Mr. Turner and the reports of other experts have to be judged and analysed.

3.4.6.7 Mr. B. Caiger's Report and Deposition

Mr. Caiger has said in his report that the Cockpit Area Microphone signal was studied in detail. According to him, in an aircraft, sound can be transmitted by multiplicity of paths. If an explosive device was located close to the microphone then the short wave from the disturbance would cause a sharp rise in pressure which was not noticed. From more remote location, however, structurally transmitted sounds could reach the microphone first and induce more complex signals. According to Mr. Caiger, at this time he did not have any evidence from occurrences of this nature that would permit any meaningful comparisons or conclusions.

3.4.6.8 Mr. Caiger obtained from the manufacturers details of Automatic Gain Control (AGC) on the cockpit area microphone. According to the information so provided it was indicated that the decrease in amplitude of the recorded noise over about 33 msec after the peak level was reached 40 msec from the start of the disturbance is most probably due to the AGC and that the actual envelope of the pressure levels at the microphone continued to increase until 90 msec from the start before establishing at about four times the recorded level until the 160 msec point when the recorded amplitude started to decrease rapidly. Mr. Caiger could not find any explanation for this marked reduction. Mr. Caiger further recorded that the large amplitude lower frequency signature, that immdediately followed this reduction, is similar to signatures observed by the manufacturer when there was an abrupt break in the line from the cockpit area microphone pre-amplifier output to the voice recorder. No similar signature was observed in tests on the crew audio channels when the appropriate lines to the recorder were similarly interrupted.

3.4.6.9 The observation of Mr. Caiger with regard to ATC tape was as follows :-

"The ATC recording that followed the cockpit area microphone sounds appears at first to contain a series of short intermittant sounds. Closer study reveals that the background noise only returns to its steady level for about 160 msec immediately after the first low level noise and again for about 85 msec just over halfway through the 5.4 sec duration of the recordings. At the end of all routine radio transmissions, a damped sine wave transmitter keying signature is observed with a frequency in the region of 450 Hz. In the accident recordings, only two of these are

observed".
"Listening to the sounds, it also appears that a human cry occurs near the end of the recordings. Spectral analysis of these sounds and comparison with voice limitations reveals that the accident sounds do not contain all the pitch harmonic frequencies normally associated with such voice sounds. The origin of all the sounds has not been identified."

3.4.6.10 From the aforesaid investigation Mr. Caiger concluded that :-
"From the voice and data recorders, Air India Flight 182 was proceeding normally enroute from Montreal to London, England at an altitude of 31,000 feet and a computed airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound the cause of which has not yet been identified. The sound continued for about 0.35 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder".
"The initial waveform of the cockpit area microphone signal is not consistant with the sharp pressure rise expected with detonation of an explosive device close to the flight deck but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, we cannot at this time exclude the possibility that it originated from such a device elsewhere in the aircraft".
"Within 1 to 2 seconds of the first detection of the loud sound on the cockpit area microphone, a series of unidentified noises were recorded on the Shannon ATC tape. These extended over a period of 5.4 seconds and are assumed to have origniated from VT-EFO. They gave the impression of abnormal conditions on the flight deck".

3.4.6.11 In his evidence in court, Mr. Caiger explained about Automatic Gain Control. He stated that the CAM channel of the CVR had an Automatic Gain Gontrol in a pre-amplifier that is installed close to the microphone. This AGC is designed to prevent excessively loud signals from saturating the microphone and the associated electronics. He further stated that from the tests conducted by the manufacturers it could be concluded that most likely at 45 msec. point the AGC came

into effect which gradually reduced the signal over the next 33 msec. before letting it stabilise at a roughly constant value. This figure of 33 msec. was taken by Mr. Caiger not by carrying out any experiment himself but it was provided to him by the manufacturers. He also stated that there was no positive indication of structural failure being evident from the flight
recorders. Mr. Caiger was asked to explain as to what was the reason for loud sound to which reference had been made in his report. In answer to the said question from the Court he said that there could be a number of reasons. The detonation of an explosive device not close to the microphone was one possibility, the occurrence of some type of structural failure was another possibility. He was further of the opinion that at the present stage of development in structural acoustics, he did not think it was possible to come up with any reasonable estimate of the location of either explosive device or some type of possible structural failure. When asked for his opinion about the sequence of events which he could determine by looking at the sound spectrum, he said as follows:
"From the study that we have made which have of course been augmented by studies done by several other groups it would appear that there was a very sharp bang that was detected by the CAM. Approximately one-third of a second after this happened the line from the CAM to the CVR was disconnected but intermitant power supply was still being sent to the voice recorder for approximately one and a half seconds. During this 1-1/2 seconds period sounds were being transmitted from the 'Kanishka' aircraft that tend to suggest that the aircraft was in some distress. Though it is difficult to be specific about the basis on which we assesss the state of the aircraft, this signal ceased after a period of 5.4 seconds and we have no more audio information concerning the aircraft from that point onwards."

3.4.6.12 Mr. R.A. Davis's Report and Deposition

Mr. R.A. Davis in his report on the analysis of CVR has stated that he did not have with him a faithful copy of the original CVR tape. The tape supplied to his contained signals which warranted investigation but any measurement could be hampered by a decreased signal to noise ratio due to the copying process. Mr. Davis however analysed the tape which admittedly according to him was not of good quality. Mr. Davis in his report states that he carried out a spectrum analysis of the different channels of the CVR. The spectra did contain the sound of a bang. He however, could not find any significant low frequency content in the spectrum which according to him, would have been expected if the sound was of a high explosive detonation.

3.4.6.13 While carrying out detailed study of the tape he also looked out for any evidence of various audio warning signals which may have been buried in the noise. One such audio warning which could have been detected was that of pressurisation warning. Mr. Davis stated that this warning possessed a very defined frequency spectrum which was not present in the signal of the CVR of Kanishka. With regard to this he, however, stated that absence of this signal was not surprising as any decompression would take a finite time before reaching the warning level. Mr. Davis further observed that the presence of warnings due to attititude display disagreement, excessive speed and fire were investigated but with negative results.

3.4.6.14 During the course of investigations, Mr. Davis had compared Kanishka CVR recording with the recordings of an explosive decompression on a DC-10, a bomb in the freight hold of a B-737 and a gun shot on the flight deck of a B-737. According to Mr. Davis the spectrum of VCR tape of B-737 showed a much low frequency content with very little content at upper frequencies. This bomb, in the forward baggage hold of B-737, had exploded while the aircraft was at a low level and therefore the CVR did not have the sound accompanied with that of depressurization. That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a high explosive device, then the spectra should have shown large low frequency content, but this was absent. He further opined that, even if there was a possibility of a bomb remote from the flight deck and of a low power, even then the characteristics of a bomb would still be apparent in the time record. He also analysed the spectrum of the sound of the hand gun shot on a B-737 flight deck and according to him the said signal was sharp edged and did not compare with that of Kanishka's signal.

3.4.6.15 Mr. Davis also analysed the sounds recorded on the ATC tape. He concluded that the sounds emanated from Air India's Kanishka aircraft. According to him the transmission from the ATC is "chopped" until at approximately 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound was similar to that heard in other accidents where there had been a rapid increase in airspeed.

In the noise which continues until the end of the transmission is heard a crying sound. This was originally thought to be a human cry. He, however, noted that a human cry would contain more harmonics than was noticed in this case. It was also reported by Mr. Davis that knocking sounds which were heard during the transmission were initially thought to be due to hand-held microphone vibration. This was discounted because of the frequency of the sounds. He noticed that almost identical sounds were heard on the DC-10 CVR after the decompression had occured and the source of that sound had not been identified. On the DC-10 the pressurization audio warning commenced 2.2 seconds after the decompression. Analysing the ATC tape Mr. Davis observed that no such warning was identified during the open microphone transmission.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-

"It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182.

"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.

"Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. Such a situation would be most unusual, if not unique, in that we have never failed to detect sounds of structural failure, decompression, explosives etc., on any accident CVR, even though the event occurred at the rear of the aircraft. If such a device was used on AI 182 it is considered that it would have to be a very small device in order not to be detected (unlikely in itself). Such a device would be unlikely to cause the sudden total destruction which occurred in this instance. It is considered that a device of sufficient power to produce this effect could not fail to be detected on the CVR. The B-747 explosions referred to earlier, blew holes several feet wide in the structure but the crew were still able to control and operate the aircraft.

"It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

3.4.6.17 In reply to a question it was stated by Mr. Davis, when he was examined in Court, that it was true that there was no evidence that rapid decompression was caused by any structural failure. In an answer to another question, as to whether in his opinion there is a low frequency content present in every situation whereever there has been a high explosive device detonated, Mr. Davis answered in the affirmative, he however added that "But we do not have sufficient numbers to indicate that that would always be the case". Mr. Davis, however, agreed that DC-10 aircraft was quite dissimilar to Boeing 747, and the sound of an explosive decompression in the aft cargo hold of a DC-10 would not be identical to an explosive decompression in the aft cargo hold of a Boeing 747.

3.4.6.18 Mr. Davis further agreed that he was looking for low frequencies in Kanishka tape, but he did not know what type of low frequencies should be looked out for because there was no available data anywhere in the world for the sound of a bomb explosion in a Boeing 747. Mr. Davis was however emphatic in saying that he could not measure the distance of the origin of the sound from the cockpit area mike. In his report, and also in the earlier part of the examination, Mr. Davis had referred to the absence of low frequency component in the spectrum and had sought to conclude that such absence showed that there was no detonation of a high explosive device. In an answer to the question put by the Court however, Mr. Davis appeared to have altered

his stand. This is evident from the following deposition of Mr. Davis :-
"Court Ques Am I to understand that there must necessarily be a low frequency whenever an explosion occurs?
Ans. No. What we thought was there would be. There was only one sample of explosion in B-737. But we would need more accidents of that nature to able to say that yes we must have a low frequency component.
Court Ques: Am I to understand that the absence of a low frequency component would not therefore necessarily mean that the sound was not that of an explosion?
Ans. Because of the absence of a low frequency component we would not be able to say positively that there was an explosion or it was not explosion."
Court Ques : Would the frequency of a particular type of sound change depending upon the environment in which that sound occurs?
Ans Yes.
Court Ques If an event results in low frequency sounds in one type of environment, can it mean that the same event can result in a high frequency sound in a different environment?
Ans. That must be possible".
3.4.6.19 Mr. S.N. Seshadri's Report and Deposition
A detailed analysis of the CVR and the ATC tapes was also carried out by Mr. S.N. Seshadri at BARC. For the purposes of comparison, CVR tapes of Iranian Air Force Boeing 747 accident as well as that of Indian Airlines Boeing 737 accident were also analysed at BARC.
3.4.6.20 The original CVR tape of Kanishka was played on a 4 channel tape recorder modified to run at 1-7/8" per second. The output of this tape recorder was copied faithfully on an eight channel HP 3968A instrumentation tape recorder. Channels 1 to 4 were used for recording the CVR data and channels 5 for recording a time marker. For further processing and signal analysis this copy of the original tape was used.
3.4.6.21 The observations of the data so recorded, as contained in the said report inter-alia are as follows :

"Repeated and careful listening to all the four channels revealed the presence of explosive sounds on all these channels occuring nearly at the end at the same time. Speech information is present on channels 3 and 4 during the last few minutes. Channel 1 does not contain any speech data during this period. Channel 2 contains indecipherable speech data about 20 to 25 seconds before the explosive sound".

"It was decided to analyse in detail the tape data during the final few seconds within which significant audio and electrical changes were observed to be present. Data from all the four channels were displayed on a Tektronix 2-channel storage oscilloscope Model 466 for initial observations. Based on this study the relevant portion of the tape was selected for more intensive snalysis. Simultanious ultraviolet recording of all the four channels on this portion of the tape was next carried out".

The following observations are relevant.

1. Channel 3, which corresponds to the area mike shows the first indication of a rising audio signal. This instant is termed, for conveniece, as zero time reference. The signal level rises from the ambient level in the cockpit by about 18.5 db in approximately 45 milliseconds. The signal then starts falling and stablises at a level about 10 db higher than the ambient level before zero time. The signal continues to remain at this level for about 275 milliseconds. The total duration of the signal from zero reference is thus about 360 milliseconds.

2. Channels 1 and 2, which are the radio channels of the pilot and the flight engineer respectively, show start of electrical disturbance signals 45 milliseconds from zero time at which the audio signal on channel 3 is at its maximum. These signals, which have do minant frequencies in the range of 70 to 210 Hz, persist for about 100 milliseconds on both channels. Subsequent to this, channel 1, shows an audio burst lasting about 200 milliseconds. Channel 2 shows a delayed audio burst lasting 25 milliseconds, 220 milliseconds from zero time, or in other words, 175 milliseconds after the peak signal from channel 3. A low amplitude tail appears after this burst and lasts around 40 milliseconds. Channel 4 which is the co-pilot's radio channel shows an electrical disturbance

commencing at 85 milliseconds from zero time and lasting around 60 milliseconds. The frequency distribution during this period is similar to those on channels 1 and 2. This is followed by an audio burst of 230 milliseconds duration. The frequency spectra of the audio portions of channels 1,2 and 4 are reasonably similar."

3.4.6.22 "Correlation of Events of ATC Shannon Tape and Channel 4 of CVR tape :

"It was observed that during the last few minutes before the stoppage of the CVR, information recorded on the ATC tape and channel 4 of the CVR tape are identical. However, the ATC tape contains a series of audio bursts approximately corresponding to the instant at which a single explosive sound is recorded on channel 4. Thus a doubt arose whether the series of audio bursts recorded on the ATC tape had originated from channel 4 of Kanishka CVR since these are not recorded on the CVR tape. In order to obtain an answer to this it was necessary to check with very good accuracy the simultaneity of the explosive sound on channel 4 and the series of audio bursts on the ATC. The procedure followed for the same is given below.

"The ATC Shannon tape and the CVR tape were run on two independent tape recorders. It was found that the speeds of the two tapes were mismatched. In order to match speeds the earliest speech signal on both the tapes.

"Seven seventy that checks maintain three five zero" was used as the reference point. The speech signals which mostly contain the conversation between the co-pilot and ATC Shannon lasts for about 146 seconds. Channel four was kept ready for starting exactly at the reference point. The ATC was next played starting well before the reference point. The tape recorder playing channel 4 was started manually exactly at the time when the reference point on the ATC was audible. By noting the time of ending of the conversation on both the tapes which corresponds to

"Right Sir squaking two zero zero five one eight two" the speed of the recorder playing the ATC tape was corrected by pitch control to approach the speed of CVR tape. The process was repeated a number of times till audibly the speeds were matched. The two tapes were next synchronously played and both the channels were simultaneously recorded on a third recorder to a point well after the explosive sound on channel 4. This tape was used for all further analysis.

"The first significant observation was that the explosive sound on channel 4 coincided with the beginning of the series of audio bursts on the ATC tape as heard by the ear. It was thus clear that both the recordings correspond to those generated by Kanishka during its last moments.

"To confirm this preliminary conclusion which was judged solely by the ear, accurate instrumented tests were carried out. The two channels were simultaneously recorded on an ultraviolet recorder at the four speeds, 0.1"/sec, 1"/sec, 10"/sec and 160"/sec for study of synchronism as well as frequency details. It was noticed that the two waveforms were not exactly suynchronised though by the ear they appeared to be so. In order to find out exactly the difference in synchronisation the following tests were done:

UV recordings at 16" per second were taken at three representative points relating to the communication of ATC with Kanishka. These points correspond to speech portions at 070838 "Five eh Squawking and eh Air India", at 070958 "Right Sir Squawking" and near the blast on channel 4. It was found that the ATC was running slightly faster. At the first point the ATC was leading by 90 milliseconds, and at the second point by 130 milliseconds. The time interval between these points is about 80 sec. By extrapolating this lead to the time of the blast which occurs about 243 sec. from the second point, it is clear that the lead of the ATC with respect to channel 4 at this point will be given by 130 + (130-90) (243/80) which is approximately 250 milliseconds. This error is very small."

"Thus one can conclude that the sounds recorded on the ATC Shannon tape are those which emanated from Kanishka during its last seconds."

3.4.6.23 "Frequency Analysis:

Mr. Seshadri also carried out frequency analysis of the CVR and the ATC tapes. His opinion with regard to the same was the follows:

"Significant audio and electrical disturbances were observed in the final few seconds of the CVR tape. It was therefore decided to analyse all the four channels for their frequency contents at the various places in this pertinent region. For Fourier analysis of each signal, digitized time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

3.4.6.24 "The frequency analysis of electrical disturbances in channels 1,2 and 4 indicate presence of low frequencies in the region of 20 Hz to 600 Hz. The dominant frequencies are in the range of 70 Hz to 210 Hz.

3.4.6.25 "The frequency spectrum of the background noise in channel 3 just before the explosive sound has a broad band spectrum with some dominant frequencies in the region of 650 Hz to 1550 Hz. At the bang, many additional frequencies appear. The frequency spectrum of bang on channel 3 indicates an increase in the bandwidth.

3.4.6.26 "The frequency spectrum of channel 1 at the bang position indicates a fairly broad spectrum with dominant frequencies in the range of 150 Hz to 1 KHz. Channel 2 displays a frequency spectrum at the bang position in which low frequencies are dominant. It has a significant frequency range between 20 Hz to about 1 KHz. The frequency spectrum of channel 4 at the bang is wide-band with a broad peak in the range of 150 Hz to 800 Hz.

3.4.6.27 "At the beginning of the crackling sound, the frequency spectrum shows narrow band peaks around 1.6 KHz. About 90 and 300 milliseconds later, the spectrum changes with additional peaks appearing around 400 Hz, 600 Hz and 1150 Hz. Frequency analysis was also carried out at 600, 800 and 1000 milliseconds before the start of the crackling sound."

3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

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3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal peaks to its maximum of 18.5 db above ambient level in about 45 milliseconds. A loud audible blast is heard when this channel is played at this point. An analysis of the frequency spectra before this loud blast and during the blast shows a definite change in the frequency composition. From all the above results it can be concluded that an explosion occurred in the aircraft. The exact position in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the Cockpit judging from the rise time of 45 milliseconds.

3.4.6.29 "Explosive sounds on all the four radio channels preceded by electrical disturbance reinforce the evidence provided by channel 3.

3.4.6.30 The synchronised recording and detailed analysis of the ATC and channel 4 confirm that the sounds recorded in the ATC Shannon tape are undoubtedly attributable to the transmissions from AI 182 Kanishka during its last moments. The sounds indicate possible breaking up of the aircraft in mid air and the air blast which follows a decompression. A very detailed UV recording does not indicate the presence of a second explosion."

3.4.6.31 "Copies of CVR tapes of well understood air crashes pertaining to an Indian Airlines Boeing 737 in 1979 and Iranian Air Force Boeing 747 in 1976 were analysed for possible reference in connection with the analysis of the CVR tape of Kanishka.

3.4.6.32 "A definite explosion near the Cockpit was the cause of the crash of the Indian Airlines Boeing 737. An explosive sound recorded on the Cockpit Area Mike shows a rise time of about 8 milliseconds which corresponds to a distance of about 8 feet. This indicates that the rise time is a measure of the distance from the Cockpit Area Mike at which an explosion has occurred.

3.4.6.33 "The Iranian Air Force Boeing 747 broke up in mid air. Analysis of the CVR tape clearly indicates that the frequency spectra of the electrical disturbances are similar to those obtained for Kanishka. Thus the series of audio bursts recorded on the ATC Shannon tape have been most probably generated by the break-up of kanishka in midair.

3.4.6.34 Mr. Seshadri was also examined in Court on 27th January, 1986. In his deposition he very succintly explained some aspects of the work which was done by him. He also dealt with the aspect of AGC to which reference has been made by Mr. R.A. Davis and Mr. Paul Turner in their reports. The relevant part of the testimony in this connection is

as follows :-
"We wanted to make sure that the CVR recording and the ATC corresponded to the same aircraft Kanishka. When we played the tapes for the first time we found that there was a difference of about 1 second. Though this figure may be tolerable because of the accuracy of the tape speeds, we wanted to investigate further to make really sure that the ATC corresponded to Kanishka. For this purpose we had simultaneously "recorded channel 4 of the CVR and the ATC on a single tape on 2 channels after synchronising the common speech signals to the best of our ability by the ear. We started with the first speech which was available on both the tapes, namely, "770 that checks maintain 350". This was a conversation with the TWA aircraft which is available on both channel 4 and the ATC. The last sound which is recorded common to CVR and ATC is the speech of the co-pilot who says "right Sir, squaking 2005 182". After this recording though by the ear the explosive sounds on the ATC. as well as the CVR seemed to match, we wanted to check it in more detail. For this purpose we had detailed UV recordings of different portions of the synchronised tapes pertaining to the conversation between ATC and Kanishka. This was done and we noticed that the ATC was running slightly fast. We had about 80 seconds reference time of conservation from Air India Boeing Kanishka and the ATC for reference and we had to extrapolate the information in this section for another 243 seconds at which time the explosive sound occurs. During the beginning of this 80 seconds reference period, we find that the ATC was leading by 90 milli-seconds and at the end of 80 seconds the lead of ATC was 130 milli-seconds. Thus, in 80 seconds, the ATC had gained 40 milliseconds.

"This extrapolated to 243 seconds and gives a figure of 250milliseconds. This is how we arrived at the conclusion that both are synchronised within 250 milliseconds. I would like to bring to the notice of the Court that we have taken great pains to confirm this information by reapeating the tests a number of times. We did not take the 400 cycle signal available on the tape as the time reference. We took for reference the bunching of signals produced by the conversation and the gaps in between the convervation which are very clear on both tapes. Hence we are sure that our results are right. The UV recording which was made has been filed along with my report.

"The main channel which was examined was the CAM channel. This was agreed to by all the experts who were present during the first analysis of the tape at the BARC between 16th and 20th July, 1985. One of the most noticeable things is that channel 3 which corresponds to cockpit area shows the first sign of disturbance. Let us say for reference that the disturbance starts at 0 time. In about 45 milliseconds the signal rises to a peak value which is approximately 18.5 db above the ambient level before the commencement of the signal. After this point the signal decays roughly exponentially in about 40 milliseconds to be almost a steady level which is 10 db above the ambient level before the explosive sound. From this we could draw conclusions. Assuming that an explosion occurred on the aircraft. The explosion produces a shock wave with a steep wave front which travels in air as well as through the aluminium body and the speed of travel will depend upon the distance of the explosive from the point of observation. It will depend on the cube root of the explosive and it will also depend on the ratio of the distance to the cube root of the weight of the explosive. The shock wave is very fast. It can travel at about 10 times the speed of sound. Also when the shock wave hits the aluminium body of the aircraft the vibrating panels which are defined by the stringers and longerons transmit the sound to the CAM location. Because the speed of sound in aluminium is about 19,200 feet per second which is 16 to 18 times that of the speed of sound in air and the shock velocity is also about 10 to 12 times. This signal will be received

"first by the CAM. Nevertheless the shock wave gets attenuated diffracted and refracted during its travels to the cockpit. Hence the signal received at the cockpit will be an attenuated signal and this small signal we have taken as instantaneous with the time of explosion. As the time passes the sound waves travel from the explosion site reinforcing the sound in the cockpit area thereby there is a rise time. Then when all the complete sound information is transmitted we get the peak of the signal and thus the rise time corresponds to the delay between the first rise in signal to the peak as compared to the speed of sound. One may ask the question what is the speed of sound because the aircraft has an explosion and is exposed to the outside environment but since the de-pressurization of the aircraft through the explosive fracture will take a minimum of a few seconds, we can reasonably assume that the pressure of the air in the aircraft corresponds to about 5000 to 6000 feet of altitude. At this presure and temperature, the sound velocity is roughly 1000 feet per second and from the 45 milliseconds delay we concluded that the explosion should have occurred about 40 to 50 feet from the cockpit. A question may be asked that the decay of the signal might be due to the AGC of the CVR coming into action. Mr. Turner, who is an acknowledged expert in the field of CVR has reported that Messrs Fairchild tested the cockpit voice recorders with a 10 db rise and fall of signals at the threshold of AGC and they got a result indicating a decay time of 33 milliseconds. The fall in the waveform of Channel 3 is about 40 milliseconds and is well near 33 milliseconds, so an argument may be advanced that the sound continued to remain steady and the fall in the signal level was effected by the AGC. In order to confirm this we tested the Cockpit Voice Recorder which was identical to the one which was on Kanishka by applying 1 KHz waveform of rectuangular modulation. To our surprise, we found that the decay time roughly was 130 milliseconds as compared to 33 milliseconds given by Mr. Turner. We repeated the tests with an initial background and without any background at all. We further tested with ramp waveforms, in other words, "slowly rising and falling waveforms of triangular shape with modulations of 1000 cycle carrier. This also confirms our finding. In order to clarify how the tests were performed so that others can judge whether it was a realistic test, I will explain the procedure. The modulated waveform was produced by a signal generator. This was fed to an amplifier. The amplifier output was fed to a loudspeaker. The output of the amplifier was checked to ensure that there was no distortion. Thus the signal going into the loudspeaker is the same modulated signal which has been applied at the input of the amplifier.

This sound coming from the loudspeaker was recorded on the CVR through the CAM in the laboratory. This is how the test was performed. We were given a CVR tape by the Department of Civil Aviation purported to be that of an explosion which occurred on a Boeing 737 aircraft which crash- landed at Madras. We did the CVR analysis of this aircraft. We first recorded the output of the CVR of Indian Airlines CAM channel on a UV recorder. We found the rise time to be very small. This was of the order of a few milliseconds, about 8 milliseconds or so. We have been told that the explosion occurred just by the side of the front toilet i.e. just behind the cockpit. This to some extent confirms that the rise time is related to the distance of the explosion from the detecting CAM. The next thing that we did was the frequency analysis of this waveform. Mr. Davis has indicated in his report that if an explosion occurs on board the aircraft there should be low frequencies present. When we analysed the frequencies of the Kaniskha aircraft Channel 3, we did not find very low frequencies in case of an explosion abroad the aircraft. When we analysed the Boeing 737 tape we did not find any low frequencies in the signals. The report of Mr. Davis also provides the frequency analysis of a pistol shot which has been fired in the cockpit of the aeroplane. This also shows no low frequency components. So our conclusion, that it is not essential for low frequencies to be present in case of an explosion abroad an aircraft, was confirmed. I will go a step further to say that the frequency received by an area mike which responds to an explosive action abroad the aircraft will contain frequencies of the structure of the defracted " and dragging shock wave, the resonant frequencies of the aluminium panels defined by the longerons and the stiffening channel members and also some frequencies which may be of objects that the shock wave encounters in its path. It is, therefore, impossible to calculate the frequency spectrum that one would expect in the cockpit due to an explosion taking place in the aircraft".

3.4.6.35 In answer to a question Mr. Seshadri categorically stated that the word "explosion" in his report meant "a bomb, a very fast device".

3.4.6.36 Mr. Paul C. Turner's Report

Lastly, a reference may be made to the report dated 13th November, 1985 of Mr. Paul C. Turner. The evaluation of Mr. Turner of the analysis done by him of the CVR and the ATC tapes, as contained in the said report, was as follows:-

"With the foregoing as background, we can make several observations. The CVR record on the CAM channel, captain's channel and flight engineer's channel show that they were all affected at about the same time; the copilot's perhaps 20 milliseconds later. Major disturbances which are recognized as electrical system disturbances can be seen to begin about 60 milliseconds after the initial disturbance. This approximates the time it would take for the electrical system protective circuitry to become active.

3.4.6.37 "A steep wave front which would be indicative of a shock wave cannot be seen on the CAM channel sound spectrum; however, the spectrum analaysis shows that impulse type sounds occurred at the beginning of the event recorded on the CAM channel of the CVR. Since audio signals propagate through aluminium approximately 16 times the speed of sound in air, the CAM channel would probably have been affected by structurally transmitted noise before being affected by airborne noise. The geometry of the aircraft was such that structure borne disturbances could be recorded before the airborne transmitted information appeared at the cockpit microphone and an air transmitted shock wave or steep wave front may not be evident on the CVR.

3.4.6.38 The captain's and copilot's selector box channels recorded signals which appeared to be electrically inducted and similar to those seen on the Huete Boeing 747 breakups. These are then followed by a signal resembling audio frequency noises similar to an open microphone in a noisy environment or the opening of a receiver squelch. Both effects have been seen during aircraft breakups. The audio noise on the captain's and copilot's channels appears to have come from a different source. The flight engineer's channel does not contain audio noise. A spectral diagram of the copilot's and captain's channel noises just show broad band noise across the spectrum. The signal frequncies extend beyond the frequency range of a microphone both on the high and the low end. It does not fit the normal microphone envelope. Spectral diagrams of the event on the CAM channel show the normal microphone preamplifier envelope summed with wide band signal of unspecified origin. Since the signal quits abruptly with a doublet, it indicates that the interference was added upstream of the CVR and was not just reflected in the CVR power supply.

3.4.6.39 "The CVR record shows a signal stayed on for about 200 milliseconds when it appears that the power may have been interrupted to both the radio channel and the CAM channel of the CVR at the same time. It further appears that the signals to the CVR were probably interrupted at 360 milliseconds from the initial disturbance possibly by severance of the signal wires. It further appears from the action of the erase head and record that the main electrical system began to fail at this point and the CVR bus voltage value dropped to a value below 70 volts but not below 20 volts. This fluctuating voltage continued intermittently for a minimum of 1-1/4 seconds at which time the voltage evidently dropped to some value below 20 volts and the recorder ceased to operate. The power for operation of the No. 1 VHF transmitter can be explained by the operation of the standby bus and battery and connection of the No. 1 VHF radio to this standby bus.

3.4.6.40 "The necking down of the signal to a low value shows that no signal was coming to the CVR from the CAM preamplifier. The lack of a signal on the radio channels, which do not need to be erased before being recorded, further suggest that the wires were severed or

"that the transmission to Cork began after what appeared to be the loss of the primary electrical system approximately 1-1/2 seconds following the event. Standby power would have become available upon loss of the primary power, the number one VHF would have become available, and CVR would have ceased to operate.

3.4.6.41 "The action of the erase circuitry in the CVR suggests that the fluctuating voltage seen was coming from the main electrical system bus. Anything else causing this fluctuating voltage down stream of the CVR circuit breaker would probably blow it.

3.4.6.42 "The signal received in Ireland indicated that a radio, most probably this aircraft's No. 1 VHF transmitter, stayed operational for about 5.4 seconds following the event at which time the entire aircraft electrical system ceased to function. This assumes that the No. 1 transmitter ceased to operate due to standby bus failure.

3.4.6.43 "In the conclusion, it appears that a catastrophic event occurred on Kanishka. It was reflected in all channels of the CVR and the CVR power supply at the same time. The main electrical bus began to fail within 0.35 second and the standby bus survived for only 6 seconds more at which time the aircraft's electrical system ceased to function. It appears that the event occurred in a manner to affect the cockpit area microphone operation severely and to force operation of the automatic gain control on the CVR. This loud noise continued for the life of the aircraft's main electrical system as reflected in the CVR.

3.4.6.44 "The mechanism of how the ATC transmission was made from Kanishka to Cork is unclear. The sound was not recorded on the CVR, indepentent studies by Canadian and British investigators have the Cork ATC call originating approximately 1-1/2 seconds following the event on the CVR. This is about the time that standby power would have become available to the No. 1 VHF.

3.4.6.45 "This report should be viewed as an accident investigation tool only and used in conjunction with other evidence gathered during the investigation.

3.4.6.46 "The United States Noard/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

3.4.6.47 It is pertinent to note that according to Mr. Turner there was "catastrophic event" which had occurrred on Kanishka. He has, however, not elucidated as to what this event was.

3.4.6.48 After the receipt of the report, the Court requested the NTSB that Mr. Turner should come and depose. It is unfortunate that permission was not granted to him. Faced with this situation and as it was thought necessary that some clarification was called for, the Court sent a telex to Mr. Turner whereby he was asked to give replies to the queries contained therein. He was requested that the reply be sent by

27th January 1986. A copy of the telex was also forwarded to the American Embassy at New Delhi for sending the same to NTSB by way of confirmation. Previously all communications addressed to NTSB were being routed through American Embassy. No reply has been received by the Court till this day either from NTSB or from Mr. Paul Turner. According to paragraph 5.14 of Annex 13 the State is required, on request from the State conducting the investigation of an accident, to provide to that State with all the relevant information available to it. It was, therefore, obligatory on the NTSB to have seen that the information sought for by the Court by way of answers to the queries was supplied.

3.4.6.49 Court Evaluation

From the reports of all the experts and the testimonies of M/s Caiger, Davis and Seshadri it is clear, and it is agreed to by all of them, that there was a breakup of the aircraft in mid-air. The experts also agreed that the sounds recorded on the ATC Shannon tape at 0714:01 Z emanated from the Kanishka aircraft.

3.4.6.50 Mr. Caiger has not said either in the report or in his statement as to what was the cause of the bang. Mr. Davis, on the other hand, is categorical in stating in his report that there was explosive decompression (meaning rapid decompression) on the aircraft. He has, however, stated in the report that there is no evidence of an explosive device. The main reason for his coming to this conclusion is that he had not been able to find low frequencies in the spectra of the CVR of Kanishka. Mr. Seshadri, on the other hand is equally vehement in concluding that an explosive device had detonated in the front cargo hold of Kanishka.

3.4.6.51 It may be that the frequency spectrum of Kanishka CVR did not contain low frequencies but, as has been admitted by Mr. Davis himself in answer to a Court question, it is not necessary that in the case of every detonation there must necessarily be low frequencies in the spectrum. Frequency spectra of 'Kanishka CVR before 'bang' and at the 'bang' position are shown in Figs. 2 & 3, indicating presence of additional high frequncies at the bang. Indeed in the case of Indian

Airlines Boeing 737, which admittedly was a case where there was an explosion of a device within about 8 feet of the CAM, the frequency analysis showed absence of low frequencies. Frequency spectrum of Indian Airlines Boeing 737 CVR is shown at Fig. 4. Merely, because therefore, there were no low frequencies present would not mean that there was no detonating device on board the Kanishka. The CVR of Indian Airlines Boeing 737 has not been analysed either by Mr. Caiger or Mr. Davis. The analysis was, however, conducted by Mr. Seshadri and as is evident from his report, there were marked similarities between the spectra of Indian Airlines 737 and Air India's Kanishka CVR. One of the important reasons for coming to this conclusion, which has been indicated by Mr. Seshadri, is the rise time of the bang signal. From the analysis of the Indian Airlines Boeing 737 tape it was observed that it had taken 8 milliseconds for the peak to be reached. It was also seen that the explosive device was approximately 8 feet away from the cockpit area mike. Keeping this in view Mr. Seshadri observed that in the case of Kanishka the peak of the bang signal was reached in about 40 milliseconds. He, therefore, concluded that the origin of the bang sound was about 40 feet away from the cockpit area mike.

3.4.6.52 It would be pertinent to note that even according to the report of Mr. Davis the rise time in the case of Kanishka, which has been given for the peak is about 40 milliseconds. He, however, does not attach much importance to this because according to him after about 40 ms automatic gain control would become effective.

3.4.6.53 Mr. Davis has no personal experience of the time which it would take for the Automatic Gain Control to take effect. He has got the figures from the manufacturer. Mr. Davis admitted that the time which it will take for the AGC to be effective is not indicated in any published document of the manufacturer.

3.4.6.54 Mr. Seshadri, however, personally carried out the experiments on a Boeing 747 by using an instrument similar to what was on board Kanishka. From the testimony of Mr. Seshadri it is apparent that the results which he got were different. As per his testimony, for the AGC to be effective it will take 130 ms. If this be so then it may be possible to conclude that in the case of Kanishka the peak was reached in 40 ms. and thereafter the signal decayed and the signal was in no way effected by the AGC.

3.4.6.55 A reference may also be made, at this stage, the frequency spectrum of the sound of the hand gun which was fired on a boeing 737 flight deck. Frequency spectrum prepared by Mr. R.A. Davis is shown at Fig. 5. He has stated that the rise time for reaching the peak is almost instantaneous. Same is the case with regard to the frequency spectrum prepared by him of a bomb in a B-737 aircraft where the bomb had been placed in the freight hold which is shown in Fig. 6. A perusal of that spectrum also shows that the peak was reached in approximately 5 ms. The forward freight hold compartment of Boeing 737 is much more than five feet away from the cockpit area mike. If the theory of Mr. Seshadri was to be applied then as per the frequency analysis of this Boeing 737 bomb, the distance from the area mike could not have been more than 5 ft. It is, however, known, as per the report of Davis, that the bomb was actually in the freight hold which would mean not nearer than about 25 feet.

3.4.6.56 From what has been stated in the various reports, as well as in the testimony of the 3 experts who apperared in the Court, the only safe conclusion which can be drawn is that possibly enough study has not been done, due to lack of adequate data, which can lead one to the conclusion as to the exact nature of the sound and the distance from which it originated.

3.4.6.57 The fact that a bang was heard is evident to the ear when the CVR as well as the ATC tapes are played. The bang could have been caused by a rapid decompression but it could also have been caused by an explsoive device. One fact which has, however, to be noticed is that the sound from the explosion must necessarily emanate a few milliseconds or seconds earlier than the sound of rapid decompression because the explosion must necessarily occur before a hole is made, which results in decompression. In the event of there being an explosive detonation then the sound from there must reach the area mike first before the sound of decompression is received by it. The sound may travel either through the air or through the structure of the aircraft, but if there is no explosion of a device, but there is nevertheless an explosive decompression for some other reason, then it is that sound which will reach the area mike. To my mind it will be difficult to say, merely by looking at the spectra of the sound, that the bang recorded on the CVR tape was from an explosive device.

3.4.6.58 There are various hypothesis and theories which the experts have to investigate before any acceptable conclusions are arrived at. It so happens that in the present case we have the opinions of four experts, but they do not agree with one another on some material aspects. Two of the experts, namely, Mr. Caiger and Mr. Davis are categorical in saying that it is not possible to measure the distance of the origin of the sound on the cockpit area mike, whereas Mr. Seshadri has come to a different conclusion. Mr. Paul Turner in his report dated 13th November, 1985 in silent on this aspect, though in his earlier report dated 19th July, 1985 he had categorically said that there was an explosive device close to the cockpit.

3.4.6.59 With regard to the nature of the sound also we have 3 different opinions. Mr. Caiger is unable to give the nature of the sound, Mr. Davis says it is rapid decompression while Mr. Seshadri says it is a sound of an explosive device followed by decompression.

3.4.6.60 In the absence of any other technical literature on the subject, it is not possible for this Court to come to the conclusion as to which of the Experts is right. The only conclusion which can, however, be arrived at is that the aircraft had broken in midair and that there has been a rapid decompression in the aircraft. Just as it is not possible to say that the spectrum discloses that the bang is due to an explosive device similarly, and as has also been admitted by Mr. Caiger and Mr. Davis, it is not possible to say that the bang is due to break up of a structure.

3.4.6.61 The bang could have been due to either of the aforesaid two causes i.e. a bomb explosion or the sound emanating due to rapid decompression. The advantage of carrying out the said analysis is that a number of possible causes of the accident are eliminated. On the other hand, if the analysis is viewed in conjunction with other evidence on the record it is further possible to determine the exact nature or cause of the bang. In the present case the bang, as already noticed, could have been due to the sound originating from the detonation of a device or by reason of rapid decompression. Other evidence on the record, however, clearly indicates that the accident occurred due to a bomb having exploded in the forward cargo hold of Kanishka. The spectra analysis and the conclusions of Mr. S.N. Seshadri are corroborated by other evidence.

TESTS AND RESEARCH

3.5.1 During the course of investigation a number of groups were formed to study and analyse evidence and data which was available. Materials like CVR, ATC and DFDR tapes were also given to the various participants.

3.5.2 The groups as well as other experts studied and analysed the material with them and submitted their reports which have been referred to earlier.

3.5.3 The experts examining the CVR tapes did carry out a number of tests. Different graphs and traces were prepared and the sound was analysed by them. The result of their analysis has been referred to in Chapter 3.4 on Flight Recorders.

3.5.4. The metallurgical examination of some of the recovered pieces was carried out at BARC. The examination of some of the pieces showed different types of damages having been recorded on the targets such as petalling and curling round the holes, spikes etc. The said team carried out certain explosion experiments. Their report on the experiments so carried out has already been set-out in paragraph 3.2 above.

3.5.5 The Indian Air Force has set up an Institute of Aviation Medicine at Bangalore. The Court visited the said Institute on 9th December 1985. During that visit an experiment was conducted in the explosive decompression and high altitude chamber to demonstrate what actually happens during explosive decompression and subsequently on exposure to hypoxia.

3.5.6 Subjects were taken to 8,000 feet in the explosive decompression chamber with oxygen. They were exposed to an altitude of 25,000 feet within one second. During the course of this explosion a loud bang was heard and inside the chamber there was misting and drop in temperature. After this the chamber was allowed to run at 22,000 feet for roughly two minutes and an experiment to show the adverse affects of hypoxia on the subjects was done. In this experiment, subjects were asked to write a given sentence while their oxygen supply was cut off. It was observed that initially the subjects kept on writing the sentence correctly and then

after about 120 seconds they started making errors while writing the sentence and finally they stopped writing. At this stage oxygen was re-started and within a few seconds, the subjects started writing their sentence once again. The experiment was completed at this stage and the altitude chamber was brought down to ground level.

3.5.7 The subjects were taken out and were asked questions as to what did they feel. They explained that at the time of explosive decompression, they heard a loud bang, felt cold and saw misting inside the chamber. They also found air escaping from their lungs. On further enquiry about the experiment pertaining to hypoxia, they said that they felt light headed and after that they did not know what happened till they once again noticed that they were writing on a piece of paper.

SECURITY

3.6.1 The evidence and the statements filed on record show that Canadian Security arrangements in place prior to 23rd June, 1985 met the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand baggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

3.6.2 Air India, as required by Canadian regulation, had a security programme. Because of the threat level assessed against the Airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and had received and arranged for extra security for the month of June, 1985. For Air India flight 181/182, Air India provided a security officer from its New York Office to oversee the security at Toronto and Montreal.

3.6.3 As it became apparent during the course of investigation that security would be an important aspect whilch would require the attention of the Court, Mr. Rodney Wallis, Director, Facilitation and Security, International Air Transport Association was good enough to appear in Court on 24th January, 1986. His testimony on certain aspects of security was recorded in camera by the Court on that date. The expert evidence has been taken into consideration while formulating some of the recommendations.

INTERNATIONAL COOPERATION

3.7.1 The manner in which persons and organisations from five different countries combined their resources and efforts in connection with this accident is an object lesson in international cooperation.

3.7.2 From the time the accident occurred, till the conclusion of the investigation proceedings by the Court in Delhi, there has been a consistent interplay amongst different persons and organisations. When all the persons got together, for the first time, at Cork the group was very heterogeneous. Each one had his own point of view, which did not necessarily coincide with that of another. At times, the atmosphere was charged with a bit of tension which continued even when the Court was constituted to investigate into the accident.

3.7.3 It was noticed that not only were the participants a bit apprehensive and suspicious but, during the course of investigation, there were also occasions when there appeared some acrimony between a few of them.

3.7.4 In such a sensitive situation, careful handling was called for. The participants' honesty of purpose could not be doubted. All that was wanted was that there should be an effort to try and understand the point of view of all the persons. This is precisely what the Court tried to do.

3.7.5 It is indeed fortunate that the efforts of the Court, in this regard, succeeded. After the Court had decided that it was not the purpose or the function of the investigation to affix responsibility for any lapse which may have been committed, one could see the general relieving of tension. With the passage of time there was a gradual building up of the confidence of the participants in the conduct of the investigation. The participants' interest for air safety transcended all barriers and any apprehension or suspicion, which was present in the minds of some, was soon dispelled. In its place there grew a deep sense of urgency, anxiety and cooperation in an effort to see that all the participants rendered utmost assistance for the satisfactory completion of the task in hand.

3.7.6 The main beneficiary of this international cooperation was not only the Court investigating the accident but it was the cause of air safety which benefited the most. Countries and Organisations went out of the way to help each other, financially and otherwise, even when they were not obliged to do so. Money and services were readily and voluntarily offered and usually the requirements of the Court were always fulfilled.

3.7.7 As the accident had occurred only about 100 miles off the coast of Ireland, the centre of activity, initially, was centred at Cork. The Government of Ireland, and the Irish people in particular, acted as though they regarded this as a national disaster. Not only did they render every assistance with regard to the search and rescue operation, hospital facilities, police etc. but the people acted as if one of their own kith and kin had died. In the situation which existed they were pillars of strength to the relatives of the deceased. Not only did complete strangers comfort such relatives but, more often than not, they even joined in their grief. The residents of Cork did everything possible to try and mitigate the sorrow of the victims' relatives. Everyone did their small bit, even the children of Cork queued up to place flowers at the coffins of the victims.

3.7.8 The Representatives of the Government of Canada also came to the scene, at the initial stages itself, and rendered full help and cooperation till the last. The major brunt of the mapping and the salvage operations was borne by Canada. Willingly and without any demur it incurred huge expenses, which must have been to the tune of a few million dollars, in carrying out these operations. It rendered full help and assitance to the Court whenever called upon to do so. For example, it offorded full facilities and help to the team which had been sent to Canada by the Court in August, 1985. It was only with the help of the Canadian Government, and the CASB and RCMP in particular, that the Court was able to obtain evidence and information relating to the accident. Without Canadian help the conduct of the investigation would have only been speculative in nature.

3.7.9 On their own, and without any request from the Court or from the Government of India, the Government of United States decided to lend a helping hand in the salvage operations. This was done at a very critical juncture when financial help and expertise were required so as to salvage the important critical pieces of the wreckage. It arranged for the services of a salvage expert and it also made necessary arrangements for the deployment of a second ship, duly fitted with necessary equipment to enable it to salvage some of the heavier pieces of the wreckage. The Court understands that the amount which was contributed in meeting the expenses by the United States was to the tune of U.S. $ 700,000.

3.7.10 The Government of United Kingdom also provided ship and helicopters in connection with the search and rescue operations. Even during the time when salvage operations were being carried out it was the British Helicopters which assisted in transporting personnel to and from the ship which were engaged in the salvage operations. The A.I.B. at Farnborough, on being asked by the Court to do so, carried out a very detailed analysis of the CVR and the ATC tapes.

3.7.11 Being the state of Registry of the aircraft and also the state holding the investigation, the major brunt of the work fell on the shoulders of officers of the Government of India and BARC. They acted as coordinators who had to oversee the work being carried out by persons belonging to diverse organisations and coming from different countries. Young engineers of Air India took turns in going aboard the ships and manning the Control Centre at Cork. They worked in conjunction with the engineers of Boeing and CASB and the crew members of the ships during the salvage operations. Without their enthusiastic participation the progress of the salvage operations would have been severely hampered.

3.7.12 The Scientists from BARC and National Aeronautical Laboratory, Bangalore were ever ready and willing to work together with the experts from abroad. Whenever called upon to do so, they rendered whatever assistance which was desired by the Court and the other participants.

3.7.13 It was seen that when the persons, coming from different countries and backgrounds, worked together with sincerety and honesty of purpose then they functioned smoothly and harmoniously, and usually arrived at an agreed solution or finding. These days it is indeed rare to see such a degree of international cooperation between different persons, organisations and countries.

ANALYSIS AND CONCLUSIONS

4.1 From the evidence which is available what has now to be determined is as to what caused the accident.

4.2 Finding the cause of the accident is usually a deduction from known set of facts. In the present case known facts are not very many, but there are a number of possible events which might have happened which could have led to the crash.

4.3 The first task is to try and marshal the facts which may have a bearing as to the cause of the accident.

4.4 It is undisputed, and there is ample evidence on the record to prove it, that Air India's Kanishka had a normal and uneventful flight out of Montreal. The aircraft had been in air for about five hours and was cruising smoothly at an altitude of 31,000 feet. The readout from the CVR shows that there was no emergency on board till the catastrophic event had occurred. This is corroborated by the printout available from the DFDR. The event occurred at approximately 0714 Z and that brought the aircraft down, and it probably hit the surface of the sea within a distance of 5 miles. The time within which the plane came down at such a steep angle could not have been more than very few minutes. There was a sudden snapping of the communication between the aircraft and the ground. The aircraft had also suddenly disappeared from the radar.

4.5 It is evident that an event had occurred at 31,000 feet which had brought down 'Kanishka'. What could have possibly happened to it? The aircraft was apparently incapacitated and this was due either to it having been hit from outside; or due to some structural failure; or due to the detonation of an explosive device within the aircraft.

4.6 Evidence indicates that after the event had occurred, though the pilots did not or were not in a position to communicate with the ground, they nevertheless appeared to have taken some action. According to Mr. Laflamme, witness No. 12, the examination of the wreckage showed that spoilers had been deployed and this must have been done with a view to enter into emergency descent. He has further speculated that such an emergency descent would support or perhaps cause a rupture in the forward area or a partial damage to the hydraulic system or damage to the control system which created such a condition that the pilots were not able to control the flight. The wreckage fruther showed that the jack screw for the stabilizer trim was found in the nose-up position and it was hard to explain how this got there merely as a result of impact with the water. The trim being in that position could only have been due to the pilot selecting it or as a result of a situation created by an explosion. In that position, and at a high aircraft speed, there would have been an extremely high g-loading on the aircraft.

4.7 It can further be speculated that if an explosion takes place in the forward cargo compartment, the oxygen stream might have been damaged so that when the pilots donned their masks as part of the emergency drill for explosive decompression, they were not breathing enriched oxygen and the time of useful consciousness at about 31,000 feet would be significantly less than 30 seconds under high stress and if the pilots became unconscious as a result of this, then the aircraft would have got out of control which would explain the subsequent events.

4.8 None of the participants have produced any evidence which could lead one to the conclusion, that there was any external hit to the aircraft. In fact in the report dated 13th November, 1985, Mr. Paul Turner has stated as follows:

"The United States Norad/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.

4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.

4.11 The circumstantial and direct evidence which leads to the aforesaid conclusion is as follows :

A. Connection with an explosion at Narita Airport :

On 23rd June, 1985 there was an explosion at the Narita Airport. The explosion occurred when a bomb exploded in a suit case which was to be interlined to Air India's Flight No. 301 from Tokyo to Bangkok. The following events, which had occurred prior to this explosion, clearly establish the connection between the two incidents :

(i) On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight Indian accent. He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vacouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

(ii) On the same date at approxmimately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

(iii) On 20 June, 1985 at about 1210 PDT (1910 GMT), a male appearing to be of Indian origin purchased the tickets with cash from a CP Air Ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to 'M. Singh'. The telephone contact number was also changed. The final itinerary was as follows :

(a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22nd June, 1985

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22nd June, 1985

(b) L. Singh - CP 003 Vacouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June, 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 time in Tokyo, local 23 June, 1985

(iv) On 22 June, 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that the was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

(v) On Saturday morning, 22 June, 1985, a CP Air passenger agent worked check-in position number 26 at the CP AIR ticket counter, Vancouver International Airport, and recalls dealing with a passenger of Indian origin booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto his baggage could not be interlined. The passenger insisted and, as the line-up were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that 'M. Singh' checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage.

(vi) The flight manifest for CP 003 shows that on the same day the person using the name of 'L. Singh' with an interline ticket to Bangkok also checked through the same counter, was assigned seat 38H, and checked one piece of baggage.

(vii) A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as 'M. Singh' and 'L. Singh' did not board these respective flights.

(viii) In a statement of William Long, annexed to the affidavit of I.G. Pole, Police Officer, City of Toronto, he has stated that on 22nd June, 1985 he was employed as a driver whose responsibility was to deliver interlined baggage between terminal 2 to Terminal 1 and vice versa at Toronto. He has further stated that he had picked up 4 bags from Terminal 1 which were destined for terminal 2 Air India. Three of these bags were from U.S. Air originating from New York city. Regarding the last bag he stated as follows :

"The fourth bag destined for Air India was, I distinctly remember looking at the baggage tag and it was pink with the CP logo in blue and letters saying CP on it there were also numbers but I can't remember the number, from CP Air and I remember it was from Vancouver. On the bottom of the tag it said vancouver using the initials YVR and the flight number which I can't remember. The bag was destined for India. When I arrived at the CP Air belt there were a number of bags from other airlines on the belt included in these were the three U.S. Air bags destined for Air India. As I was finishing loading the carts, a CP Air station attendant who had been unloading bags from containers, I noticed as I checked once more for anymore bags, drop another bag on the conveyer belt. This was the bag destined for Air India. It was dark brown Samsonite Hard sided Type 01A on the Baggage Identification

Chart. After they were loaded onto the cart I took them over to Air Canada domestic belt at Gate 89-91".

To further questions posed to him, Long stated that this bag from CP Air weighed approximately 70 lbs and there was something which rattled inside the bag. He could not say what it was but he said that "it sounded small". When specifically asked whether he thought there was something big inside the bag, he answered in the affirmative, and added that he did not know what was in it but it was heavy. There was discrepancy in the time when he is alleged to have picked up the bags which he had indicated in his schedule when compared with CP Air Vancouver flight which had arrived at 1622 hours. When this was pointed out to Long, he answered "I could have may be got the time wrong, it was during the busy period. It could have been an estimate time. But I do remember the bag came off CP air. It could have been 16:34 Hrs. I don't know."

(ix) The aircraft departed from Toronto for Mirable and London with the suitcase unaccompained by the passenger who had checked it in at Vancouver. Similarly, CP Air 003 departed Toronto for Tokyo with the baggage of one passenger 'L. Singh' to be interlined to Air India flight AI 301 to Bangkok even though 'L Singh' had not boarded that flight.

(x) The linking of the two occurrences namely the blast at Narita Airport and the Air India accident becomes startingly evident if we look at the following chronology of events:

CPA 003 (VANCOUVER-TOKYO) CPA 060 (VANCOUVER-TORONTO) Connection to Connecting to Air India 301 Air India 182 WESTBOUND EASTBOUND All Times GMT Thurs 20 June, 1985 0057 A male called C.P. Air Reservations in Vancouver and after discussing a number of routings, booked a one-way ticket and CPA 060 to Toronto with connections to Air India 182 under the name of Jaswand SINGH. A return ticket was also booked on CPA 003 to Tokyo connecting with Air India 301 to Bangkok in the name of Mohinderbel SINGH.

1912 A male attended the CP Air Ticket Office in Vancouver. He paid $ 3005.00 in cash for the above tickets after changing the ticket of Mohinderbel SINGH to L. SINGH and changing
from a return to a one-way ticket. He changed the Jaswand SINGH ticket to M. SINGH.

Saturday 22 June A Mr. SINGH called Reservations and got 1330 confirmation on his one-way ticket to Toronto with luggage to be sent through to India. M. SINGH checked in with seat 10B confirmed to 1550 Toronto. Wanted suitcase interlined to AI 182. Agent relents. 1618 CPA 060 departed Vancouver 18 minutes late. M. SINGH not in assigned seat. L. SINGH checked in for CPA 003 and one suitcase interlined to Air India 301. Assigned seat 38H. CPA 060 arrived Toronto 2022 12 minutes late. Some passengers and baggage interlined to AI 181.
CPA 003 departed 17 min. late for Tokyo. L. SINGH not in 2037 assigned seat. Sunday 23 June Air India 181 departed 0015 Toronto for Mirabel 1 hour 40 minutes late. 0100 Air India arrived Mirabel. 0218 Air India 182 departed Mirabel 1 hour 38 minutes late. CPA 003 arrived Narita Airport, Tokyo. Arrived 14 minutes early 0541 Baggage cart explodes in transit area. 2 killed, 4 injured, 0619 0714 Air India 182 disappeared from Radar
Air India 301 departed Narita. 0805 0815 Air India 182 Scheduled arrival Heathrow (fuel stop).
(xi) It would indeed to too much of a coincidence that two persons, whose tickets were bought at the same time and who had checked in under the names of 'L. Singh' and 'M. Singh' missed their respective flights, more so when 'M. Singh' had insisted at the check in counter at Vancouver that he should be interlined, even though his seat from Toronto on AI 181/182 was not confirmed, and his baggage (one suitcase) accepted and be routed through to Delhi. If there had been some reason for 'gate no-show' by both of them, one would ordinarily

have expected both, or at least one of them, to have made efforts, at that time or thereafter, either to ask for refund of money or they should have contacted the airline staff at the Airport and asked that they should be put on another flight.

(xii) A large amount of money had been spent on the purchase of the two tickets and a question which comes to mind is as to why was this money spent if both the tickets were to be wasted and no one was to travel on them, after having checked in and obtained boarding cards. Furthermore, no effort has been made by any of these two persons to try and lodge a claim for the baggage which they had checked in.

(xiii) The aforesaid facts clearly indicate the connection between the travel plans of so called 'L. Singh' and 'M. Singh'. In fact the manner in which the reservations were changed to the names of 'M. Singh' and 'L. Singh' shows the anxiety of some one to hide behind the identity of persons who bore notorious names.

(xiv) The interlined baggage exploded at Narita Airport and there is strong probability that the suticase from Vancouver, which was interlined to AI 182, contained a device similar to the one which had exploded at Narita Airport on 23 June, 1985.

B. CVR and DFDR both stopped simultaneously:

There was simultaneous interruption of electrical power to the flight recorders. The electrical supply could have been interrupted either because of the cables being cut or because of total electric failure. Power supply wires to the CVR and the DFDR run under the passenger cabin ceiling on the left and the right hand side. The supply of electricity through these cables originates from the MEC compartment, which is in front of the forward cargo hold. If the CVR and the DFDR had stopped due to the breakage of electrical supply wires as a result of possible explosion in the aft cargo hold there would have had to be an instantaneous break of almost the entire section of fuselage, because both these recorders had stoped simultaneously. In such a catastrophic event it is not possible that the bottom skin panels of the aft cargo compartment would remain undistorted, or would have no rupture or holes in them. Furthermore, in such an event the tail portion of the aircraft would have been found in the beginning of the wreckage trail, but this was not so. On the other hand, and explosion in the forward cargo compartment would have resulted in damage to the electrical buses located in the MEC and that would, in turn, result in cutting off the electrical power supply causing simultaneous stoppage of the recorders.

C. The ATC Transponder Stopped Transmitting :

The transponder is located at the bottom of the one of the forward rakes immediately forward of the front cargo compartment. Signals from this also stopped being received by the secondary radar at Shannon. Keeping in view that the CVR and the DFDR had stopped simultaneously at about the same time, when the signals from ATC transponder had also ceased, it is reasonable to presume that there must have been a complete breackdown of electrical supply which had affected all the three units. The only event which could have caused such a damage to paralyse the entire MEC compartment could only have been an explosion in the forward cargo hold. It was not possible that any rapid decompression caused by a structural failure could have disrupted the entire electricl power supply from the MEC compartment. In known cases of aircraft being subjected to rapid decompression there has never been such an instantaneous and total stoppage of electrical power and in fact aircrafts have been known to have continued to fly and communicate with the ground even after decompression.

D. Non-supply of Oxygen :

Oxygen supply cylinders are located in the ceiling of the forward cargo compartment. Any rupture of the only pipeline which supplies oxygen to the passengers would result in there being no surge of oxygen flow, which alone drops the oxygen masks. The inspection of the wreckage shows that there is no indication of the oxygen masks ever having dropped. A rupture of this pipeline, simultaneously with power rupture, could only have been caused if there had been a detonation of the explosive device in the front cargo hold.

E. Damage in air :

The examination of the floating and the other wreckage shows that the right hand wing leading edge, the No. 3 engine fan cowl, right hand inboard mid flap leading edge and the leading edge of the right hand stabilizer were damaged in flight. This damage could have occurred only if objects had been ejected from the front portion of the aircraft when it was still in the air. The cargo door of the front cargo compartment was also found ruptured from above. This also indicates that the explosion perhaps occurred in the forward cargo compartment causing the objects to come out and thereby damaging the components on the right hand side.

F. Evidence of Overpressurization :

The examination of the structural panels and the other parts of the forward cargo compartment and the aft cargo compartment, recovered from the sea bed, indicates that overpressure condition had occurred in both the cargo compartments. The failure of the passenger cabin floor panels in upward direction also indicates that overpressure was created in both the compartments. It cannot be disputed that whenever an explosive detonates very high pressure shockwaves are formed which travel in all directions and high speed fragments of the container, or the loose material, also move away from the source of explosion. It is, therefore, clear that there was overpressurization in the cargo compartments which resulted in such rupture of the cabin floor panels.

G. Holes in the front cargo hold panels

While the skin panels of the aft cargo compartment are fairly straight and undamaged, the panels of the front cargo compartment are ruptured and have a large number of holes. This shows that there was occurrence of an event in the front cargo compartment and not in the aft cargo compartment.

H. Buckling of Seats :

The seats towards the rear of the aircraft had only the aft legs buckled, whereas the seats towards the front had both the front and the aft legs buckled. This indicated that the whole floor was subjected to a vertical force and was more severe towards the front. Moreover, the upper deck storage cabin was found among floating wreckage. The bottom of this cabin was pushed up in the shape of a dome with no evidence of impact damage. This deformation was indicative of having been caused, possibly, as a result of a shockwave.

I. Metallurgical Examination Results :

A metallurgical examination, especially of Targets 362 and 399, clearly confirms that there was an explosion in the forward cargo compartment. Microscopy around some of the holes discloses that they have such characteristics like twinning which can be present only if the holes had been puntured due to the detonation of an explosive device.

J. CVR Tape Analysis :

The report of CVR tape analysis by Mr. S.N. Seshadri also corroborates the aforesaid evidence i.e. that there was a bomb in the forward cargo hold of the aircraft.

RECOMMENDATIONS

5.1 ICAO, IATA and the States should :-

(a) undertake an ongoing review of established aviation security standards to prevent the placement of explosive substances on board commercial aircraft;

(b) establish a programme of monitoring the implimentation of security measures in airports around the world, in cooperation with the Governments concerned. For each airport studied, it should report its findings and recomend any improvements that may be required;

(c) consider establishing a group of civil aviation experts to investigate serious breaches of security. The purpose of these investigations would be to determine the facts of an incident so that necessary measures could be developed and implemented world wide to prevent similar breaches in the future.

Note : As it may take some time for ICAO and IATA to implement these recommendations, at least those countries which have international air traffic should take up effective measures without delay.

5.2 ICAO should :-

(a) develop a model clause on security that could be used in the bilateral air agreements that govern the exchange of air traffic rights between countries;

(b) consider establishing standards for the training of security personnel.

5.3 IATA should develop practical procedures for reconciliation of interlined passengers and their baggage at intermediate airports.

5.4 Interlining of checked-in baggage should not be done if a passenger does not have a confirmed reservation on the onward carrier flight.

5.5 The baggage of interlined passengers should be matched with passengers by the onward carriers before loading the baggage on the aircraft.

5.6 Whenever a Government becomes aware of particular high risk security threat it should notify not only the airline at risk, but also all connecting airlines in order that extra precaution can be taken at potential points of introduction of interline baggage into the system.

5.7 When an Airline is aware of a high security threat it should communicate the same to the host state as well as, if possible and prudent, to the other airlines operating there.

5.8 Passenger count should be done at boarding gate and in case of 'no gate show' of a passenger, his baggage must be off-loaded.

5.9 All checked-in baggage, whether it has been screened by X-ray machine or not, should be personally matched and identified with the passengers boarding an aircraft. Any baggage which is not so identified should be off-loaded. This is advisable as examination of the baggage with the help of an X-ray machine has its own limitations and is not fool proof. Some explosives hidden in Radios, Cameras etc. may not be readily detected by such a machine. In fact an explosive not placed in a metallic container will not be detectable by an X-ray machine. Similarly, a plastic explosive can be given an innocuous shape or form so as to avoid detection by an X-Ray. Reliance on an X-Ray machine alone may in fact provide a false sense of security.

5.10 Effectiveness of the instrument known as PD-4 is highly questionable. It is not advisable to rely on it.

5.11 All unaccompanied baggage should be placed on the aircraft after their contents have been physically checked. In the alternative, it should be loaded only after it has been placed in a decompression chamber and the host state is satisfied that the baggage is clean and the shipper has been identified.

5.12 Airlines should have effective backup security equipment or procedures available in case of machanical break down of security equipment.

5.13 All hand baggage, including that of the crew, should be opened and the contents physically checked even if the said baggage has been x-rayed. This will no doubt be a bit time consuming and laborius but if security is to be meaningful, then slight inconvenience has to be endured in order to ensure a safer flight.

5.14 The manufacturers of aircraft should take effective steps for protecting sensitive parts of the aircraft from explosive damage.

5.15 Studies should be undertaken to determine the feasibility of physically separating the avionics bay and emergency oxygen systems from the cargo area in aircraft so that these sensitive and essential areas of the aircraft cannot be damaged or destroyed by a relatively small explosive deivce concealed in luggage.

5.16 The seats should have safety belts which can act as restraint for the upper part of the body e.g. like a shoulder harness with inertial restraint.

5.17 The seats in the aircraft should be so designed so as to incorporate shock absorbing systems within the seat and they should be manufactured by using material which does not break easily.

5.18 In addition to the cockpit voice recorder, there should be in the cockpit a video/scanning camera which would record the movements and the audio sounds in the cockpit. This will not only assist in ascertaining as to how the pilots act during as emergency but, in the case of hijacking, would also assist in the identification of the hijackers.

5.19 The CVR should record all the conservation and sounds in the cockpit for the entire duration of the flight, and not merely for the last 30 minutes.

5.20 The CVR and the DFDR should be powered from two alternative sources of energy.

5.21 The oxygen for the flight crew should be supplied from two different sources i.e. in the event of an emergency the pilot and the co-pilot must don the oxygen mask and the oxygen must be supplied from different source.

5.22 Suitable provisions should be incorporated in Annex 13 which would give power to an Investigator to record evidence outside the country of investigation and also to summon witness from abroad. It should also be mandatory on the contracting States to give information sought for by an Investigator.

(B. N. KIRPAL)

February 26, 1986 COURT

We agree with the conclusions and recommendations stated above.

ASSESSORS

(V. Ramachandran) (J.S. Gharia)

(J.S. Dhillon) (J.K. Mehra)

(B.K. Bhasin)

ACKNOWLEDGEMENTS

When I was appointed as the Court to investigate into the accident, the magnitude of the task involved was known. With the help, assistance and cooperation of a team of dedicated workers, the work was, however, completed in not too long time. The assistance received from those who helped me cannot be too highly praised.

From amongst my Assessors, Captian B.K. Bhasin was the only one who was permanently stationed in Delhi. We met for the first time on 15th July, 1985 and little did I realise then that, by the time our work would be over, how much I would be depending upon him. Not only was his advice on the technical aspects of flying and air safety invaluable but, whenever any difficulty or a problem arose, I invariably turned to him for assistance and advice which I readily got. I found him having a very practical and positive approach to all the problems but, at the same time, he very rightly was not prepared to compromise on any principal issues.

The only interest Dr. V. Ramachandran appeared to have was to do his work to perfection. No praise can be too high for the manner in which this Metallurgist from landlocked Bangalore volunteered and boarded

the salvage ships which were carrying out operations in the cold and choppy waters of Atlantic Ocean. He sarificed all comforts and went to sea with a view to be present on board the ships at the time when salvaged pieces of wreckage were brought on board. His deep knowledge of metallurgy greatly assisted the examination of the salvaged pieces of wreckage. In this connection the entire metallurgical examination was planned and organised by him.

Whenever any information was required concerning explosives, Mr. J.S. Gharia was ever eager and in a position to provide the information.

Mr. J.K. Mehra looked into the engineering aspect of the accident and he spent a lot of time in going through various Air-India Maintenance Manuals. He always made discussions very lively and interesting.

Captain J.S. Dhillon came out of his retirement and provided useful information to the Court on some aspects of flying.

This work would never have been satisfactorily completed without the help and assistance received by the Court from late Mr. S.N. Seshadri of Bhabha Atomic Research Centre. From the time when the CVR was first played by him at BARC on 16 July, 1985 till the very end, he most willingly and pleasantly undertook any assignment which was given to him by the Court. It was a great national loss when he suddenly passed away on 2nd February, 1986, only a few days after he had deomonstrated his brilliance when his testimony, regarding the analysis of the CVR tape, was recorded by me in the Court.

I am also grateful to the other Scientists and staff of B.A.R.C. who rendered considerable assistance to the Court. The facilities made available by Dr. P.K. Iyengar, Director, B.A.R.C. with regard to the finalisation and completion of the report cannot be easily forgotten. In the absence of late Mr. S.N. Seshadri, with whom I had developled a personal rapport, Dr. Ashok Mohan and Mr. V.K. Chadda met with all our requirements in the finalisation and preparation of the Report. Dr. Asundi of BARC and the other Metallurgists of that Organisation and of the National Aeronautical Laboratory also spent a considerable amount of their time and energy in successfully carrying out metallurgical tests and examination of the salvaged pieces.

During the investigation I had to visit Ireland on two occasions. I immediately realised the extent of help, assistance and guidance which was being rendered to all of us by Mr. Kiran Doshi, the Indian Ambassador to Ireland. There was no problem to which he did not have a solution. On my visit to Dublin not only did I enjoy the hospitality of Kiran and his wife Razia but it also gave an opportunity to personally meet Mr. Mitchel, the Minister of Communications, and senior officials of his Ministry, and to express my gratitude to them for all the help and assistance which the Government and people of Ireland had, most willingly, rendered.

At Tokyo the Indian Ambassador and members of his staff looked after all our needs and arranged meetings with the Japanese officials whom we wanted to meet.

As representatives of the Court in Cork, Mr. P.R. Chandrasekhar and Mr. C.D. Kolhe did a commendable job. They kept me informed of the progress which was taking place at Cork and, whenever required to do so, they took vital decisions while coordinating the mapping and salvage operations.

Mr. H.S. Khola, Director of Air Safety, New Delhi willingly carried out all the directions of the Court. Special mention must also be made of Mr. Satendra Singh, Regional Controller of Air Safety, Bombay, who worked day and night when the flight recorders were first opened and the copies of the tapes made and the data analysed.

I have also to express my gratitude to the Counsel who assisted the Court in the Investigation. Without their help and cooperation, it would not have been possible to complete the work in 7-1/2 months.

On my trip to Bombay, the Staff and Management of Centaur Hotel made my stay very comfortable. It was like a home away from home.

The work done during the salvage operarations by four young engineers of Air-India was highly commendable and valuable. All of them namely, Mr. Balasubramanium, Mr. L.S. Carvalho, Mr. G.D. Nayar and Mr. A.K. Sheode, worked round the clock even during adverse climatic conditions.

The Registrar of the Delhi High Court, Ms. Usha Mehra spared no efforts in rendering every assistance whenever the same was required. She ably marshalled all the resources available in the High Court in order to ensure the smooth and efficient functioning of my office. My own personal staff in particular, headed by Mr. V.P. Ahuja, Court Master and Mr. Balram Chopra, Private Secretary, as usual, rose to the occasion. While Mr. Ahuja kept complete control of hundreds of documents and affidavits which had been filed, Mr. Chopra besides bearing the brunt of the typing work, very ably supervised the work of other Stenographers.

It was most fortunate that I was able to persuade Mr. S.N. Sharma to accept the trying job of being the Secretary to the Court. His vast experience in such Investigations, he had been a Secretary in three such Investigations earlier, made my task much lighter. Moreover, as an Aircraft Engineer, he was always ready to explain technical intricacies involved in the case. Without his help I could not have completed my work within the stipulated time.

(B. N. KIRPAL)

26th February, 1986 COURT

POSITIVELY IDENTIFIED DEBRIS AIR INDIA 747 VT-EFO KANISHKA AIRCRAFT

SECTION TARGET LAT LONG DESCEIPTION 41 DOOR 192 51 03.28 12 47.74 FIRST CLASS AND COCKPIT AREA (+ UPPER DECK DOOR) 41 131 51 03.21 12 47.93 LEFT HAND UPPER DECK SLIDE MECHANISM 41 134 51 03.28 12 47.81 NOSE LANDING GEAR 41 265 51 02.37 12 44.51 LANDING GEAR DOOR (NOSE GEAR) 41 244 51 03.56 12 48.19 UPPER DECK WINDOW TRIM (REVEAL) 41 63 51 02.51 12 47.37 2 FIRST CLASS SEATS 41 77 51 02.59 12 47.83 2 FIRST CLASS SEATS 42 DOOR 193 51 03.30 12 47.85 PIECE OF FUSELAGE, WING PLUS LANDING GEAR (#2 LEFT DOOR) 42 138 51 03.37 12 47.77 SMALL PIECE OF WRECKAGE (BS 800) 42 200 51 03.347 12 47.831 Dual Heat Exchanger 42 DOOR 204 51 03.33 12 47.87 FORWARD CARGO DOOR + FLOOR 42 255 51 03.72 12 48.01 GALLEY COMPLEX (UPPER DECK) 42 232 51 03.49 12 47.92 'P93' RACK MARKED

'DANGER HIGH VOLTAGE' (BS 670) 42 327 51 01.62 12 43.03 NACA SCOOP 42 DOOR 358 51 03.39 12 47.86 MASS OF DEBRIS (#2 RIGHT DOOR) 42 361 51 03.384 12 47.848 BOX MARKED "FAN BLADES" 42 362 51 03.372 12 47.840 MASS OF DEBRIS FUSELAGE SKIN 42 383 51 03.32 12 47.81 MASS OF DEBRIS WITH UPPER DECK FLOOR 44 DOOR 137 51 03.30 12 47.80 CENTER FUSELAGE SECTION WITH #3 LEFT DOOR 6 WINDOWS AFT OF DOOR AND 13 WINDOWS FORWARD. LEFT UPPER WING SKIN AND ONE MAIL LANDING GEAR ATTACHED. 44 103 51 02.86 12 46.37 LANDING GEAR DOOR 44 105 51 02.81 12 46.04 LEFT WHEEL WELL LANDING GEAR DOOR 44 186 51 03.32 12 47.825 KEEL BEAM 44 195 51 03.32 12 47.78 WING STRUCTURE 44 224 51 03.46 12 48.49 TWO WHEELS FROM MAIN LANDING GEAR 44 239 51 03.62 12 47.38 MAIN BRAKE UNIT WITHOUT AXEL, PLUS EQUALIZING ROD 44 240 51 03.62 12 47.44 MAIN TIRE AND RIM 44 241 51 03.62 12 47.40 MAIN TIRE AND RIM PLUS AXEL 44 242 51 03.61 12 47.40 MAIN BRAKE UNIT 44 267 51 03.35 12 44.45 PART OF LANDING GEAR DOOR 44 275 51 02.13 12 44.10 BODY LANDING GEAR DOOR 44 279 51 02.30 12 44.64 MAIN LANDING GEAR DOOR 44 280 51 02.26 12 44.61 SECTION OF MAIN LANDING GEAR DOOR 44 343 51 03.285 12 47.809 MAIN LANDING GEAR DOOR 59 51 02.57 12 45.73 SECTION OF LANDING GEAR 44 218 51 03.41 12 47.86 STEP WELL AREA (STA 1250-1480)
46 6 51 02.79 12 49.44 SMALL MOTOR 10" x 8" (FAN) 46 7 51 02.90 12 49.92 LOWER SKIN OF CARGO AREA 4' x8' (BS 1480)) 46 #11 51 02.04 12 45.44 PIECE OF OUTER SKIN BODY STATION #1760 PART NO. 65B04325-403 46 25 51 02.21 12 46.27 BODY FRAME (BS 1660-1680) 46 26 51 02.20 12 46.72 CABIN SECTION WITH 4 WINDOWS (ABOVE 'T' IN REG No.) 46 28 51 02.31 12 47.02 SKIN PANEL 1460-1800 46 33 51 02.49 12 48.28 AFT FUSELAGE SKIN PANEL 'YOUR PALACE IN THE SKY' (AFT OF #5 DOOR) 46 34 51 02.49 12 48.29 RIGHT HAND FUSELAGE SKIN PANEL AT DOOR #5 46 DOOR 40 51 02.47 12 47.41 CARGO DOORS C2, C3 46 47 51

02.39 12 46.61 REAR CARGO FLOOR 46 50 51 02.38 12 46.60 CARGO FLOOR (STA 1500) 46 DOOR 74 51 02.49 12 47.71 FIVE FRAMES AND DOOR-PORT SIDE AFT (#5 LEFT DOOR) 46 78 51 02.52 12 47.95 FRAME SECTION (SHEAR WEB STA 2000-2020) 46 87 51 02.58 12 48.43 BUILT UP STRUCTURE (STA 2412) 46 DOOR 97 51 02.52 12 47.38 FUSELAGE SKIN SECTION WINDOW BELT AREA WITH DOOR FOLDED UNDER FRAME 46 DOOR 101 51 02.84 12 47.14 5 WINDOWS AND DOOR (#4 RIGHT DOOR) 46 292 51 01.81 12 44.24 FRAME (STA 2240) 46 321 51 02.39 12 46.61 '4R' DOOR ENTRANCE WITH NO DOOR AND 10 WINDOWS (BS 1700) 320 51 01.84 12 44.59 FUSELAGE BOTTOM SKIN NEAR OUTFLOW VALUE 46 336 51 01.34 12 42.03 BULK CARGO COMPARTMENT FLOOR AND STRUCTURE 46 369 51 02.17 12 46.20 FUSELAGE PANEL SECTION, 4 WINDOWS 48 31 51 02.37 12 48.43 HORIZONTAL STAB 48 37 51 02.47 12 47.99 VERTICAL TAIL FIN (+ PRESSURE BULKHEAD SECTION) 48 35 51 02.50 12 48.08 AFT PRESSURE BULKHEAD (25%) 48 22 51 02.19 12 45.68 ELECTRICAL PANEL (RUDDER RATIO JUNCTION BOX) 48 27 51 02.20 12 46.83 APU HOUSING 48 66 51 02.59 12 47.54 BODY FRAME (BS 25XX) 48 67 51 02.55 12 47.50 FUSELAGE SKIN (3 FRAMES FORWARD OF APU BS 2638) 48 68 51 02.57 12 47.55 FUSELAGE SECTION (BS 2598) 48 73 51 02.51 12 47.70 PART OF PRESSURE BULKHEAD 48 75 51 02.47 12 47.63 FRAME FOR OVERHEAD LUGGAGE COMPARTMENT (ROW 46 F-G) 48 88 51 02.90 12 48.84 CONTROL LINKAGE FROM TAIL OF AIRCRAFT (ELEVATOR CONTROL QUADRANT) 48 99 51 02.71 12 47.92 FUSELAGE SKIN SECTION (BS 2598) 48 296 51 02.03 12 43.17 PART OF PRESSURE BULKHEAD 48 314 51 01.84 12 44.19 APU AIR DUCT 48 371 51 02.51 12 48.28 AFT FUSELAGE SKIN 10'x15' (HORIZ. STAB CUTOUT)
SECTION TARGET LAT LONG ENGINES 7.13 108 51 02.97 12 47.12 AIRCRAFT ENGINE (WITH STRUT) 149 51 03.26 12 47.38 ENGINE AND STRUT 154 51 03.32 12 47.75 ENGINE SECTION (5th ENGINE) 171 51 03.16 12 47.16 TURBINE

SECTION OF ENGINE (POSSIBLY COMPLETE ENGINE) 235 51 03.63 12 47.07 AIRCRAFT ENGINE ENGINE PARTS 106 51 02.98 12 46.41 ENGINE COWLING (INLET) MARKED 'A124' (5th ENGINE) 109 51 02.97 12 47.11 STARTER FOR AIRCRAFT ENGINE 111 51 03.02 12 47.20 ENGINE COWL 116 51 02.99 12 47.80 ENGINE DEVICE 124 51 02.85 12 48.47 FIFTH ENG CENTER DOME 150 51 03.25 12 47.36 PART OF ENGINE 151 51 03.29 12 47.42 SMALL PART OF ENGINE 152 51 03.31 12 47.44 LOWER PORTION OF ENGINE 153 51 03.31 12 47.44 LOWER ENGINE COWLING 155 51 03.32 12 47.44 FAN INNER EXIT AREA 156 51 03.32 12 47.43 PART OF ENGINE 158 51 03.23 12 47.35 PART OF ENGINE COWLING 159 51 03.25 12 47.29 ENGINE COWLING 161 51 03.26 12 47.29 PORTION OF ENGINE COWL 165 51 03.20 12 47.21 THRUST REVERSER SLEEVE 166 51 03.20 12 47.21 UNIDENTIFIED ENGINE PARTS 167 51 03.21 12 47.24 UNIDENTIFIED ENGINE PARTS 168 51 03.20 12 47.22 UNIDENTIFIED ENGINE PART 169 51 03.18 12 47.20 UNIDENTIFIED ENGINE PARTS 170 51 03.19 12 47.19 PART OF DIAPHRAM (OIL COOLER) 172 51 03.25 12 47.21 ENGINE EXHAUST CONE 173 51 03.27 12 47.38 ENGINE EXHAUST CONE AND EXHAUST 237 51 03.690 12 47.10 ENGINE PARTS CASE 238 51 03.72 12 47.10 ENGINE INLET COWL 206 51 03.34 12 47.50 SECTION OF ENGINE EXHAUST STAGE #7 207 51 03.35 12 47.49 ENGINE HOT SECTION AREA 208 51 03.37 12 47.51 ENGINE TAIL CONE 214 51 03.19 12 47.36 CASCADE VANE

STRUTS 7.12 4 51 02.87 12 49.05 #3 ENGINE NACELLE STRUT 157 51 03.23 12 47.36 STRUT (SIMILAR TO 149) 110 51 03.15 12 47.16 NACELLE STRUT WING PARTS 17 120 51 03.01 12 47.98 OUTBOARD AILERON (50%) 16 135 51 03.28 12 47.81 TRAILING EDGE FLAP AND DRAG JACK 16 136 51 03.31 12 47.81 TRAILING EDGE FLAP JACK SKREW 12 140 51 03.35 12 47.83 LEADING EDGE SECTION OF WING 14 145 51 03.34 12 47.85 WING LEADING EDGE VARIABLE CAMBER FLAP 16 177

51 03.34 12 47.91 TRAILING EDGE FLAP 12 181 51 03.38 12 47.87 LOWER CARGO COMPARTMENT AND WING LOWER SKIN 16 183 51 03.38 12 47.87 SECTION OF FLAP SKIN 16 188 51 03.33 12 47.81 TRAILING EDGE FLAP WITH JACK SKREW 16 189 51 03.32 12 47.80 TRAILING EDGE FLAP WITH SKREW JACK 16 191 51 03.32 12 47.78 FLAP ACTUATOR AND FLAP TRACK 16 194 51 03.32 12 47.77 TRAILING EDGE OF FORE FLAP 16 253 51 03.32 12 47.86 PIECE OF TRAILING EDGE FLAP 16 254 51 03.40 12 47.86 PIECE OF TRAILING EDGE FLAP 16 264 51 02.47 12 44.74 TRAILING EDGE FLAP FAIRING 16 277 51 02.18 12 44.40 WING FLAP 16 344 51 03.294 12 47.802 TRAILING EDGE FLAP AND FLAP TRACK 16 384 51 03.33 12 47.80 T/E FLAP TAPER AND DRIVE SHAFT 16 398 51 03.325 12 47.85 PIECE OF TE MID FLAP   15 190 51 03.32 12 47.79 SPOILER ACTUATOR   14 187 51 03.34 12 47.81 LEADING EDGE FLAP SECTION 14 387 51 03.33 12 47.853 PIECE OF L/E FLAP MECHANISM

12 54 51 02.38 12 45.86 LE FROM WING 12 202 51 03.33 12 47.86 WING LOWER SKIN 12 221 51 03.39 12 47.89 UPPER EDGE LEFT WING 12 225 51 03.38 12 48.78 SMALL PIECE OF WING LEADING EDGE PANEL 12 222 51 03.38 12 47.94 WING FILLER & WING PARTS 12 243 51 03.59 12 47.85 PIECE OF LEADING EDGE FLAP 12 252 51 03.38 12 47.84 LOWER WING SECTION 12 262 51 03.85 12 46.92 MID LOWER WING SKIN, ONE AFT FLAP TRACK WITH JACK SKREW 12 266 51 02.36 12 44.46 LANDING GEAR DOOR 12 297 51 01.91 12 43.18 PART OF WING TIP 12 345 51 03.28 12 47.842 'REAR WING SPAR' 12 365 51 03.338 12 47.842 REAR SPAR RIB WITH SPOILER ACTUATOR 12 379 51 03.315 12 47.785 WING REAR SPAR AND SPOILER STA 1150 12 381 51 03.40 12 47.88 LE OF WING SECTION 12 182 51 03.38 12 47.87 POSSIBLE REAR SPAR, (WING STA 802 I.D. ON PART)   17 274 51 02.19 12 43.57 LEFT INBOARD AILERON

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:48 PM PDT
To: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Subject: **Contact**

Dear Jaspreet, call me Barry.

Call me at your convenience so you can check me out. I sense distrust.

What you see is what you get with me.

Sincerely,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Dear John,

My contact info. is:

Jaspreet S. Malik
6475 Marguerite St.
Vancouver, BC
V6M 3L5
jsmalik@wwdb.org

Cell: 604-861-8858

As for a resume you have my introduction e-mail which lists all I have to say for now.

Jaspreet

At 2:52 PM -0800 3/11/01, John Barry Smith wrote:
To: PSi <psi@interchange.ubc.ca>
From: John Barry Smith <barry@corazon.com>
Subject: Apology
Cc:
Bcc:
X-Attachments:
Dear Parmajit,

I'm sorry if I quoted you without permission. I fully appreciate the pressures you are under and respect your decision on how to proceed. I often worry about Boeing coming down on me because for four years I have had a web site that essentially says their airplanes are unsafe. It's best to be prudent sometime.

Sincerely,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:48 PM PDT
To: Jerry <Sterns@trial-law.com>

Subject: **wiring/cargo door/explosive decompression**

Barry, we are always willing to look at any possible meritorious case involving aviation matters. I know we have been in touch before, but I don't remember the case. Can you refresh my memory? Please forward whatever information you can and we will have a look. Mailing address 901 Clay Street, Oakland 94607; ph 510 267 0500; fax -0506. Thanx for thinking of us.
Regards, G Sterns

Dear Mr. Sterns, (We went through this before, G for Gerald and called Jerry? Just deducing...as is my wont.)

The accident I was in contact with you before was TWA 800. I contend it was wiring/cargo door/explosive decompression and not bomb, missile, nor spontaneous center tank explosion with mystery ignition source.

The instant case is AI 182.

The accused is considering a new defence counsel more aviation oriented and I have suggested your name and others.

I am involved because the accused, Mr. Malik, supports my wiring/cargo door/explosive decompression explanation for AI 182 and rejects the bomb explanation. My explanation is stated on www.corazon.com.

If you would like to contact a principal, Mr. Aniljit Singh Uppal, his email is: aniljitsingh@hotmail.com He is articulate, well informed, and very easy to talk to.

I recommended you because of your experience with the DC 10 event. You don't laugh, while others do, when the suggestion is made that an open cargo door can cause the destruction of a huge airliner and the deaths of hundreds.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:48 PM PDT
To: "PSi" <psi@interchange.ubc.ca>
Subject: **Questions, yes, questions.**

Hi John,
Please call me Parmjit,

Dear Parmjit, Thank you for kind words, please call me Barry.

Well, questions....why no preliminary hearing for Mr. Malik?

What's next on April 4th?

What are the discovery rules in Canada? Can Mr. Malik ask for and receive the following items below:

Can he have computer in cell?

Can he have internet access via phone lines?

Can he receive and send out removable disks for laptop computer?

Is he eligible for assistance from the Crown for a legal expert and technical expert?

What is the sequence of prosecution from arrest to hearing to trial to appeal?

Is he a joint defendant with Mr. Bagri or independent?

What is a realistic timetable for future legal milestones?

Can an American (California) aviation trial attorney practice in Canada or what capacity can he assist?

I find it interesting that the document that concludes a crime was committed, which implies a criminal, was made by an Indian judge at a hearing. It was not Canadian, not a trial, and it was not aircraft investigators. In essence Mr. Malik is being accused of an event labelled a crime by a judge far away and unable to be deposed or cross examined in Canada. What is your opinion about the jurisdictional issues of that?

Thanks for helping, it is a complex lengthy case. We have only just begun.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Aircraft:
AI 182:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the RCMP and TSB.
2. Access to all hard evidence of the wreckage which was retrieved from ocean.
3. Interviews with TSB, AAIB, and NTSB investigators who contributed to the AI 182 report through deposition or voluntary meeting.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

PA 103: The same officials who worked on the AI 182 report also worked on the PA 103 AAIB report.

1. Interviews with NTSB metallurgists and Boeing explosive expert and British law enforcement involved with the investigation.
2. Copies of all videotapes, photographs, interview notes, and sketches now held by the AAIB and Scotland Yard.
3. Access inside the hangar at Farnborough of the Pan Am 103 wreckage for at least 40 hours (five days at 8 hours a day) by at least five of your team.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

TWA 800: The same officials who worked on AI 182 and PA 103 worked on TWA 800.
1. Access to the hangar where the wreckage of TWA 800 is stored for at least 40 hours (five days at 8 hours a day) by at least five of your team.
2. Copies of all photographs, videotapes, interviews about TWA 800 now held by FBI and NTSB.
3. Interviews with NTSB metallurgists, explosive expert and American law enforcement involved with the investigation.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

UAL 811:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the NTSB.
2. Access to any existing wreckage.
3. Interviews with NTSB metallurgists, explosive expert and American law enforcement involved with the investigation.

4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

Airport:
Narita:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the RCMP and TSB and Japanese airport and police authorities
2. Transcripts of the trial

Manufacturer:
Boeing:
1. Copies of all memos, data, and information about cargo doors and cargo holds on Boeing 747s.
2. Copies of all memos, data, and information about cargo doors and cargo holds on DC-10, MD-11, and MD-12.

Airlines:
Pan Am, TWA, Air India, United Airlines:
1. Copies of all videotapes, photographs, interview notes, and sketches regarding PA 103, AI 182, TWA 800, and UAL 811
2. Access to any existing wreckage held by them.
3. Interviews with airline staff involved with the accidents.
4. Maintenance logs for the accident aircraft long before and just before the fatal flights.

Miscellaneous:
1. Copies of all data about Canadian Pacific Air Flight 003, another Boeing 747 supposed to have a bomb on board and by inference, abetted by you, sir, or your fellow Sikh, Mr. Reyat.
2. Copies of all Data about Airworthiness Directives about cargo

door on commercial airliners held by FAA and NTSB databanks.
3. Brantingthorpe 747 evidence.
4. DC 10 CVR data, explosive decompression accidents, Windsor and Paris.

Air India bombing suspects make closed circuit court appearance

*Updated 3:49 PM ET March 9, 2001*VANCOUVER (CP) - Two men accused of the worst mass murder in Canadian history made a brief court appearance via closed circuit television Friday. Ajaib Singh Bagri and Ripudaman Singh Malik made their first court appearance in B.C. Supreme Court since the Crown filed a direct indictment against them for the bombing of an Air India flight that killed 329 people.

The direct indictment means all future court appearances will be in B.C. Supreme Court. There will be no preliminary hearing for the men, who are charged with the first degree murder of the passengers and crew of Flight 182 and the attempted murder of those aboard Air India Flight 301.

Friday's court appearance was procedural.

Bagri and Malik face eight charges, including the murders of two Japanese baggage handlers killed when a bomb concealed in luggage destined for Flight 301 exploded at the Narita airport in Tokyo.

The bombing of Flight 182 off the coast of Ireland on June 23, 1985, was the worst act of aviation terrorism in the world.

Malik, a Vancouver millionaire, and Bagri, a sawmill worker from Kamloops, B.C., were arrested last October following 15 years of investigation.

They have been held in custody since then.

Bagri, who alone faces an additional charge of attempted murder for the 1988 attempted assassination of a moderate Indo-Canadian newspaper publisher, is appealing the decision denying him bail.

RCMP say there will be more arrests.

Inderjit Singh Reyat and Talwinder Singh Parmar are named as unindicted co-conspirators in the deaths.

Parmar was a leader of the militant Sikh separatist group Babbar Khalsa, dedicated to the creation of a separate state called Khalistan in Punjab.

He was killed by Indian police in October 1992.

Reyat was extradited from Britain in 1989 and convicted for his role in the bombing at the Narita airport in Japan.

The Crown is seeking permission from Britain to charge Reyat, whose 10-year sentence is finished in June, in the bombing of Flight 182.

British extradition laws don't allow new charges to be laid without Britain's permission. Reyat holds both Canadian and British citizenship.

The terms of Reyat's 1989 extradition from Britain were based on charges stemming from the explosion at Narita, which killed two baggage handlers. They didn't include charges for bombing of Flight 182.

The men return to court April 4.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:48 PM PDT
To: PSi <psi@interchange.ubc.ca>
Subject: **Apology**

Dear Parmajit,

I'm sorry if I quoted you without permission. I fully appreciate the pressures you are under and respect your decision on how to proceed. I often worry about Boeing coming down on me because for four years I have had a web site that essentially says their airplanes are unsafe. It's best to be prudent sometime.

Sincerely,
Barry

To: jsmalik@wwdb.org, aniljitsingh@hotmail.com, khalsaq@yahoo.com, maan100@worldonline.nl, KaurSingh@webtv.net, AMARDEEP@klse.com.my, npsingh@wans.net
From: John Barry Smith <barry@corazon.com>
Subject: Media coverage
Cc:

Bcc:
X-Attachments:
Fly the airplane, don't let the airplane fly you.

Dear Crew, 11 Mar 01

I apologize for any quoting of sensitive material that was sent to me. I shall be more discrete in the future.

I am assuming all these emails are being delivered to Mr. Malik; I really would like to know he is receiving all our current thinking.

The press cat is out of the bag, sort of. I appreciate the efforts of Shyrone to get the wiring/cargo door/explosive decompression story out. The main power of the explanation will be when the defence formally announces support for it. It is one thing for an independent safety investigator to claim a probable cause for an airplane crash not currently supported by authorities, but it is entirely different when a defence announces they fully support the explanation as correct and are putting a man's life on the line as proof.

And that is why we have to be rock solid on the facts. There are lingering doubts as to where the 'explosion', bomb or otherwise, took place, aft or forward cargo hold. My analysis, based on the evidence of AI 182 report and the matches to UAL 811 and others, firmly support the forward cargo hold as the locus of the explosion. The Kirpal Commission agreed but said the cause was a bomb and not explosive decompression caused by door rupture.

To say that the forward cargo hold of AI 182 exploded is consistent with the official report and therefore not controversial.

We just offer a mechanical explanation for the explosion with precedent which is a reasonable alternative to bomb. Again, not too dramatic a change.

When it is formally announced that the defence has a three pronged strategy, then the world's press will pay attention. The three prongs are, in my humble opinion, subject to revision of course, are: 1. Mr. Malik had nothing to do with AI 182, whether it was bomb, center tank explosion, door design, or installation of wiring. 2. Most unlikely bomb. 3. Most probably wiring/cargo door/explosive decompression.

Support for our defence and alternate explanation to bomb is new evidence unavailable to the original investigators such as UAL 811.

Before the announcement is made officially, we shall have to have the go ahead from Mr. Malik. A formal statement shall be prepared and checked over. I have contacts in the media, TV and print, and electronic aviation safety forums, but have decided to wait until given the go ahead from the principals, Mr. Malik, Aniljit, Narinder, and Jaspreet.

It is one thing for us as individuals to support the decompression explanation but quite another for the defence team. So, we wait for the decision. It's all part of the legal strategy. I consider myself the pilot of the wiring/cargo door/explosive decompression explanation and not the leader of parts one and two of the defence. I can assist in the 'most unlikely bomb' position.

Thank you Santokh for your resume and a very impressive one it is. We are extremely fortunate to have an aviator of your caliber to assist us. I look forward in the future, when relaxed, for us to trade flying stories. To go from flying DC 3 in 1966 to Boeing 707 two years later must have been a thrill.

Let me add a few personal details: Born Feb 19th 1944, Birkenhead England of British parents, emigrated to USA in 1946. Married 1979 to Corazon Luna Smith, one daughter, Laura Ashley Smith, age 9, in third grade. My wife is a registered nurse at a local hospital. I operate a business in web sites and domain names at www.internetpagepublishing.com.

Sincerely,
Barry

Santokh Singh Maan

Born 10-8-1944 in Agra, India.
Schooling in Singapore.
Flying training in 1964, AST, Perth, Scotland.

Co-pilot 1966 - 1971 Malaysia Singapore Airlines
1966 DC3, F27
1967 De Havilland Comet 4
1968 - 1971 Boeing 707

Captain 1972 - 1986 Singapore Airlines
1972 F27
1973 Boeing 737 (Instructor)
1974 Boeing 707 (Instructor)

1976 - 1986 Boeing 747   (Line Instructor)

1986 Migrated to the Netherlands.
1987-1989 Programmer Diploma, HTS Amsterdam
1990 - 1994 Computer Programmer

Since then have been helping to promote Sikh thought amongst Sikh youth in the diaspora, on the Internet.
Groot Dorregeest 9
1911ND Uitgeest
Netherlands
(31) 251 654525

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:48 PM PDT
To: sterns@trial-law.com
Subject: **Aviation trial attorneys for case.**

Dear Mr. Sterns, below are excerpts of email just sent to a possible client for you involved with explosive decompression in an airliner.

Would you like to contact him?

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Commercial pilot, instrument rated, former FAA Part 135 certificate holder.

Below are the well known aviation trial attorneys that have been involved with decompression/bombing crashes over the years.

Mr. Sterns was involved with the successful efforts to show that the DC 10 cargo door explosive decompression was based on a design flaw from the manufacturer, McDonnell Douglas. He would be very aware of the dangers of explosive decompression and knows it has happened in the past leading to fatalities.

Mr. Granito and Mr. Kriendler and his son both are believers in the bomb explanation for PA 103 and probably for AI 182. The Kreindlers are very influential on the PA 103 bombing and now represent TWA 800 families.

Mr. Wolk believes in the center tank explosion for TWA 800 and unknown for AI 182.

All are experienced in aviation trial matters and could be expected to give best efforts towards a positive resolution for

All are worth checking out. I recommend Mr. Sterns. His email is below and the firm is located on the San Francisco peninsula.

Cheers,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:48 PM PDT
To: Sterns@trial-law.com
Subject: **UAL 811 AAR**

Format Revision 7/95
PB92-910402
NTSB/AAR-92/02
(SUPERSEDES NTSB/AAR-90/01)
NATIONAL
TRANSPORTATION
SAFETY
BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION--
LOSS OF CARGO DOOR IN FLIGHT
UNITED AIRLINES FLIGHT 811
BOEING 747-122, N4713U
HONOLULU, HAWAII
FEBRUARY 24, 1989
U.S. GOVERNMENT PRINTING OFFICE: 1989 0-942-365
NTSB/AAR-92/02 PB92-910402
NATIONAL TRANSPORTATION
SAFETY BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989
Adopted: March 18, 1992 Notation 5059C
Abstract: This report explains the explosive decompression resulting from the loss of a cargo door in flight on United Airlines

flight 811, a Boeing 747-122, near Honolulu, Hawaii, on February 24, 1989. The safety issues discussed in the report are the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, and emergency response. Recommendations concerning these issues were made to the Federal Aviation Administration, the State of Hawaii, and the U.S. Department of Defense.

CONTENTS

EXECUTIVE SUMMARY

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.

The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.

A year after the accident, the Safety Board was uncertain that the cargo door would be located and recovered from the Pacific Ocean. The Safety Board decided to proceed with a final report based on the available evidence without the benefit of an actual examination of the door mechanism. The original report was adopted by the Safety Board on April 16, 1990, as NTSB/AAR-90/01.

Subsequently, on July 22, 1990, a search and recovery operation was begun by the U.S. Navy with the cost shared by the Safety Board, the Federal Aviation Administration, Boeing Aircraft Company, and United Airlines. The search and recovery effort

was supported by Navy radar data on the separated cargo door, underwater sonar equipment, and a manned submersible vehicle. The effort was successful, and the cargo door was recovered in two pieces from the ocean floor at a depth of 14,200 feet on September 26 and October 1, 1990.

Before the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.

Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.

The issues in this investigation centered around the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff.

Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

As a result of this investigation, the Safety Board issued safety recommendations concerning cargo doors and other nonplug doors on pressurized transport category airplanes, cabin safety, and emergency response.

NATIONAL TRANSPORTATION SAFETY BOAR

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989

1. FACTUAL INFORMATION

1.1 History of the Flight

On February 24, 1989, United Airlines (UAL) flight 811, a Boeing 747-122 (B-747), N4713U, was being operated as a regularly scheduled flight from Los Angeles, California (LAX) to Sydney, Australia (SYD), with intermediate stops in Honolulu, Hawaii (HNL) and Auckland, New Zealand (AKL).

The flightcrew assigned to the LAX/HNL route segment reported no difficulty during their flight.

A flightcrew change occurred when flight 811 arrived at HNL. The oncoming captain stated that he and his crew reported to UAL operations 1 hour and 15 minutes prior to the flight's scheduled departure time from HNL. The crew had completed a 34-hour layover (rest period) in HNL.

The captain reviewed the flight plan, the weather, pertinent NOTAMs, and maintenance records, and signed the Instrument

Flight Rules (IFR) clearance before boarding the airplane.

Flight 811 departed HNL gate 10 at 0133 Honolulu Standard Time (HST), 3 minutes after the scheduled departure time, with 3 flight crewmembers, 15 cabin crewmembers, and 337 passengers. The flightcrew attributed the short delay to cabin crew problems with arming the 5L cabin door emergency exit slide and the normal securing of the 2L door after a somewhat extended passenger boarding process. The second officer stated that all cabin and cargo door warning lights were out prior to the airplane's departure from the gate. He said that he dimmed the annunciator panel lights at his station while the airplane was departing the gate area.

The captain was at the controls when the flight was cleared for takeoff on HNL runway 8R at 0152:49 HST. The auxiliary power unit (APU), which was used during the takeoff, was shutdown shortly after making the initial power reduction to climb thrust. The flightcrew reported the airplane's operation to be normal during the takeoff and during the initial and intermediate segments of the climb. The flightcrew observed en route thunderstorms both visually and on the airplane's weather radar, so they requested and received clearance for a deviation to the left of course from the HNL Combined Center Radar Approach Control (CERAP). The captain elected to leave the passenger seat belt sign "on."

The flightcrew stated that the first indication of a problem occurred while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed (IAS) of 300 knots. They heard a sound, described as a "thump," which shook the airplane. They said that this sound was followed immediately by a "tremendous explosion." The airplane had experienced an explosive decompression. They said that they donned their respective oxygen masks but found no oxygen available. The airplane cabin altitude horn sounded and the flightcrew believed the passenger

oxygen masks had deployed automatically.
The captain immediately initiated an emergency descent, turned 180(to the left to avoid a thunderstorm, and proceeded toward HNL. The first officer informed CERAP that the airplane was in an emergency descent and appeared to have lost power in the No. 3 engine. The appropriate 7700 emergency code was placed in the airplane's radar beacon transponder and an emergency was declared with CERAP at approximately 0220 HST. The No. 3 engine was shut down shortly after commencing the descent because of heavy vibration, no N1 compressor indication, low exhaust gas temperature (EGT), and low engine pressure ratio (EPR).
The second officer then left the cockpit to inspect the cabin area and returned to inform the captain that a large portion of the forward right side of the cabin fuselage was missing. The captain subsequently shut down the No. 4 engine because of high EGT and no N1 compressor indication, accompanied by visible flashes of fire. The flightcrew initiated fuel dumping during the descent to reduce the airplane landing weight.
The airplane was cleared for an approach to HNL runway 8L. The final approach was flown at 190 to 200 knots with the No. 1 and No. 2 engines only. During flap extension, the flightcrew observed an indication of asymmetrical flaps as the flap position approached 5(. The flightcrew decided to extend inboard trailing edge flaps to 10(for the landing. The right outboard leading edge flaps did not extend during the flap lowering sequence. The airplane touched down on the runway, approximately 1,000 feet from the approach end, and came to a stop about 7,000 feet later. The captain applied idle reverse on the Nos. 1 and No. 2 engines and employed moderate to heavy braking to stop the airplane. At 0234 (HST), HNL tower was notified by the flightcrew that the airplane was stopped and an emergency evacuation had commenced on the runway.

After the accident, UAL ramp service personnel, who had been involved with the cargo loading and unloading of flight 811 before takeoff from HNL, stated that they had opened and closed the forward cargo door electrically. They said that they had observed no damage to the cargo door. The ramp service personnel said that they had verified that the forward cargo door was flush with the fuselage of the airplane, that the master door latch handle was stowed, and that the pressure relief doors were flush with the exterior skin of the cargo door.

The dispatch mechanic stated that, in accordance with UAL procedures, he had performed a "circle check" prior to the airplane's departure from the HNL gate. This check included verification that the cargo doors were flush with the fuselage of the airplane, that the master latch lock handles were stowed, and that the pressure relief doors were flush or within 1/2 inch of the cargo door's exterior skin. He said a flashlight was used during this inspection.

The second officer stated that, in accordance with UAL Standard Operating Procedures (SOP) he had performed an operational check of the door warning annunciator lights as part of his portion of the cockpit preparation. The second officer also stated that he used a flashlight while performing an exterior inspection, again in accordance with UAL procedures. The exterior inspection was conducted while ramp service personnel were performing cargo loading operations and the cargo doors were open. He stated that he had observed no abnormalities or damage.

1.2 Injuries to Persons

Injuries Flightcrew Cabincrew Passengers Others Serious *Lost in flight. An extensive air and sea search for the passengers was unsuccessful.

1.3 Damage to the Airplane

The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward.

Examination of all structure around the area of primary damage disclosed no evidence of preexisting cracks or corrosion. All fractures were typical of fresh overstress breaks.

Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos. 3 and 4. No damage was noted on the left side of the airplane, including engines Nos. 1 and 2.

The right wing had sustained impact damage along the leading edge between the No. 3 engine pylon and the No. 17 variable camber leading edge flap. Slight impact damage to the No. 18 leading edge flap was noted.

There was a break and scuff in the wing leading edge aft of engine No. 4 and a scuff in the wing leading edge outboard of engine No. 4. There was a large indentation (to a depth of nearly 8 inches) in the area just above the outboard landing light, and the landing light covers were broken. There was a small puncture in the upper surface of the No. 14 krueger flap and impact damage to the wing leading edge just aft of the No. 14 krueger flap. There was a gash on the upper wing surface aft of the No. 14 krueger flap and leading edge, as well as punctures to the wing leading edge aft of the number 16 krueger flap. The under wing surface aft of the krueger flaps also sustained impact damage.

The right wing also had sustained damage at the wing-to-body fairing and two flap track canoe fairings.1 Wing-to-body fairing damage was limited to surface scraping forward of and below the wing. The outboard surface of the No. 6 flap track canoe fairing revealed a slightly more significant gouge mark. The most severe damage was evident on the inboard surface of the No. 8 flap track canoe fairing, where three separate punctured areas were observed. The trailing edge flaps were not damaged.

The leading edge of the right horizontal stabilizer had several dents. The most severe dents, located 8 to 10 feet from the stabilizer root, were approximately 3 inches wide and 1 inch deep. No punctures were found. The vertical stabilizer had multiple small and elongated indentations with a maximum depth of 1/2 inch near the right base of the leading edge. A small gouge and two small scrapes were noted at midspan of the upper rudder.

A piece of cargo container was found lodged between the No. 3 engine pylon (inboard) and the wing underside. The piece of metal had severed the pneumatic duct for the leading edge flaps. Various nicks and punctures were evident on the inboard side of the No. 3 engine pylon. The No. 4 engine pylon had a small puncture near the leading edge of the wing.

The external surfaces of the No. 3 engine inlet cowl assembly exhibited foreign object damage including small tears, scuffs and a large outwardly directed hole. The entire circumference of all the acoustic (sound attenuator) panels installed on the inlet section of the cowl had been punctured, torn, or dented. None of the No. 3 engine cases were penetrated by objects, nor was there evidence of fire damage to any visible engine components and accessories. The

leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage.

External damage to the No. 4 engine inlet and core cowls was confined to the inboard side of the inlet cowl assembly. The

damage consisted of one major scuff mark, four lesser scuff marks and one crescent- shaped cut. The sound attenuator panels that were installed in the inlet area of the inlet cowl assembly had not been penetrated. The No. 4 engine fan blade airfoils had sustained both soft and hard object damage from foreign objects.
The cargo door separation resulted in the loss of fuselage shell structure above the cargo door, along with main cabin floor structure below seats 8GH through 12GH (see figure 3). The missing floor area extended inboard from the interior of the right side fuselage wall to the inboard seat track of seats 8GH through 12GH.
The supply and fill lines from the flightcrew oxygen bottle, and the supply line for the passenger oxygen system had been broken below the cabin floor inboard of the missing cargo door.
The two cabin pressurization out-flow valves, located on the underside of the fuselage, aft of the rear cargo compartment, were found fully open. The two over-pressure relief valves located on the forward left side of the airplane were found in the normal closed position. These valves were removed and bench tested. (See section 1.16.3, Pressurization System.) The majority of the cabin floor-to-cargo compartment blowout panels were found activated. The blowout panels are designed to relieve excess pressure differential following an explosive decompression to prevent catastrophic damage to the cabin floor structures.
The estimated damage to the airplane was $14,000,000, based on UAL's costs to repair it.

1.4 Other Damage

No other property damage resulted from this accident.

1.5 Personnel Information

The crew consisted of 3 flight crewmembers (the captain, the first officer, and the second officer) and 15 cabin crewmembers. (See appendix B.)

1.6 Aircraft Information

1.6.1 General

On February 24, 1989, the United Airlines B-747 fleet consisted of 31 airplanes, including: 2 B-747-222B, 11 B-747-SP, 5 B-747-123, and 13 B-747-122 series airplanes. N4713U was equipped with four Pratt & Whitney model JT9D engines.

The accident airplane, serial No. 19875, registered in the United States as N4713U, was manufactured as a Boeing 747-122 transport category airplane by the Boeing Commercial Airplane Company (Boeing), Seattle, Washington, a Division of the Boeing Company. N4713U, the 89th B-747 built by Boeing, was manufactured in accordance with Federal Aviation Administration (FAA) type certificate No. A20WE, as approved on December 30, 1969. The airplane was certificated in accordance with the provisions of 14 CFR Part 25, effective February 1, 1965. The maximum calculated takeoff weight for flight 811 was 706,000 pounds. The flight plan data showed an actual takeoff weight of 697,900 pounds. The center of gravity (CG) for takeoff was computed at 20.4 percent mean aerodynamic chord (MAC). The forward and aft CG limits were 12 and 29.7 percent MAC, respectively.

At the time of the accident, N4713U had accumulated 58,815 total flight hours and 15,028 flight cycles. N4713U had not been involved in any previous accident. Records indicated that the airplane had been inspected and maintained in accordance with the General Maintenance Program as defined in UAL Operations Specifications and in accordance with the FAA approved Aircraft and Powerplants Reliability Program. The records indicated that all required inspection and maintenance actions had been completed within specified time limits and all applicable airworthiness directives (AD) had been accomplished or were in the process of being accomplished, with the exception of AD 88-12-04, which was applicable to the B-747 lower lobe cargo door, and which had only been complied with partially. (See section 1.6.8 for explanation).

1.6.2 Cargo Door Description and Operation

Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Electrical power for operation of the cargo door switches and actuators is supplied from the ground handling bus, which is powered by either external power or the APU. See figure 17 for a diagram of the cargo door electrical circuitry. The engine generators cannot provide power to the ground handling bus. APU generator electrical power to the ground handling bus is interrupted when an engine generator is brought on line after engine start. The APU generator "field" switch can be reengaged by the flightcrew, if necessary on the ground, to power the ground handling bus. The air/ground safety relay automatically disconnects the APU generator from the ground handling bus, if it is energized, when the airplane becomes airborne and the air/ground relay senses that the airplane is off the ground.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with pull-in hook pins on the sides of the door frame. (See figure 4 for

cargo door components).
The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. Figure 5 depicts a lock sector and latch cam in an unlocked and locked condition.

Figure 4.--Boeing 747 lower lobe forward cargo door.

Figure 5.--Cargo door latch cam and lock sector in unlocked and locked ositions.

The door has three electrical actuators for opening/closing and latching of the door. One actuator (main actuator) moves the door from the fully open position to the near closed position, and vice versa. A second actuator (pull-in hook actuator) moves the pull-in hooks closed or open, and the third actuator (latch actuator) rotates the latch cams from the unlatched position to the latched position, and vice versa. The latch actuator has an internal clutch, which slips to limit the torque output of the actuator.

Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull- in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator.

The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch

lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The B-747 cargo door has eight (8) view ports located beneath the latch cams for direct viewing of the position of the cams by means of alignment stripes. Procedures for using these view ports for verifying the position of the cams were not in place or required by Boeing, the FAA, or UAL (see 1.17.5 for additional information).

Closing the door manually is accomplished through the same sequence of actions without electrical power. The door actuator mechanisms are manually driven to a closed and latched position by the use of a one-half inch socket driver. The door can also be opened manually with the use of the socket driver. There are separate socket drives for the door raising/lowering mechanism, the pull-in hooks, and the latches.

Operating procedures for the normal electrical operation of the forward and aft cargo doors are outlined in the UAL Maintenance Manual (MM). Authorization for deferral of maintenance on the door power system is contained in the UAL B-747 Minimum Equipment List (MEL). In addition, operating procedures for dispatching aircraft with an inoperative door electrical power system (manual operation) are specified in the operator's MEL.

The UAL MM differs from Boeing's recommended MM. UAL had modified Boeing printed material or replaced pages with their own methods and procedures for conducting maintenance functions. The modifications to the manufacturer's MM were accepted by the FAA through "approval" by the FAA Principal Maintenance Inspector (PMI). Electrical cargo door open/close operations in the UAL and Boeing MM's are approximately the same, except the final "Caution" statement differs in methods to ensure that the latch cams are closed:

United Airlines Maintenance Manual

CAUTION DO NOT FORCE HANDLE. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

Boeing Airplane Company Maintenance Manual

CAUTION DO NOT FORCE HANDLE. IF RESISTANCE IS FELT, CHECK LATCH ALIGNMENT STRIPES THROUGH VIEWING PORTS IN DOOR. LATCH CAMS NOT FULLY

CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

The following step in Boeing's MM does not appear in the UAL MM: "Check that the Cargo Door Warning Light on flight engineer panel goes out." The UAL flightcrew checklist includes a check of the warning light as part of the cockpit procedures for dispatch.

Prior to the issuance of AD-88-12-04 (see 1.6.8), UAL ramp service personnel only operated the cargo doors electrically. Manual operation was accomplished only by maintenance personnel. AD-88-12-04 required the additional procedure of recycling the master latch lock handle following manual operation of the latch actuator.

1.6.3 UAL Boeing 747 Special Procedures--Doors

The Safety Board's investigation revealed that UAL had published a "special maintenance procedure" in the UAL MEL for manual operation of the cargo door. The Maintenance Manual Special Procedures, 5-8-2-52, dated January 1988, were incorporated into UAL's MEL for use by maintenance controllers and work foremen in issuing instructions or procedures to mechanics. The procedure allowed the use of a special 1/2-inch socket drive wrench as the primary tool for use in manually opening or closing the cargo door. The document further authorized, as an alternate tool, an air-driven torque-limiting screwdriver. UAL procedures required approval by San Francisco Line Maintenance and the station maintenance coordinator before an air-driven screwdriver could be used to operate the doors of a B-747 airplane with an inoperative cargo door power system.

At the Safety Board's public hearing, the FAA PMI and the FAA B-747 maintenance inspector for UAL testified that prior to the accident they were unaware of an FAA authorization for UAL's use of an air-driven torque-limiting screwdriver on B-747 cargo doors. However, the FAA's approval for the use of the tool was noted in the MEL section of the airline's maintenance manual. The original approval had occurred before the current inspectors assumed their respective positions. Both testified that they had not reviewed UAL's B-747 MEL because they assumed that the previous inspectors had reviewed it.

According to UAL, the calibration/adjustment for the torque-limited air-driven screwdrivers was tested every six months. Safety Board investigators found no records for the calibration/adjustment of the power tools used to manually open and close UAL B-747 cargo doors.

The Safety Board received statements from UAL supervisory maintenance personnel at all UAL stations and contract facilities for B-747 operations indicating that air-driven screwdrivers had not been used by maintenance personnel to open or close the forward cargo door on N4713U in the months prior to the accident.

1.6.4 UAL Maintenance Program

Airplanes operated by UAL are maintained under an FAA-approved continuous airworthiness maintenance program, as required by 14 CFR Part 121, Subpart L. The requirements of the UAL maintenance program are detailed in their Operations Specifications, dated November 21, 1988. Generally, UAL has an overall in-house capability to perform virtually all of the maintenance required on its own airframes and powerplants. All of the required major airframe and powerplant maintenance for N4713U had been performed at the UAL maintenance facility in San Francisco, California.

UAL's maintenance and inspection program is scheduled either at specific flight hour or calendar intervals. These maintenance and inspection programs are designated as: Service No. 1, Service No. 2, or A, B, C, MPV, and D Checks.

The work scope of Service Checks consists of a general inspection of the airplane and engines, including servicing of consumable fluids, oxygen, and tire pressures. The Service No. 1 check involves an inspection at each maintenance facility where the airplane lands. The Service No. 2 check is performed at a maintenance facility where the airplane is scheduled for at least 12 hours of ground time. The maximum time interval between Service No. 2 Checks is not to exceed 65 flight hours.

The "A" Check is performed at intervals not to exceed 350 flight hours. This check includes an extended inspection of the cockpit, cabin, cargo compartments, landing gear, tires, and brakes. It does not include a detailed inspection of the cargo doors.

The Phase Check ("B" Check) is scheduled on a calendar basis, not to exceed 131 days. The scope of the "B" Check contains items of inspection such as interior safety equipment and functional verification of various aircraft systems and components. It does not include a detailed inspection of the cargo doors.

The "C" Check is heavy maintenance oriented and is scheduled on a calendar basis, every 13 months. The "C" Check work scope is substantial and includes:

structural inspection items;

corrosion repair;

prevention and inspection of critical flight control systems; and,

a detailed inspection of the cargo doors.

The Mid-Period Visit (MPV) Check is a heavy maintenance inspection that is scheduled at intervals not to exceed 5 years. Items requiring scheduled overhaul are contained in the check as well as inspections of the airplane structure and interior.

The D Check, completes the routine scheduled B-747 maintenance plan and is scheduled at intervals not to exceed 9 years. The work scope is very similar to the MPV Check and consists of heavy maintenance to the airplane structure, landing gear, interior, and airplane systems, including the cargo doors.

1.6.5 Maintenance Records Review

A review of the airplane's history indicated that the forward and aft cargo doors were the original doors and neither had been removed for repair or replaced for cause. There was no record of major repair to either door or adjacent airplane structure.
The forward cargo door's forward mid-span latch pin had been removed because of gouging of the pin surface, during the last "C" check on
November 28, 1988. According to the available maintenance documents, including the most recent "D" check, a full cargo door rigging check had not been accomplished. UAL maintenance personnel indicated that no rigging of the forward or aft cargo doors was required during the following checks:

1. "D" check accomplished April 1984;
2. "C" checks accomplished November 11, 1987, and November 28, 1988; and,
3. "B" checks accomplished March 21, 1988 and July 27, 1988;

The records prior to the "D" check in 1984 and the "C" check accomplished in November 1987 were not required to be retained. This procedure complies with FAR 121.380.
The logbook of N4713U was reviewed and all numbered pages were in sequential order with none missing. The airplane had been released for flight by UAL, HNL Maintenance, in accordance with UAL procedures. The Los Angeles to HNL segment of flight 811, on February 23, 1989, generated four logbook discrepancy entries. All items were cleared by HNL maintenance and none were related to the cargo door. No new deferred items were generated and no current deferred items were corrected. The Maintenance Release document for flight 811 indicated that all deferred items were in accordance with the UAL Minimum Equipment List (MEL) and none referenced the forward cargo door.
UAL stores its maintenance information in an "electronic logbook," entitled Aircraft Maintenance Information System

(AMIS). This system tracks on a daily and worldwide basis the flightcrew defect reports, all nonroutine maintenance defects, and maintenance corrective actions for the UAL airplane fleet. The system follows an Airline Transport Association (ATA) chapter format. According to UAL, the AMIS information is used as part of UAL's FAA approved maintenance reliability program affording the capability to assess trends at any given time.

A complete history of N4713U was reviewed for the following ATA Chapters:

Chapter-00-Miscellaneous

No significant items associated with the cargo door systems.

Chapter-21-Air Conditioning and Pressurization

An entry, dated August 19, 1988, indicated "Auto and Standby pressure controllers were erratic." UAL maintenance cleared this item as "Checked per Maintenance Manual Chapter (MM) 21-31-00.

Chapter-31-Instruments (Not related to any specific system)

No significant items associated with the cargo door systems.

Chapter-52-Doors (Cargo door section only)

During the period September 7, 1988, through November 1, 1988, a series of five discrepancies on the forward cargo door's electrical opening and closing system were noted. Ground handling personnel were required to operate the door by the manual system. On November 1, 1988, UAL maintenance corrective action for this discrepancy was signed off as, "replaced power unit [lift mechanism] per Maintenance Manual Chapter 52-34-02.

An expanded AMIS history of the N4713U forward cargo door system was prepared beginning December 1, 1988, and continuing until the date of the accident. The history tracked the airplane by each flight and station transited.

During the period December 5, 1988, through December 23, 1988, eight defect reports regarding the opening and closing of the forward cargo door were entered into the system. The reported defects involved problems with the cargo door not always operating with the normal electrical system. Appendix E contains the details of the writeups and corrective actions.

During the period December 23, 1988, through February 23, 1989, two forward cargo door discrepancies were noted on N4713U. On January 3, 1989, the discrepancy was, "Manual lock seals broken." The corrective action was signed off as, "recycled [door] per placard on door and documented. No door problems." On January 15, 1989, the discrepancy was, "cargo door seal, lower aft corner is torn and loose from retainer." The corrective action was "repaired seal." There were no further recorded discrepancies.

On February 23, 1989, a written discrepancy noted "Aft cargo door damaged aft lower corner." The corrective action listed, "Interim repair per (EVA) LM-8-433. Accomplish permanent repair within 60 flight hours."

Chapter-53-Structures (Fuselage)

During the period March 1988, through February 24, 1989, one defect was noted for each of the forward and aft cargo doors on N4713U.

Forward Cargo Door.--On September 6, 1988, the discrepancy was, "Approximately six inches of forward cargo door jamb damaged center of lower side sealing surface." The corrective action was, "Installed doubler and sealed area."

Aft Cargo Door.--On April 22, 1988, the discrepancy was, "Aft cargo door rear sill latch does not spring up to lock." The corrective action was, "Replaced latch."

1.6.6 Service Difficulty Report Information

A review was made of the Service Difficulty Reports (SDRs) for ATA Chapter 52 for all UAL Boeing 747 airplanes. Thirty-nine SDRs were recorded over the period January 31, 1983, through March 21, 1989. The following summarizes data concerning the

forward and aft cargo doors:
cases of corrosion;
cases of cracking;
cases of door open (false) indications;
cases where cabin did not pressurize;
cases of cabin pressure loss; and
case of dent caused by ground equipment.
None of the noted SDR cases were recorded for N4713U.

1.6.7 Service Letters and Service Bulletins

Boeing issues information to its customers via Service Letters (SL's) and Service Bulletins (SB's) to inform operators of reported and anticipated difficulties with various airplane models. Twelve SL's provided guidance for maintenance or information applicable to the B-747 cargo doors. Twenty-nine SB's provided guidance for maintenance or information applicable to the B-747 cargo door.

SB-747-52-2097, "Pressure Relief Door Shroud Installation--Lower Lobe and Side Cargo Doors," was issued on June 27, 1975. Revision 1 to SB-747-52-2097 was issued November 14, 1975. In general, the SB recommended the installation of shrouds on the inboard sides of the cargo door pressure relief door openings. The purpose of the shrouds was to prevent the possibility of the pressure relief doors being rotated (blown) to the closed position during the pressurization cycle. This condition could only occur if the master latch lock handle had been left open and the flightcrew failed to note the cargo door open warning before takeoff.

UAL records for N4713U indicated that SB-747-52-2097 had been complied with and the shrouds had been installed on the forward and aft cargo doors. However, examination of the aft cargo door on N4713U revealed that the shrouds were not in place. UAL could not find records to verify if the shrouds had been installed or if they had been removed from either door.

1.6.8 Airworthiness Directives

There had been 141 Airworthiness Directives (ADs) issued that were applicable to the accident airplane. Two ADs were pertinent to the cargo door. AD 79-17-02-R2 ("Inspection of Fore and Aft Lower Cargo Door Sill Latch Support Fittings,") required an inspection every 1,700 flight hours. The second, AD 88-12-04 ("To Insure That Inadvertent Opening Of The Lower Cargo Door Will Not Occur In Flight,") issued on May 13, 1988, required an initial one time inspection of the cargo door latch locking mechanisms within 30 days of issuance of the AD, and certain repetitive inspections until terminating action for the AD was taken.

The circumstances of a Pan American World Airways (Pan Am), Boeing 747-122 cargo door opening in flight (see 1.17.1 for details) led to the issuance of Boeing Alert Service Bulletins (ASB) 52A2206 on April 8, 1987, and 52A2209 on August 27, 1987, entitled, "Doors - Cargo Doors Lower Lobe Forward and Aft Cargo Doors, Latch Locking System Tests, Operation and Modification." Tests and investigation revealed that latch lock sectors would, in some instances, not restrain the latch cams from being driven open manually or electrically. Movement of the latch cams without first moving the lock sectors to the stowed [unlocked] position would cause bending, gouging, and breaking of the sectors. The FAA issued AD-88-12-04 to make the provisions of SB's 52A2206 and 52A2209 mandatory.

The terminating action for AD 88-12-04 called for installing steel doublers to add strength to the lock sectors to prevent the latch cams from being able to be driven to the open position manually or electrically with the sectors in the locked position. AD 88-12-04 also required that, if the door could not be operated normally (electrically), a trained and qualified mechanic was to open and close the door manually, rather than ramp service personnel. Further, the AD required an inspection of the lock sectors for damage once a cargo door was restored to electrical operation after any malfunction had required manual operation of the door. The amount of time allowed for completing the terminating action portion of AD 88-12-04 was either 18 months or 24 months, from the issue date of the AD, depending on the Boeing 747 model series. Terminating action for the AD had not been accomplished on N4713U prior to the accident, nor was it required since, for this airplane, the deadline for compliance with the terminating action was January 1990. According to UAL, N4713U was scheduled for completion of the terminating action in April 1989, when the airplane was scheduled for other heavy maintenance.

During the Safety Board's investigation it was determined that a clerical error was made by UAL personnel, while attempting to expedite the processing of an advanced copy of a Notice of Proposed Rulemaking (NPRM 87-NM-148-AD), preceding AD 88-12-04. The error involved the omission of one line of text during the typing of the document. Because of that error, the portion of the text of the NPRM (and the final text of the AD) was left out of UAL's maintenance procedures. The omitted text required an inspection of the B-747 cargo door lock sectors every time a cargo door was restored to normal (electrical) operation after manual operation was required.

The UAL maintenance internal auditing system, including quality assurance personnel, did not detect the omission until after the accident. UAL personnel stated that, for unknown reasons, no one within the maintenance or quality assurance programs had reviewed the final AD language for comparison with the UAL maintenance procedure.

A review by Safety Board investigators of forms used by UAL to verify compliance with applicable FAA AD's issued indicated that all of the applicable mandatory ADs were satisfied within their specified time limits. The list provided by UAL to the FAA as part of the FAA's oversight responsibilities showed compliance with

AD-88-12-04, with the exception of the terminating action. Section 1.17.3 contains information relevant to the B-747 cargo door corrective actions taken since the accident.

1.7 Meteorological Information

The accident occurred in night visual meteorological conditions. No adverse weather was experienced, although the flight did have to deviate around thunderstorms during the descent.

1.8 Aids to Navigation

There were no navigational problems.

1.9 Communications

There were no radio communication difficulties between flight 811 and air traffic control (ATC). Members of the flightcrew did not have any difficulty in verbally communicating with each other; however, attempts to communicate with the cabin crewmembers by interphone were unsuccessful following the explosive decompression.

1.10 Aerodrome Information

After the explosive decompression, the airplane returned to HNL, a 14 CFR Part 139 certificated airport on the island of Oahu, Hawaii. The airport is located about 4 miles west of Honolulu, Hawaii.

HNL is a "joint use" airport that is used by the State of Hawaii, the U.S. Air Force, general aviation, commercial, air carrier, air taxi, and military aircraft. Aircraft Rescue and Fire Fighting (ARFF) services are provided by State and Hickam Air Force Base ARFF units. Prior to the emergency landing at Honolulu, flight 811 requested that all available rescue and medical equipment to be on hand when they landed. When the crash alarm was broadcast, all civilian and military fire units responded and were in position in 1-minute at pre-designated stations at runway 8 left.

The Safety Board's investigation revealed that there was no direct radio communications between the State Airport vehicles and

Hickam ARFF vehicles. Because there were no direct radio communications, the Chief of the airport's units had to drive his vehicle to the vehicle of the Chief of the Hickam units to coordinate the positioning of ARFF units prior to the landing of United 811.

The Hickam vehicles are painted olive drab camouflage. During the response, the Chief of the State ARFF vehicles observed a near collision between a State and a Hickam vehicle. He attributed this to the camouflaged Hickam vehicle not being visually conspicuous in spite of the fact that each of the vehicles had a red rotating beacon operating. The response took place on a moonless night and in light rain.

1.11 Flight Recorders

The airplane was equipped with a Sundstrand model 573 digital type Flight Data Recorder (DFDR) and a Sundstrand model AV557-B Cockpit Voice Recorder (CVR).

Examination of the data plotted from the DFDR indicated that the flight was normal from liftoff to the accident. The recorder operated normally during the period. However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent.

The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.

1.12 Wreckage and Impact Information

An extensive air and surface search of the ocean conducted immediately following the accident failed to locate the portions of the airplane lost during the explosive decompression. However, the Safety Board, as well as other parties to the investigation, pursued several avenues to search for and recover the cargo door. Navy radar near Honolulu tracked debris that fell from the airplane when the cargo door was lost. Refinement of the radar data led to a probable "splashdown" point in the ocean. Further assistance from the Navy regarding the ocean currents and drift information led to a probable location of the cargo door and associated debris on the ocean floor.

The undersea search operation was begun on July 22, 1990, using the Orion, a state-of-the-art Navy side-scanning sonar "fish." Searching in the area selected by analysis of radar data and undersea currents, the Orion located a debris field on its first pass over the 14,200-foot-deep ocean floor. The second pass located a significant sonar target, which later analysis indicated was probably the cargo door. Since the Orion is only capable of searching, the debris field was marked with transponders for use during the subsequent recovery phase.

On September 14, 1990, the recovery ship Laney Chouest sailed from Pearl Harbor with the manned, deep-sea submersible Sea Cliff. Safety Board, FAA, Boeing, and UAL engineering staff assisted the recovery team aboard the Laney Chouest. After four dives in the area previously identified as the debris field, only pieces of cargo container and other small debris from the airplane had been recovered. (It appears that the significant target identified by the Orion was a piece of cargo container rather than the cargo door.) On the following dive, however, the lower portion of the cargo door was located and recovered. The fuselage structure above the cargo door was located and raised to the surface on the sixth dive, but heavy seas prevented its recovery. The upper portion of the door was recovered during the Sea Cliff's seventh dive on October 1, 1990. Afterward, it was decided that no further effort could be justified to recover the fuselage structure above the cargo door, and the recovery mission was terminated.

Following recovery of the cargo door, each piece was sprayed with a corrosion inhibitor. The ship promptly returned to Pearl Harbor, and the retrieved door portions were removed and examined before being shipped to Seattle, Washington, for detailed examinations under the supervision of Safety Board staff. Visual examinations on the recovery ship and in Pearl Harbor confirmed that the cargo door lock sectors were in the locked position and that the latch cams were in the nearly open position. Figure 6 depicts the position of the lock sectors and cams as recovered from the ocean. There was no evidence of progressive fractures in the door structure.

The cost for the search mission was $193,000, and the cost for the recovery mission was $250,000. These costs were shared by the Safety Board, the FAA, UAL, and Boeing. Section 1.16 contains information on the examination of the recovered wreckage.

1.13 Medical and Pathological Information

Appendix D contains a list of injuries.

1.14 Fire

There was no fire in the cabin or fuselage. The fires in engines No. 3 and 4 were extinguished after the engines were shut down.

1.15 Survival Aspects

The fatal injuries were the result of the explosive nature of the decompression, which swept nine of the passengers from the airplane.

At 0210, the FAA notified the U.S. Coast Guard that a United Airlines, Inc., B-747, with a possible bomb on board, had experienced an explosion and was returning to HNL. The Coast

Guard Cutter, Cape Corwin, departed Maui at 0248 to search the area for debris and the missing passengers. Ultimately, 4 shore commands, 13 surface/air units, and approximately 1,000 persons took part in the combined search and rescue (SAR) operation. The search was t™ erminated at 1200 on February 26, 1989, without recovery of any passenger bodies.

The flight attendants had approximately 20 minutes to prepare the cabin and the passengers for an imminent ocean ditching, and subsequently, for an emergency evacuation. During the 20 minutes they attended to injured flight attendants and passengers, attached the face masks to their emergency oxygen bottles, helped each other don life preservers, helped numerous passengers don life preservers, held up safety cards and life vests to call attention to these items for passengers to use, briefed "helper" passengers to assist in the evacuation, cleared debris away from the exit doors and aisles, closed the doors of the storage compartment above doors 2 left and 2 right, prepared the cabin for an emergency evacuation, and told the passengers to brace for impact.

Several problems were experienced by the flight attendants and the passengers following the decompression, while preparing for a possible ditching, and preparing for the emergency evacuation. These problems included difficulties encountered by flight attendants in connecting face masks to their portable oxygen bottles, the lack of a sufficient number of megaphones, limited visibility from a flight attendant seat, overhead storage compartment doors opening, and donning and fastening life preservers.

Federal Aviation Regulation 14 CFR 25.1447 (c)(4) requires that "portable oxygen equipment must be immediately available for each cabin attendant." Those portable oxygen bottles on N4713U, which were readily available, were not immediately usable because the masks were not attached to the regulators. The flight

attendants reported difficulties in attaching the masks to the regulators.
The aft purser ran back to the flight attendant jumpseat at door 5-left for a portable oxygen bottle. However, she found no bottle at this location (none was installed). She then ran back to the 4-left jumpseat, by which time she was "light headed." After the aft purser reached jumpseat 4-left, flight attendant No. 14, who was already sitting there, placed an oxygen mask on her face. The aft purser further stated, "considering the fact that in this case there was no other available source of oxygen, you can't imagine how horrible I felt going back there needing oxygen but finding no oxygen bottle at 5-left. It was terrifying."
A portable emergency oxygen bottle was not required to be stowed at the flight attendant seat at exit 5-right; however, one was stowed in the right coat closet behind the flight attendant seat. In addition, the left side closet and rest rooms were physically separated from the right side closet and rest rooms. This arrangement requires a flight attendant, who was seated at exit 5-left to walk around to the right side of the cabin to obtain the oxygen bottle.
Communication between the flight attendants and passengers was very difficult because of the high ambient noise level in the cabin after the decompression, even though the public address (PA) system was operational. Flight attendants were located at each of the 10 exit doors, yet there were only two megaphones required to be on the airplane; one located at door 1-left and another located a 4-left.
The flight attendants, who were responsible for each of these two doors, used the megaphones to broadcast commands to passengers in their immediate areas and to other flight attendants in preparation for the landing and subsequent evacuation. The other 13 flight attendants (including the one deadheading flight attendant) had to shout, use hand signals, and show passengers

how to prepare for the evacuation by holding up passenger safety cards, so passengers could review the information and also know how to put on their life preservers.

As soon as the decompression occurred, the flight attendant in the upper deck business class section went to her jumpseat and donned her oxygen mask, life preserver, and restraint system. While she waited for instructions, and because of intense cabin noise she had to communicate with passengers by holding up a safety card and a life preserver. Passengers sitting in the front rows, in turn, showed safety cards and life preservers to other passengers seated behind them. Eventually everyone understood that they were to read the safety card and put on their preservers. However, the 5 foot 3 1/2 inch flight attendant stated that her jumpseat was so low that she could not directly observe the passengers in the 4th row (last).

A two door overhead stowage compartment that had formerly stored a life raft was located above each exit door. These compartments contained blankets and passenger carry-on luggage. At doors 2-left and 2-right the doors of each compartment had opened downward and blocked each exit. Also the contents of the compartments fell to the floor at the exits. The doors had to be closed before the evacuation because they partially blocked the exit.

The chief purser was not able to tighten the life preserver's two straps around her waist and needed the deadheading flight attendant to tighten them for her. Several flight attendants and passengers had difficulties connecting the two straps around their waists. One flight attendant helped about 36 passengers don their preservers.

Safety Board investigators and United Airlines personnel examined several life preservers from each of the types of preservers produced by five manufacturers. The strap of one manufacturer's preserver was very difficult to tighten around the waist while another from the same manufacturer was easy to tighten. The two vests had different strap material and strap adjustment fittings. Also, the straps are very difficult, if not impossible, to tighten when they are pulled at an acute angle from the wearer's body, i.e. from about 45 to 70 degrees. Holding the hands and straps closer to the waist facilitates easier adjustment of the straps.

1.16 Tests and Research

1.16.1 Cargo Door Hardware Examinations

1.16.1.1 Before Recovery of the Door

The following forward cargo door closing and latching components were returned to the Safety Board's Materials Laboratory for analysis after they were documented in place on the airplane:

Two pull-in hook pins, one from the lower end of the forward side of the door body cutout forward frame, and one from the lower end of the aft side of the body cutout aft frame, with housings;

Two mid-span pins, one from the forward side of the door body cutout forward frame, and one from the aft side of the door body cutout aft frame.

All components were initially examined while installed on the airplane. All eight forward cargo door latch pins, with housings, were removed for further laboratory examination. Also, for comparison, one of the latch pins, with housing, from the aft cargo door was also removed. For orientation purposes, the eight lower latch pin assemblies are referred to by number, with the No. 1 latch pin being the most forward on the lower door sill, and the No. 8 pin being the most aft. When referencing a circumferential location on the latch pins or mid-span pins, a clock position was used. The clock code was oriented looking forward with 12 o'clock being straight up and 9 o'clock being directly inboard.

Based on the orientation of the latching mechanisms, the fully unlatched latching cams would first contact the latch pins from about the 1:15 o'clock position to the 7:15 position as the door was closed. As the cams are being latched around the pins, they would rotate approximately 80(, making contact with the pins from about the 4:15 position to the 10:15 position (See figure 7). Detailed examination of the exposed surface of the pins (the portion of the pins extending from the housings) revealed various types of wear and damage. In general, all of the forward door cargo latch pins had smooth wear over the entire portion of the pin area contacted by the cams during normal closing and opening of the door. The pins also had distinct roughened (smeared) areas between the 6:15 and the 7:30 positions (See figure 8). The roughened areas had evidence of "heat tinting" and transfer of cam material to the surface of the pins. On pins 1 and 8 the roughened areas extended past the pin bottom to the 5:00 position. The 7:30 position approximately corresponds to the area on the pin where the lower surface of the cam would be relative to the pin when the latch cams are in the unlatched or nearly unlatched position.

The forward pull-in hook pin was not significantly bent, but the structure to which it was attached was deformed outward, so the hook pin was deflected significantly outward. Three of the four bolts holding the aft pull-in hook pin had sheared, so the hook pin was also deflected outward. Both hook pin ends were damaged, but neither pin was significantly deformed along its length. There was significant heat tinting on the damaged area of the forward hook pin. Boeing engineering calculations determined that the pull-in hook pins would fail at a 3.5 psi differential cabin pressure with the latch cams unlatched.

The forward mid-span latch pin was relatively undamaged. The aft mid-span latch pin had definite areas of damage. Both pins had wear areas where the cams would contact the pins during latching.

1.16.1.2 After Recovery of the Door

The documentation of the recovered cargo door was divided into four areas: 1) door structure, 2) master latch lock system, 3) latch system, and 4) hook system. A description of the recovered door follows.

1. Door Structure:

The cargo door had fractured longitudinally near the mid-span lap joint near stringer 34R, just beneath the mid-span torque tubes. Except for an area of missing skin between frames 2 and 3 and a portion of frame webs where the upper latch lock torque tube had torn out, the frames and skin of the upper door piece mated to the lower door piece.2 Several areas of the upper door skin along the longitudinal fracture were bent back. In addition, a large area of lower door skin between frame 6 and the aft door edge had peeled downward from the fracture line. The two door pieces are shown together in Figures 9 and 10.

Examinations of the fracture surfaces of the skin and frames revealed no evidence of pre-existing cracks. All fractures were typical of overstress separation.

Seven of the eight lock sector slots in the lower beam showed evidence of contact and scraping by the lock sectors. Only the No. 1 lock sector slot was undamaged, although the bracket forward and above the No. 1 slot did appear to have been damaged by contact from the lock sector (slots numbered 1-8, forward-aft). The direction of the scraping on the slots could not be determined conclusively.

The decal covering the latch actuator manual drive port was found broken circumferentially around the edge of the port cover, which was loose and rotated from its normal position (See figure 11). There was an impression in the decal similar to a Phillips-head screw slot in line with the center of the retainer screw securing the cover. There was also a 0.06-inch-long linear slit from

10 to 4 o'clock approximately centered over the retainer screw head (See figures 12 and 13). There was no rotational tearing and no loss of decal material in the area covering the screw head location. During examinations of the door at Boeing, it was noted that the retainer bracket on the inside of the latch actuator manual drive port cover was bowed outward; the port cover was not deformed. The retainer bracket on the inside of the hook actuator manual drive port cover was similarly bowed outward, and the port cover was bowed outward.

The hinge that attaches the cargo door to the fuselage is comprised of several hinge sections--those attached along the upper edge of the cargo door and those along the fuselage just above the cargo door cutout--interconnected with hinge pins. The hinge pins and all hinge sections from N4713U's forward cargo door were intact; all hinge sections rotated relatively easily. All attach bolts from the hinge sections on the door remained attached; conversely, no bolts remained attached to the hinge sections on the fuselage. Several areas on the hinge sections, such as the fuselage hinge sections, showed evidence of contact from the door during overtravel (See figure 14). In addition, the fuselage forward hinge sections

were slightly bent. The upper flange of the door, to which the door hinges are attached, was not deformed. The forward cargo door can rotate open 143 degrees before the hinge would deform, permitting the door to contact the fuselage above.

Examination of the outer skin contour of the upper door piece revealed that it had been crushed inward. There were also many areas on the outer skin where blue and red paint transfer marks could be seen. These marks were generally forward of the aft pressure-relief door, and the blue marks were located above the red marks. The UAL paint pattern incorporates red and blue stripes along the fuselage above the cargo door. Figure 15 is a plot of the documented paint marks on the upper door piece.

There was no evidence of the pressure relief door shrouds found on the forward door; however, most of the inner door lining to which the shrouds attach was missing.

2. Master Latch Lock System:

All eight lock sectors were found in the locked position--actually past the fully locked position. They had been pulled through the lock sector slots in the lower beam of the cargo door. (When they are fully locked, the lock sectors should be recessed in the lower beam approximately 3/8 inch). All lock sectors had deflected off the high shoulder of the latch cams due to interference with the partially unlatched cams. Prior to disassembly of the components, the interference between the cams and the lock sectors was removed by rotating the cams to the latched position.

Examination of the lock sectors disclosed that the bottom of the lower arm of each lock sector was gouged. For seven of the eight lock sectors, the distance from the main gouge area to the location of the interference between the latch cam and the lock sector was approximately 0.75 inch. (The No. 2 lock sector was corroded and had fractured at the location of the large gouge common to the other seven lock sectors. Consequently, it was not in contact with the No. 2 latch cam when the door was retrieved).

The master latch lock handle housing and trigger were found relatively flush with the door outer skin. The top of the handle was recessed approximately 0.50 inch inward from flush, and the bottom of the handle was protruding approximately 0.40 inch outward from flush (See figure 16). This

Figure 15.--Documented paint marks on outer skin of upper door piece. Dashed line is approximately 8 degrees from horizontal.

position of the handle indicates that the lock sectors were in a position past fully locked. The fuse pin was found in three pieces but was heavily corroded. The handle housing was undamaged. Two of the three connecting rods between the master latch lock handle and the lock sector torque tube were bowed slightly, but they were otherwise intact. No deformation was observed on any section of the lock sector torque tube, although one of the six bearings assembled on the torque tube had been damaged. The No. 3 bearing inner race and its torque tube locator sleeve were displaced forward approximately 0.20 inch from the bearing housing centerline. The outer race was broken and pushed forward out of the housing.

The lower two connecting rods between the lock sector torque tube and the torque tube below the pressure-relief doors were undamaged; however, the upper connecting rod had separated at the upper, tapered end. The torque tube below the pressure-relief doors were missing, and the pressure-relief door connecting rods had separated at the lower, tapered end. The remaining portion of each rod was undamaged, but the forward pressure-relief door was jammed open into the cutout.

3. Latch System:

All eight lower latch cams were found in a nearly unlatched position, and all of them were binding against the lock sectors except the No. 2 cam (lock sector No. 2 had broken). Latch cams 1-6 were approximately 62 degrees from the fully latched position, and cams 7 and 8 were approximately 70 degrees from fully latched. Full rotation of the latch cams is 80 degrees.

Several of the lower latch cams contained compression and smearing damage on the lower lip of the latch cam cavity ("lower" relative to an open cam). This damage is consistent with the forceful movement of the cams across the latch pins.

The four rods between the latch actuator torque tube and the four bellcranks containing the latch cams were attached and undamaged. No section of the latch actuator torque tube was damaged, and the bearings/supports along the tube were intact. The latch actuator was removed and later disassembled. No anomalies were found.

4. Pull-in Hook System:

The forward and aft pull-in hooks were found near the closed position. Both of them exhibited wear patterns consistent with contact with the pull-in hook pins during door operation. For both the forward and aft hooks, the inboard edge of the pull-in hook channel contained compression and smearing damage consistent with a forceful movement of the hooks over the pins while the hooks were in the closed or nearly closed position.

1.16.2 Forward Cargo Door Electrical Component Examinations

1.16.2.1 Before Recovery of the Door

Several electrical components associated with the operation of the forward cargo door were examined on the airplane and were then removed for further testing. These components included the No. 2 ground handling power bus relay, the air/ground safety relay, the No. 1 auxiliary power circuit breaker, and the outside and inside door control switches. All of these components were tested for both single faults and intermittent failures. The test results showed that all of the switches/relays were functional, although a loose wire connection was found on the outside door control switch. This loose wire connection showed evidence of overheated insulation on the two terminal lugs that attach to terminal No. 5, and there was evidence of a burn (arc point) on the top of the screw head for terminal No. 5. Terminal No. 5 is associated with power for the door "close" cycle, and not the door "open" cycle.

An electrical continuity check was performed on the cockpit cargo door warning light system components that remained with the airplane. This check confirmed the integrity of the circuit from the door area to the cockpit. The examination of the two bulbs that comprise the forward cargo door warning light revealed that one bulb was inoperative. The other bulb, which is in parallel with the inoperative bulb, was found operative. The illumination of the display legend, which reads "FWD CARGO DR" on the flight engineer's panel, was discernible with one bulb inoperative. A functional check of the circuit, which allows the cockpit warning lights to be dimmed during night operations, was also performed. The check consisted of removing the card containing this circuit and installing it in another B-747. The test was satisfactory in that the dim/bright circuit functioned properly.

1.16.2.2 After Recovery of the Door

Switches--General

The cargo door was recovered with all of its position sensing switches installed in their proper locations. The electrical junction box was found attached to the door but damaged. The switches recovered and examined were: S2 Master Latch Lock; S3 Door Warning; S4 Latch Close; S5 Hook Position; S6 Fwd Mid-Span Latch Open; S7 Door Close; S8 Hook Close; and S9 Aft Mid-Span Latch Open. Figure 17 provides a diagram of the cargo door's electrical circuitry.

Five of the eight position-sensing switches installed on the door had evidence of external damage to the switch housing. The damage on four switches (S2,S3,S4,S8) consisted of primarily compression dimpling on the housing. The S5 switch exhibited mechanical impact damage on the switch housing and mounting bracket. The striker assembly for switch S8 was loose (2 of 3 rivet fasteners sheared). The electrical wiring recovered with the door exhibited signs of tensile separation from overload at all failure points examined.

Each switch was photographed and its installed position was documented. Electrical continuity readings were taken with an ohmmeter across the poles of each switch at the first point of wire separation as found on the door. After the readings were recorded, all switches were removed from the door so that photographs and x-rays of each switch could be taken. Electrical continuity readings were retaken.

Disassembly of each switch consisted of: (1) drilling two holes in the switch housing to release trapped water from the switch (2) cutting a small window in the switch housing to examine the internal basic switches (3) removing the housing, (4) removing the internal bracket, and (5) removing basic switch covers.

During the drilling step, water was released from every switch when the holes were drilled in the switch housing. The water was filtered into a glass container. The quantity was not measured but appeared to be less than 5 mL. The residue from the filtered water trapped on the filter media had a blue-green color.

After the switch housing was removed, an ohmmeter was connected across the 1-2 poles of the switches that would not transfer electrical continuity (S2,S3,S4,S6,S7) when actuated. The rivets were then drilled out of the internal bracket. After the last of the two rivets were drilled out, the switch contacts

Figure 17b.--Diagram of cargo door electrical circuitry.

transferred to the other pole on S2, S3, and S4. On S6, the used3 basic switch was held closed by its plunger. S7 transferred after the switch housing and water inside were removed.

During removal of the basic switch covers, a trend was noted in the discoloration of some of the basic switches. The used switch had a reddish-brown coloration. The unused switch was not discolored.

Each switch was found to be wired correctly to its poles and through its contacts within the basic switches. All contacts operated with light finger pressure after removal of the basic switch covers. There was no evidence of pitting, excessive corrosion, or heat distress in the contacts of any of the switches.

The following sections detail pertinent observations concerning each switch.

The S2 master latch lock is given particular significance because of its function to protect against inadvertent door operation and is thus described in more detail. It is a single-pole double-throw (SPDT) switch used to sense the unlocked position of the door lock sectors. The switch is mounted in the aft lower corner of the door. A bracket attached to the No. 7 lock sector depresses the switch when the door lock sectors are rotated to their unlocked position. When the bracket attached to the lock sector contacts the switch plunger and depresses it, the circuit path through the switch is closed and 28VDC electrical control power to the door is established. When the force on the plunger is relaxed, the circuit is opened and 28VDC electrical control circuit is removed.

The wires leading to the S2 switch had been cut by the team after the recovery in an attempt to test continuity through the switch. The door recovery team reported that it found continuity through the 1-3 contacts but not through the 1-2 contacts. The switch plunger was actuated by the recovery team. The recovery team noted that the switch did not transfer continuity during these tests. The operation of the switch plunger would normally transfer continuity. Subsequent detailed examination of the S2 switch confirmed the findings of the recovery team.

The area around the upper face of the internal bracket was bent toward the basic switches and had evidence of corrosion residue. The bracket was found broken. The switch contacts transferred from the 1-3 actuated position to the 1-2 nonactuated position when the bracket was removed. Scanning electron microscope examination of the fracture surfaces revealed evidence of overload and corrosion.

The external switch housing was dented. The final examination performed on the switch consisted of removing the plastic covers on the basic switches. Prior to removal of the basic switch covers, it was noted that the cover to the used basic switch was cracked. The contacts functioned normally when exercised by light finger pressure.

Microscopic examination revealed a black discoloration near one of the lower contact posts of the used basic switch. Energy dispersive spectrometric examination of the residue disclosed the presence of gold, iron, magnesium, sodium, and chlorine. No mechanical or electrical anomalies were detected with the basic switch contacts.

Additional testing was performed by Boeing on switches of a similar design to those used on the accident airplane's cargo door. The testing was conducted to identify conditions that would result from salt water immersion at a pressure depth of 14,200 feet for 18 months. The testing verified that external damage to the switch housing occurred at pressure depths of 7,000 feet and greater. Switch seal leakage and subsequent internal corrosion was also noted. None of the testing performed by Boeing duplicated internal switch damage that caused basic switch contact closure or internal damage to the switch support bracket.

Wiring:

The electrical wiring recovered with the cargo door was documented in place before being removed for further tests. About 40 percent or 112 feet of wire from the original length of approximately 274 feet was recovered and examined. Of this amount, about 46 feet of wire installed in the aircraft forward of the cargo door was not examined. Most of the wires leading from the door to the fuselage were not recovered. There was no visible external evidence of burning, arcing, or heat distress in any of the wires removed. Several areas of wire insulation damage were found.

Thirty five wires were identified that could provide a possible short circuit path that could drive the latch actuator open with or without failures of other door electrical components if the ground handling bus was energized. The wires were schematically coded by function. Wires coded (-..-..-) were denoted for wiring that provides open command logic to the latch actuator. Wires coded (--.--.--.) were denoted for additional wiring enabled by an activated (failed) S2 switch. Wires coded (-o-o-o-o) were denoted for wiring providing 28VDC power from the C285 circuit.

Potential short circuit paths were identified for the cargo door that could provide 28VDC to the latch actuator control circuit relay. These potential short circuit paths can cause the latch actuator to drive the latches toward their open position if 115VAC power is available to the latch actuator motor. The potential short circuit paths include two bare wires shorting against each other, bare wire-to-metal structure-to-bare wire contact, wire to conductive fluid (such as water) to wire, or a combination of the aforementioned.

Conductive contact of (-o-o-o-o) or (--.--.--) coded wire with (-..-..-) coded wire could potentially result in providing a 28VDC circuit path to the latch actuator open circuit. Direct wire-to-wire paths are coded in Figure 17 as defined above. The two-wire short circuit paths are identified as wire pairs consisting of wire 101-20 shorting with any of the following wires; 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

If the S2 master latch lock switch fails in the "Not Locked" position, there are additional wire pairs that provide short circuit paths. These are coded in Figure 17 as (--.--.--) to (-..-..-..) wire pairs.

Short Circuit Wire Damage Simulation Tests:

Tests were conducted by Boeing and United to simulate typical examples of bare wire short circuiting to determine the extent of visible wire damage that would be expected in the 28VDC cargo door control circuit.

United performed tests on BMS 13-42 wire, the wire type used in the B-747 cargo door control circuit. Visible electrical short circuit damage on bare BMS 13-42 wire surfaces was difficult to create at 28VDC. Surface damage was considered visible when detected by microscopic examination at 15X magnification. United testing simulated the relay coil resistance variations that would be found during typical in-service conditions. A current of 1.0 A at 28VDC created visible surface damage on momentary bare wire-to-bare wire contact. Multiple contacts at 1.0 A provided a more positive indication. A single momentary contact between two bare BMS 13-42 wires with 0.160 A at 28VDC did not create visible surface damage. Contact between a BMS 13-42 bare wire and Alclad 2024-T3 metal (airplane and cargo door structure) with 0.160A at 28VDC did not create visible surface damage. Boeing performed wire tests on BMS 13-48 20 gauge wire. The test setup used the MS27418-2B door latch actuator control relay in parallel with the 60B00311-2 door restraint solenoid, the actual electrical loads used in the B-747 cargo door latch actuator control circuit. A single momentary contact of a bare 28VDC power wire, with a bare wire connecting to the relay of the solenoid, showed small pithead area developed at the point of wire contact that was visible without magnification.

Wire Examination Procedure:

All of the recovered wires were examined in the Safety Board's Materials Laboratory on a mylar sheet to simulate their installed positions. Labels were used to identify the coded wires using the manufacturer's original wire identification numbers imprinted on each wire's insulation. Wire pairs for direct electrical short circuiting were located in two common wire bundles installed on the cargo door. One common wire bundle was associated with the P3 plug connector, the other with the P4 plug junction box. The wire bundles were examined visually for areas of obvious insulation damage. Each individual wire was also examined with a stereo-microscope. Representative wire damage features were photographed.

Wire Damage Found:

Seven wires numbered 101-20, 102-20, 105-20, 107-20, 108-20, 122-20, and 135-20 had visible damage located near a 3.8 inch position as measured from the P3 plug pin tips. This common position on the wire corresponds to a 360-degree loop in the wire bundle, which is located immediately below the junction box.

Figures 18 and 19 show typical wire damage. Wire 122-20 had an open insulation area approximately 0.25 inch long. The other four wires had flattened insulation damage areas.

In the P4 plug connector wire bundle, three wires displayed insulation damage. Wires 113-20, 121-20, and 124-20 had transverse insulation nicks, which exposed bare conductors. All three had insulation nicks 3 inches from the P4 plug pin tips; wires 121-20 and 124-20 had additional insulation nicks 34 inches from the plug pin tips. The two P4 insulation damage locations corresponded to wire bundle clamp positions.

1.16.3 Pressurization System

The pressure relief valves located on the left side of the fuselage in the forward cargo compartment were removed from the airplane and subjected to bench tests at the UAL maintenance facility in San Francisco, California. No significant anomalies were discovered and both valves performed within specified tolerances.

1.16.4 General Inspection of Other UAL Airplanes

During the on-scene phase of the investigation, the Safety Board investigators examined six other B-747 airplanes while they were on the ground at HNL (four UAL airplanes and two operated by other carriers) to observe routine cargo door operations and to assess the condition of latching components. Generally, the door operations were normal. During the examination of latch pins on these airplanes, it was noted that most had a smooth wear ridge at the 9:00 position (looking forward) or were undamaged. All wear areas on the pins were smooth.

During electrical operation of the aft cargo door on one of the other UAL B-747 airplanes (N4718U), the pull-in hooks did not pull the door fully closed and the latch cams completed the closure. During operation of the latch cams, the bottom of the door moved, first circumferentially downward and then inboard. This additional movement was approximately 1/4 inch. A definite "thunking" noise was discernible as the door moved to its closed position at the end of cam rotation. On one occasion, the door would not open under electrical power. The door was "kicked" by a UAL mechanic, power was reapplied, and the door opened properly. Examination of the door by UAL mechanics, disclosed that the riveted plate holding the aft pull-in hook switch striker was loose.

All eight lower latch pins for the forward cargo door on N4718U exhibited a smooth ridge near the 9:00 position. Pins No. 1 and 2 also showed a smooth ridge at the 6:30 position with a smooth wear area between the 6:30 and 9:00 position. The forward and aft midspan cams of both forward and aft cargo doors had a heavy gouge mark corresponding to the end of the midspan latch pin. N4718U was subsequently removed from service for repair of the aft cargo door latching mechanisms.

1.17 Additional Information

1.17.1 Previous Cargo Door Incident

On March 10, 1987, a Pan American Airways B-747-122, N740PA, operating as flight 125 from London to New York, experienced an incident involving the forward cargo door. According to Pan Am and Boeing officials who investigated this incident, the flightcrew experienced pressurization problems as the airplane was climbing through about 20,000 feet. The crew began a descent and the pressurization problem ceased about 15,000 feet. The crew began to climb again, but about 20,000 feet, the cabin altitude began to rise rapidly again. The flight returned to London.

When the airplane was examined on the ground, the forward cargo door was found open about 1 1/2 inches along the bottom with the latch cams unlatched and the master latch lock handle closed. The cockpit cargo door warning light was off.

According to the persons who examined the airplane, the cargo door had been closed manually and the manual master latch lock handle was stowed, in turn closing the pressure relief doors and extinguishing the cockpit cargo door warning light. Subsequent investigation on N740PA revealed that the latch lock sectors had been damaged and would not restrain the latch cams from being driven open electrically or manually. It was concluded by Boeing and Pan Am that the ground service person who closed the cargo door apparently had back-driven (opened) the latches manually after the door had been closed and locked. The damage to the sectors, and the absence of other mechanical or electrical failures supported this conclusion.

Further testing of the door components from N740PA and attempts to recreate the events that led to the door opening in flight revealed that the lock sectors, even in their damaged condition, prevented the master latch lock handle from being stowed, until the latch cams had been rotated to within 20 turns (using the manual 1/2 inch socket drive) of being fully closed. A full cycle, from closed to open, is about 95 turns with the manual drive system.

1.17.2 FAA Surveillance of UAL Maintenance

The Denver, Colorado, FAA Flight Standards District Office (FSDO) holds the operating certificate for United Airlines, Inc. The FAA FSDO in San

Francisco, California, has the primary surveillance and oversight responsibility for UAL maintenance.

The FAA's PMI has the responsibility to oversee an airline's compliance with Federal Regulations with respect to maintenance, preventive maintenance, and alteration programs. The PMI determines the need for, and then establishes work programs for, surveillance and inspection of the airline to assure adherence to the applicable regulations. A portion of the PMIs position description reads as follows:

Provides guidance to the assigned air carrier in the development of required maintenance manuals and recordkeeping systems. Reviews and determines adequacy of manuals associated with

the air carrier's maintenance programs and revisions thereto.
Assures that manuals and revisions comply with regulatory requirements, prescribe safe practices, and furnish clear and specific instructions governing maintenance programs. Approves operations specifications and amendments thereto.
Determines if overhaul and inspection time limitations warrant revision.
Determines if the air carrier's training program meets the requirements of the FARs, is compatible with the maintenance program, is properly organized and effectively conducted, and results in trained and competent personnel.
Directs the inspection and surveillance of the air carrier's continuous airworthiness maintenance program. Monitors all phases of the air carrier's maintenance operation, including the following: maintenance, engineering, quality control, production control, training, and reliability programs.
At the Safety Board's public hearing on this accident, the PMI for United Airlines at the time of the flight 811 accident stated that he was trained as an FAA air carrier inspector and had been assigned to United Airlines since November 25, 1985. In addition to attending the normal FAA indoctrination course, he had received training in accident investigation, compliance enforcement, nondestructive testing, enforcement, and composite materials. To qualify for the position of PMI, he had completed a 3-week management training course at Lawton, Oklahoma. This was supplemented by a 2-week course on management training systems.

According to the PMI, FAA surveillance of UAL B-747 maintenance activities was organized around the daily work schedule of the FAA air safety inspector, specifically assigned to the UAL B-747 fleet by the PMI. The schedule for surveillance is normally prepared a year in advance by the FAA computerized Work Planning Management System (WPMS). Each FAA inspector is assigned specific responsibilities in the surveillance and monitoring of the airplane fleet to which he is assigned.

The PMI stated that assigned inspectors conducted surveillance of the UAL airplanes while they were in light or heavy maintenance and when they were released to service or in the process of preparing for a flight. Postflight surveillance was also performed. He said, as a routine, the inspectors visually inspected the airplanes and reviewed the airplane log records either during en route checks, while in flight, or upon termination of various flights. He said that inspectors conduct spot ramp inspections; however, they do not routinely observe ramp service operations as part of the surveillance program.

He said that FAA inspectors are not required to inspect the airplanes, but merely are to observe ramp service activities. Deficiencies or malfunctions were to be noted. The assigned inspector or the PMI would then report these observations to the UAL quality assurance liaison person or directly to UAL management.

The PMI stated that the FAA had conducted five special surveillance inspections of UAL in the previous 3 years and 5 months. The last special inspection, an MEL Survey Inspection, was completed in 1988. That inspection primarily addressed how many deferred maintenance items were being carried or deferred on each aircraft during a specified time period.

The PMI stated that his office does not approve the method by which the carrier complies with an AD, unless specified in the AD. However, a scheduled surveillance method was in place to review the carrier's AD compliance process and the ADs applicable to certain fleets. Each assigned inspector had a schedule for performing this oversight in his work program. The PMI or his staff review a monthly report from the carrier listing ADs applicable to a particular fleet and their compliance. The FAA's surveillance of the carrier's AD compliance process involved a review of this list, not actual shop visits to verify compliance.

The inspector assigned to the UAL B-747 fleet stated that approximately 30 percent of his time was spent on actual ramp maintenance surveillance. Other activities included: en route inspections, station inspections, meetings, classes and administrative paper work. Spot ramp inspections were scheduled as a normal routine, as well as by mandate in a particular AD.

The PMI stated that foreign contract maintenance bases were inspected once a year at a minimum. The PMI had the prerogative to use geographical surveillance inspectors (inspectors from other FAA offices), or inspectors from his office more familiar with UAL maintenance procedures to conduct inspections or investigations.

The PMI and the B-747 maintenance inspector assigned to UAL testified that, prior to this accident, they were not aware of any problems involving the operation of B-747 cargo doors, including the problems reported with N4713U during December 1988. The PMI testified that he could always use more inspectors to "conduct more in-depth surveillance and monitor UAL's fleet more adequately."

The extensive documentation of maintenance performed on UAL B-747 airplanes was forwarded to the PMI's official library by US mail. The data were ultimately channeled to the B-747 maintenance inspector. The PMI and maintenance inspector testified that the voluminous paperwork and work schedules precluded their monitoring the information to determine trends on problem areas.

1.17.3 Corrective Actions

On March 31, 1989, the FAA issued telegraphic (AD) ADT 89-05-54. This AD superseded AD 88-12-04 and required certain procedures to be accomplished when operating the cargo doors.

These included: confidence checks of the door mechanical and electrical systems, inspections of the door locking mechanisms, and repairs if necessary. The AD also accelerated the schedule for terminating action to place steel doublers on the latch lock sectors, and it reinstituted the procedures for using the eight view ports to verify the position of the latch cams, after the door is latched and locked.

The FAA, in conjunction with the Air Transport Association, the manufacturers, and other interested parties, are collectively working to address the human factor issues in the readability and understandability of ADs and SBs by line maintenance personnel. They are also reviewing the entire range of design, maintenance, and operation of outward opening doors to develop advisory information for pertinent parties.

FAA representatives stated at the Safety Board's public hearing that the FAA is increasing their operations and airworthiness inspector staffing by approximately 1,000 new hires in the next 3 fiscal years.

The PMI for UAL at the time of the accident stated at the Safety Board's public hearing that, as a result of the accident, "we have intensified our surveillance on the cargo door activities to the point where the assigned inspectors and inspectors who are not assigned to that particular fleet, 747s, are doing night surveillance, early morning surveillance, and we have intensified our surveillance on the cargo door in watching the operation of the cargo door to comply with the Airworthiness Directive."

On August 23, 1989, the Safety Board issued three safety recommendations (A-89-92 through -94) to the FAA. The recommendations urged the FAA to:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during

mechanical or electrical operation of the latch cams.
Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently.
Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions.
Section 4.0 contains the FAA's response to the recommendations and the status of the followup actions.
On October 12, 1989, the FAA issued NPRM 89-NM-148-AD, which proposed the amendment of ADT-89-05-54. The proposed revisions would require modification of the warning systems for the forward and aft cargo door, and the main deck cargo door, if installed. The modifications would provide visual warnings to flightcrew and ground crew when the doors are not fully closed, the latch cams are not rotated to the closed position, or the lock sectors are not in the locked position. Further, the source for the warning signal would monitor the position of the latch cams. Public comments for the NPRM were due by December 27, 1989.
Boeing has completed tests that have verified the integrity of the upgraded latch lock sectors to prove that the latch cams cannot be back-driven through the lock sectors mechanically or electrically. Boeing also has been conducting tests on the B-747 cargo door to evaluate the effects of unrepaired damage and abuse on the latch/lock system. The tests, which determined the allowable damage limits on the latch lock system and mechanism support structures, were completed in March 1990. Additionally, Boeing conducted tests to evaluate any unlatching tendencies under cabin pressure loads. These tests were completed in November

1990 and included the measurement of loads in the latch system as the latch cams are rotated incrementally from the fully latched position to the unlatched position under pressurization loads. The first series of tests included electrical backdriving of the latch cams into the lock sectors (both steel and steel reinforced were tested) with a modified latch actuator (the maximum output torque of the modified latch actuator was roughly twice that of a normal, torque-limiting latch actuator.) During these tests, the maximum cam rotation was 22.2 degrees against steel reinforced lock sectors and 18.8 degrees against the all-steel lock sectors. During the second set of tests, which measured the effects of internal pressure loads on partially unlatched cams, it was discovered that pressurization did not create any significant loads in the latch mechanism with the door fully closed and the latch cams positioned up to 45 degrees from the fully latched position. Both series of tests show that if the latch cams were somehow electrically backdriven by a latch actuator that had no torque-limiting ability, the steel or steel-reinforced lock sectors would limit the amount of cam rotation such that the partially unlatched cams would still prevent pressure loads from forcing the door open.

1.17.4 Boeing 747 Cargo Door Certification

Title 14 CFR 25.783, Amendment 25-15, effective October 24, 1967, was the original certification basis for Boeing 747 cargo doors. Specifically, Part 25.783(e) and (f) applied to doors for which the initial opening movement is outward (non-plug type doors). Those rules specified that:

(e) There must be a provision for direct visual inspection of the locking mechanism by crewmembers to determine whether external doors, for which the initial opening movement is outward (including passenger, crew, service, and cargo doors), are fully locked. In addition, there must be a visual means to signal to appropriate crewmembers when normally used external doors are closed and fully locked.

(f) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure.

Amendment 25-23, effective May 8, 1970, added the following text to paragraph (f): "...or failure of a single structural element." Amendment 25-23 did not apply to the initial certification basis for the B-747.

Amendment 25-54, effective October 14, 1980, expanded Part 25.783 (e), (f), and (g) to read:

(e) There must be a provision for direct visual inspection of the locking mechanism to determine if external doors, for which the initial opening movement is not inward (including passenger, crew, service and cargo doors), are fully closed and locked. The provision must be discernible under operational lighting conditions by appropriate crewmembers using a flashlight or equivalent lighting source. In addition, there must be a visual warning means to signal the appropriate flight crewmembers if any external door is not fully closed and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed and locked indication is improbable for doors for which the initial opening movement is not inward.

(f) External doors must have provisions to prevent the initiation of pressurization of the airplane to an unsafe level if the door is not fully closed and locked. In addition, it must be shown by safety analysis that inadvertent opening is extremely improbable.

(g) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure or failure of a single structural element.

At the Safety Board's public hearing, the FAA and the Boeing representatives acknowledged that during certification of the Boeing 747 the loss of a lower lobe cargo door was not considered to be an "acceptable event." Therefore, redundant mechanical devices and operational procedures were incorporated to protect against loss of the door in flight. Initial FAA certification approval of the Boeing cargo door design and operation included the installation and use of eight view ports on the door for ground personnel to observe the alignment of paint stripes on the latch cams with arrows on the latch pin support fitting, thereby complying with the requirements of 14 CFR 25.783(e), which require a ". . . provision for direct visual inspection of the door locking mechanism ...," to determine if the door is closed and locked.

In correspondence dated November 24, 1969, and May 15, 1970, Boeing requested that the FAA approve the use of a visual inspection of the pressure relief doors of the cargo doors as an alternate method for determining the locked condition of the door. This design also provided a visual indication to the flightcrew via the cargo door warning light on the flight engineer's warning light annunciator panel. Boeing's request stated that this means of compliance "... provides a simpler check whereby only the pressure relief doors need to be checked ...," by the ground crew, in lieu of actually observing the latch cams and alignment stripes through the eight view ports. Boeing also provided a Failure Analysis to support its request. The conclusion of the Failure Analysis reads: "Any failure, mechanical or electrical, within the latching system which results in open latches will always be indicated by open pressure relief doors." The FAA approved their alternate method on June 8, 1970. Subsequently, the procedures for maintaining the view ports and the alignment stripes in a serviceable condition, which had been included in the UAL MM were removed. Also, the provision for observing the alignment stripes as part of the door closing procedure were not required for B-747 airline operators.

At the Safety Board's public hearing, a Boeing witness, in answer to a question relative to Boeing's possible consideration of modifications or design changes to the B-747 cargo door indication system to install a position switch directly on the latch cams, stated, "We are looking into the best possible designs that would provide indication on the cams and door closed, both exterior to the aircraft and in the flight deck. We are going to look into that.... However, we want to achieve the required indication in the most reliable method and we have not yet determined what that will be, or any changes (that) are necessary, or would make it more reliable than the way the system operates currently."

1.17.5 Advisory Circular AC 25.783-1

Advisory Circular (AC) 25.783-1 was issued December 10, 1986, on the subject, "Fuselage Doors, Hatches, and Exits." AC 25.783-1 set forth the acceptable means of compliance with the provisions of Part 25 of the FAR's dealing with the certification of fuselage doors. Specifically, it provides for an acceptable method for showing compliance with the provisions of Part 25.783, Amendment 25-54.

Neither the provisions of Part 25.783, Amendment 25-54, nor the guidelines of AC 25.783-1 were part of the certification basis of the Boeing 747.

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.

The airplane was being prepared for flight at the UAL

maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further
work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.

The aft cargo door was cranked open manually, the C-288 circuit breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident. With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage.

UAL personnel notified the Safety Board of the occurrence, and the airplane was examined at JFK by representatives of the Safety Board, United Airlines, and Boeing. After the wires in the damaged area were electrically isolated, electrical operation of the door was normal when the door was unlocked. When the door was locked (master latch lock handle closed), activation of the door control switches had no effect on the door. This indicated that the S2 master latch lock switch was operating as expected (removing power from the door when it was locked). After the on-site examinations, the wiring bundle was cut from the airplane and taken to the Safety Board's materials laboratory for further examination.

The wiring bundle with the damaged wires contained all electric control wires (28 volt DC) and power wires (115 volt AC) that pass between the fuselage and the aft cargo door. From the forward side of the J-4 junction box, the bundle progresses in the forward direction, just above the forward pressure relief door, then upward, following the forward lift actuator arms. The bundle then enters an empty space between two floor beams, where the bundle has an approximate 180-degree bend when the door is closed. From this location, the wiring bundle progresses inboard, through a fore-to-aft intercostal between two floor beams. The wiring bundle then splits, with wires going in several directions.

The bundle is covered by the flexible conduit approximately from the lower end of the lift actuator arms to the fore-to-aft intercostal between the floor beams.

The conduit covering the wiring bundle is intended to prevent the wire bundle from being damaged during opening and closing of the door and during cargo handling operations. The conduit is a sealed flexible interconnector consisting of a convoluted helical brass innercore covered by a bronze braid. The innercore is soldered at every other convolute, and should be capable of withstanding pressures exceeding 1,000 pounds per square inch (psi). Boeing has indicated that the conduit is an evolutionary improvement and that it has been installed on all B-747 airplanes produced since 1981 (from line number 489 on). Airplane N152UA was delivered in April 1987.

Airplanes produced prior to 1981, including N4713U, used a bungee retraction system, to retract the cargo door wire bundle. Guidelines for the replacement of the bungee sys tem with the flexible conduit were covered in Boeing Service Bulletin 747-752-2170, dated August 1981. The service bulletin was prompted by reports that the wire bundle bungee retraction system had not retracted the wire bundle sufficiently to prevent trapping the bundle between the cargo door and the door frame. UAL did not perform the retrofit on N4713U, which was line number 89, nor was the company required to do so.

Examination of the wires in the damaged area on the wiring bundle revealed that four of the wires were similar in appearance, with insulation breaches that progressed through to the underlying conductor. Adjacent to the breach on these four wires, the insulation was blackened, as if it had been burned. Another wire contained an extensive breach but no evidence of burned insulation. The damaged area was located on the bundle at a position approximately corresponding to a conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism. This support bracket was found bent in the forward direction. In addition, mechanical damage was noted on adjacent components in this area.

A second damaged area was noted on the wiring bundle at a position approximately corresponding to the conduit swivel clamp at the elbow between the two arms of the forward lift actuator mechanism. Wires in this area were missing portions of their exterior coating, but no breaches to the underlying conductors were noted.

The exterior braid on the conduit contained minor rub marks and was slightly kinked at a position corresponding to the area on the wires with breached insulation. Additional examinations revealed that the innercore of the conduit contained multiple circumferential cracks in the areas corresponding to the damage areas on the wires. The cracks were in the convoluted innercore

directly adjacent to the inside diameter of the conduit.
The lock sectors, latch cams, and latch pins from the aft cargo door were examined on the incident airplane and were generally in excellent condition. There was no evidence to suggest that the cams had ever been electrically (or manually) driven into or through the lock sectors.
Boeing also informed the Safety Board that, in May of 1991, a B-747 operated by Quantas was found to have chafing of the wires in the wire bundle to the aft cargo door. This airplane also had a flexible conduit protecting the wires, and the chafing was located approximately at the standoff pin on the bracket at the upper arm of the forward lift actuator.
The Safety Board determined that the chafing of the wires on the airplane involved in the JFK occurrence was caused by, or was greatly accelerated by, the circumferential cracks in the conduit and that the cracks in the conduit were caused either by repeated flexing of the conduit as the cargo door opens and shuts or by unusual stresses on the conduit generated concurrently with damage to the conduit guide bracket and attached standoff pin on the upper end of the forward lift actuator upper arm.
A portion of the wire bundle for the forward cargo door on many B-747 airplanes is also covered by a flexible conduit that is very similar to the conduit for the aft cargo door. However, there are substantial differences between the orientation of the flexible conduits for the two doors, and the Safety Board has not become aware of problems associated with the flexible conduit for the forward door.
Nevertheless, because of the concerns about the chafed wires and possible electrical short circuits, on August 28, 1991, the Safety Board recommended that the FAA:
Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between the fuselage and aft cargo door to require an expedited

inspection of:
(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test method or visual examination);
(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;
(3) the flexible conduit for the presence of cracking in the convoluted innercore.
Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an appropriate cyclic interval. (Class II, Priority Action) (A-91-83)
Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in A-91-83. (Class II, Priority Action) (A-91-84)
The FAA responded to these safety recommendations on November 1, 1991, stating that it agreed with the intent of the recommendations and that the issuance of an NPRM was being considered to address the issues in the safety recommendations. The Safety Board replied on November 27, 1991, classifying each of the recommendations as "Open--Acceptable Response," pending the completion of the rulemaking process. Since that exchange of correspondence, the FAA has published an NPRM which is now being reviewed by the Safety Board. Safety Recommendations A-91-83 and -84 will continue to be classified as "Open--Acceptable Response" until an acceptable final rule is published.

2. ANALYSIS

2.1 General

This analysis is based on the facts gathered during the initial investigation phase, without the benefit of the evidence from the cargo door, updated to include the findings from the subsequent examinations of the door after it was recovered.

The flightcrew and flight attendants were trained and qualified in accordance with the applicable Federal regulations and UAL standards and requirements. There were no air traffic control or weather factors related to the cause of this accident.

The airplane had been properly maintained, with the exception of certain requirements pertaining to the cargo doors. Those discrepancies will be discussed in detail in this analysis.

The evidence examined by the Safety Board during its investigation revealed conclusively that this accident was precipitated by the sudden loss of the forward lower lobe cargo door, which led to an explosive decompression. There was no evidence of preexisting metal fatigue or corrosion in the structure surrounding the cargo door. All breaks were the result of overload at the time of the loss of the door. There was no evidence of a bomb or similar device that caused an explosion on the airplane.

The explosive decompression of the cabin when the cargo door separated caused the nine fatalities. The floor structure and seats where the nine fatally injured passengers had been seated were subjected to the destructive forces of the decompression and the passengers were lost through the hole in the fuselage. Their remains were not recovered. Most of the injuries sustained by the survivors were caused by the events associated with the decompression, such as baro-trauma to ears, and cuts and abrasions from the flying debris in the cabin. Other injuries were incurred during the emergency evacuation.

The loss of power to the Nos. 3 and 4 engines was caused by foreign object damage when debris were ejected from the cargo compartment and cabin during the explosive decompression. The debris also caused damage to the right wing leading edge flap pneumatic ducting, and other areas along the right side and empennage of the airplane.

During the approach to HNL, all of the leading edge flaps had extended, except the outboard sections 22 through 26 on the right wing. The reason that they failed to extend probably was the damage to the pneumatic duct caused by the ejected debris. The pneumatic pressure probably was too low to actuate the most outboard flaps to the extended position.

The failure of the flightcrew and passenger oxygen systems was caused by structural deformation and damage to the supply lines in the area adjacent to the cargo door and failed fuselage structure.

The Safety Board's analysis of this accident concentrated on the reasons for the loss of the cargo door and the events that led to its loss in flight. The analysis included an evaluation of the design, certification, and approval processes for the B-747 cargo doors, and the operational, maintenance, and inspection processes for the doors. Also, the analysis included an evaluation of the historical events that had occurred over the past months and years that eventually led to this accident.

2.2 Loss of the Cargo Door

The calculated pressure differential at the time of the loss was about 6.5 psi, which would have exerted a load on a properly closed and locked door that was substantial, but well within design limits.

There was no evidence of a structural problem with the cargo door that could have caused it to fail from metal fatigue or corrosion. Although the cargo door was recovered in two pieces on the floor of the ocean, there was no evidence of a preseparation structural failure of the door. All fractures and damage found on the door were determined to be the result of the sudden opening of the door rather than the cause. The evidence showed that the door was intact when it flew open violently and that its integrity was compromised when it struck the upper fuselage structure and most likely when it struck the water. The fracture in the cargo door occurred just below the midspan latch cams. Paint marks on the outer surface of the door that matched upper fuselage structure paint pattern, damage to the latch pins, pull-in hooks and hook pins, as well as damage to the floor structure near the upper door hinge area were consistent evidence that the door was intact when it flew open.

The evidence was also conclusive that the failure of the door did not result from the failure of the structure surrounding the door. The damage to the cabin floor beam structure, adjacent to the cargo door hinge area, showed that decompression loads in the cabin broke the beams downward when pressure was released from the cargo compartment. The fuselage skin above the door was torn away during the decompression as the door separated violently from the airplane. Unfortunately, the upper skin structure was not recovered from the sea.

There are no reasonable means by which the door could open in flight with the cams properly closed and locked. If the lock sectors were in proper condition, and were properly situated over the closed latch cams, the lock sectors had sufficient strength to prevent the cams from vibrating to the open position during ground operation and flight. Thus, the only ways in which the cargo door could open while in flight involve the placement of the cams in a partially latched or unlatched position. Either the latching mechanisms were forced open electrically through the lock sectors after the door was secured, or the door was not properly latched and locked before departure. Then the door opened when the pressurization loads reached a point at which the latches could not hold.

2.3 Partially Closed Door

Examination of the eight latch pins that had been removed from the lower sill of the forward cargo door revealed smooth wear patterns where the latch cams had normally rotated around the pins. These wear patterns indicate that interference had existed during normal operation between the cams and the pins over an extended period of time. All eight pins also had roughened areas from approximately the 6:15 position to the 7:30 position (clock references are as looking forward, 9:00 being directly inboard). The 7:30 position corresponds closely to the area where the lower surface of the cam first contacts the pin as the door reaches the nearly closed position, before the cams are rotated to the latched position.

The hoop stresses generated by pressurization of the airplane create a bearing load against the cam/pin contacting points. Even if the cams are in the unlatched position, and the airplane is pressurized, this bearing load could act as a frictional latch between the cams and the pins and would tend to keep the door in the closed position.

Transferred cam material and heat tinting of the pin surface was found to extend from the point where the cam-to-pin interface at the near fully open position of the latch cams (7:30 position) to a position corresponding to the bottom of the pin (6:15 position). This evidence was found on the roughened areas on all of the pins. The heat tinting and metal transfer are indicative of the high stress and rapid movement of the cam across the pin when the door separation occurred. Therefore, the location of this evidence indicates the probable location of the cams just before, and at the time of, separation of the door. The Safety Board concludes that these markings and their location on the pins resulted from a very fast, high bearing stress, separation of the cams across the pins, when the cams were in or very close to the unlatched position. Further, examination of the recovered cargo door confirmed that the latch cams were in a nearly unlatched position at the time the separation occurred. The lock sectors were found in the locked position jammed against the cams. Therefore, the cargo door latch cams had been closed, the master latch lock handle had been closed, and the lock sectors had moved to the locked position. Subsequently, the cams had been back-driven to the near-open position, deforming the lock sectors.

The pull-in hooks and pull-in hook pins would also counteract the pressurization loads in the outward direction, providing that the latch cams were not engaged on the latch pins and carrying the pressurization loads. However, Boeing studies showed that the pull-in hooks would fail at a pressure differential of about 3.5 psi, assuming that the cams are in the unlatched position and that there is no bearing load on the pins. Therefore, based on the probable pressure differential of about 6.5 psi just before the door separated, it is concluded that forces other than the pull-in hooks/pins were holding the door closed. Since the flightcrew and passengers reported no pressurization difficulties until the explosive decompression, it is reasonable to conclude that the door was being held closed by the bearing stresses of the cam-to-pin interfaces as well as by the pull-in hooks.

The Safety Board believes that the approximate 1.5 to 2.0 seconds between the first sound (a thump) and the second very loud noise recorded on the CVR at the time of the door separation was probably the time difference between the initial failure of the latches at the bottom of the door, and the subsequent separation of the door, explosive decompression, and destruction of the cabin floor and fuselage structure. The door did not fail and separate instantaneously; rather, it first opened at the bottom and then flew open violently. As the door separated, it tore away the hinge and surrounding structure as the pressure in the cabin forced the floor beams downward in the area of the door to equalize with the loss of pressure in the cargo compartment.

Three possible theories to explain why the latch cams could have been in a partially latched condition during flight are examined: (1) they were never closed fully before the door was "locked" before takeoff. (2) they were backdriven manually after the door had been fully latched and locked or (3) they were back-driven electrically after the door had been fully latched and locked.

2.4 Incomplete Latching of the Door During Closure

The Safety Board considered the possibility that the master latch lock handle had not been closed before the airplane departed the gate, and the possibility that the shrouds recommended by SB-747-52-2097 for the cargo door pressure relief doors were not installed on the forward door. If this were the case, it is possible that this condition allowed the pressure relief doors to be rotated closed when the airplane pressurized.

The Safety Board believes that these events were very unlikely based on the statements of the ramp personnel, line maintenance personnel, and the flightcrew. The ramp and maintenance personnel would have to have missed seeing the master latch lock handle in the unstowed position and the pressure relief doors open before departure. Also, the flightcrew would have to have missed seeing the cockpit cargo door warning light indication.

The examination of the recovered forward cargo door did not provide confirmation that the pressure relief door shrouds were actually installed on the forward door, although UAL records showed that they had been installed on both cargo doors of N4713U, in accordance with SB-747-52-2097. However, the shrouds were found not to be installed on the aft door, contrary to UAL records, and therefore may not have been installed on the forward door. Without the shrouds, the pressure relief doors could have rotated shut during the pressurization cycle. Because the closure of the pressure relief doors would back-drive the lock sectors, this scenario would presume previous damage to the sectors, which would permit the sectors to move over the unlatched cams.

Before recovery of the cargo door, the Safety Board believed that the lock sectors might have been damaged some time prior to the accident flight to the extent that they could have been moved to the locked position even though the latching cams were not fully closed.

During closure of the door, the latch actuator may not be able to rotate the cams to the fully closed position because of excessive binding forces between the latch cams and pins. This could occur if the cargo door is misaligned (out of rig) or if the pull-in hooks do not pull the door in far enough to properly engage the cams around the pins. There is sufficient evidence of wear on the pins and from the previous discrepancies with the door to indicate that the door was misaligned and not properly rigged.

The smooth wear areas found on the pins from N4713U are signs of heavy contact (interference) between the cams and pins during numerous past closings and openings of the door. This wear, other evidence from the door, and the maintenance history of the door, suggest strongly that the door was out of rig during the weeks and months before the accident.

The wear pattern damage to the pull-in hook pins also showed interference during the normal ground operations prior to the accident. This is further evidence of an out-of-rig door. It is also possible that the excessive binding force acting over a period of time precipitated a failure of the latch actuator. Regardless of the reason(s), the conditions of the latch pins and pull-in hook pins showed prolonged out-of-rig operation.

Most of the previous discrepancies with the forward cargo door on N4713U during December 1988 involved problems with closing the door electrically. These problems always occurred when the airplane was fully or nearly fully loaded, just before departure. The trouble-shooting and corrective actions by UAL maintenance, which on some occasions only involved cycling the door and finding it functional, were performed when the airplane was not fully loaded, during overnight maintenance inspections. The flexing of the fuselage with a full load of fuel, cargo, and passengers could have caused distortion of the door frame and resulted in misalignment between the cams and pins. In this case, the pull-in hooks may not have pulled the door fully in before the cam actuator attempted to latch the door. The wear evidence on the latch pins from N4713U suggests that this event had been occurring before the accident.

Safety Board investigators also witnessed this event during inspection and operation of the aft door on another UAL B-747, N4718U, in HNL. It was noted that the door on N4718U was not being pulled in fully by the pull-in hooks, so the latch cams completed the closing cycle with significant interference and "thunking" sounds. In fact, the out-of-rig door on N4718U failed to operate electrically at one point during its examination.

By design, any attempt to close the master latch lock handle and move undamaged lock sectors into place would not be successful unless the cams were rotated to near the fully latched position. This condition was substantiated by Boeing tests. Even with severely damaged lock sectors, as found on the Pan Am B-747, if the cams were more than 20 turns from the fully closed position on the Pan Am airplane, the master latch lock handle could not be stowed. Examination of the recovered N4713U door indicated that the door lock sectors were generally intact and jammed against the cams that had been back-driven into the lock sectors. Consequently, if the latch cams had been in the nearly unlatched position as found on the recovered door at the time the cargo handler attempted to move the master latch lock handle, the interference between the cams and the lock sectors would have prevented the master latch lock handle from moving to the closed position. Furthermore, this interference would have prevented the closure of the pressure relief doors as the airplane pressurized, irrespective of the possible absence of the pressure relief door shrouds. This conclusion is supported by extensive testing of the latch/lock mechanisms following the recovery of the door.

Therefore, based upon the examination of the lock sectors and the tests that were conducted, the Safety Board concludes that the latches were fully closed and that the locking handle was placed in the stowed position after the cargo was loaded.

2.5 Manual Unlatching of the Door Following Closure

It is possible that the cams could have been manually back-driven (about 95 turns) after the door had been secured; however, the UAL ramp personnel involved with dispatching the flight stated that the door was operated electrically. Furthermore, it seems unlikely that the ramp personnel would have driven the manual latch actuator 95 turns toward the open position after the door was fully latched.

The placard/seal located over the latch actuator manual drive on the recovered door was found with damage that initially suggested it had been previously compromised. If this were the case, it would indicate that someone may have used the manual drive to operate the door latches on an earlier flight or possibly immediately before the accident flight. However, the Safety Board believes that an insertion of a screw driver and rotation of the plate retaining screw would have caused rotational tearing around the circumference of the screw head. There was no such tear. Rather, the damage to the placard/seal was more consistent with that which would occur from impact and underwater pressure

forces. Therefore, the evidence strongly suggests that manual operation of the latch actuator by ground service personnel after the door was properly closed is unlikely.

2.6 Electrical Unlatching of the Door Following Closure

2.6.1 Conditions or Malfunctions Required to Support

Hypothesis

It was determined in 1987, after the Pan Am incident, that the locking sectors for B-747's, including those installed on N4713U, could be overcome by the force of the latch cam actuator, electrically or mechanically. If the latch cam actuator had been energized for some reason with the originally designed unstrengthened lock sectors installed, the latch actuator motor was capable of driving the latch cams open through properly positioned lock sectors, whether they were damaged or undamaged. Therefore, the locking sectors installed as original equipment for B-747's, and those installed on N4713U, would not perform the locking function as intended by the design. They would not "lock" the latches in place as implied by the name "lock sectors."

The investigation has shown that there are several conditions that must be met before the latch actuator will electrically drive the latch cams to the unlatched position on the B-747 after the door has been properly closed and locked. First, the ground handling power bus must be energized by having external power connected, or the APU must be operating and the APU generator field switch in the cockpit must be set to power the bus via the No. 2 ground handling power relay. Second, the air/ground relay must be in the "airplane on the ground" position. These two conditions are normally present when the airplane is on the ground before engine startup. Third, there must be a signal to the door open position in one of the two door open/close switches. Fourth, the S2 master latch lock switch, which cuts off power to the door actuators when the handle is stowed, must sense "not locked."

Therefore, it would take several independent conditions and some failures to provide for electrical power to be available to drive the door open electrically once it is closed and locked. The number of conditions and combinations depend upon the phase of operation of the airplane.

While the airplane was on the ground, before engine startup, with the master latch lock handle stowed, the external power connected (or with the APU running), and the ground handling bus powered, an "open" signal to the cargo door latch actuator would have occurred if any of the following combinations of conditions had been met: (1) a malfunction of the S2 master latch lock switch and the placement by someone of one of the door control switches to the "open" position; (2) a malfunction of the S2 master latch lock switch and certain short circuits; or (3) a two-wire short circuit path consisting of wire 101-20 shorting with any of the following wires: 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

While the airplane was on the ground, after engine startup, and with the cargo door master latch lock handle stowed and the APU running, an "open" signal to the door latch actuator would have occurred if the following conditions had been met: (1) an energized ground handling bus resulting from the flightcrew reenergizing the APU generator field or failure of the No. 2 ground handling power relay; (2) a malfunction of the S2 master latch lock switch; (3) a malfunction of either of the door open/close switches or the placement of the switch in the "open" position by someone. An "open" signal would have also occurred had certain wire short circuits been present with condition (1) alone, or with conditions (1) and (2).

Regardless of the cause, electrical power to the latch actuator would have had to persist for the time necessary to rotate the cams to the nearly open position. If the electrical power had been applied for a longer time, the latch cams could have opened fully and caused the pull-in hooks to rotate open, a situation that would have prevented the airplane from pressurizing after takeoff. However, it is also possible that the latch actuator stalled before they opened fully because of the forces of the interference between the lock sectors and the cams as they were back-driven. After takeoff, electrical operation of the door latch actuator would have required: (1) the APU to be running; (2) malfunction of the air/ground relay, (3) malfunction of the No. 2 ground handling power relay; and (4) malfunction of the S2 master latch lock switch and one of the cargo door open/close switches or a short circuit of the aforementioned wire pairs. Although the flightcrew could conceivably energize the ground handling bus from the APU by actuating the APU generator "field" switch, there was no evidence that they did so.

Thus, regardless of the phase of operation, either a wiring short circuit or a failure of the S2 master latch lock switch combined with some other anomaly or action would be required to cause the latches to move toward the open position. Before the recovery of the door, the Safety Board was able to examine two of the electrical relays and the door open/close switches from N4713U that would have to have failed to allow electrical operation of the cargo door in flight, with the APU running. These were the No. 2 ground handling power relay, the air/ground relay, and the internal and external door open/close switches. The examination of the relays and switches revealed no evidence of a single fault or conditions that might have caused an intermittent failure mode. The arcing noted on the No. 5 terminal of the outside door control switch was on the door "close" circuit and could not have been related to a short to the open mode. Further, because the flightcrew did not note a cargo door warning light, and the fact that the airplane was able to be pressurized, confirms that the master latch lock handle was in the closed position before takeoff. This position would actuate the master latch lock switch to disconnect power to the door opening actuators.

According to the flightcrew testimony and the pilots' comments recorded on the CVR during the flight, the APU was shut down shortly after takeoff and remained in that condition. Engine generators cannot power the ground handling bus from which the cargo door actuating mechanisms are powered. Once the APU was shut down, there was no power available to any of the cargo door electrical components. Therefore, an electrical actuation of the latch cam actuator at the time of the door loss was not possible.

The Safety Board believes that there is another reason why the opening of the door could not have been caused by electrical actuation shortly before the explosive decompression. Because the door carries the structural loads (hoop stresses) through its hinge and latches, the latch cams would be heavily loaded against the latch pins when the airplane was pressurized to the 6.5 psi differential pressure that was calculated to have been present at the time of the decompression. In that case, the torque limiter within the actuator would probably slip well before the actuator could achieve the torque necessary to drive the cams open against the frictional lock produced by the high bearing stresses resulting from pressurization.

2.6.2 Electrical Switches and Wiring Examinations--Recovered Door

All cargo door position sensing switches (S2 through S9) were found installed in their proper position. The cargo door recovery team found the S2 master latch lock switch in the "not-locked" position immediately after the door was aboard the recovery ship. This position would be consistent with the master latch lock handle being open. Further tests of the S2 switch revealed damage that probably resulted from the pressures under the sea. The only notable exception was a broken internal bracket that may have affected the operation of the switch prior to the accident. Other similar switches did not exhibit this failure. It is therefore possible that the S2 master latch lock switch failed prior to the accident, allowing more possibilities for electrical short circuits to power the latch actuator. Nevertheless, despite extensive testing, it could not be determined whether the S2 switch was functional before the accident.

The examination of 35 wires that remained with the recovered cargo door revealed several areas of damaged insulation that could have permitted an electrical short circuit to power the latch actuator. However, no evidence was noted of arcing that was indicative of short circuits. Furthermore, a significant number of the wires that had the potential for allowing for short circuits to power the latch actuator were not recovered. Testing conducted by Boeing and by UAL was inconclusive regarding whether a short circuit would have left detectable evidence of arcing. Therefore, the Safety Board was unable to determine whether the latch actuator was inadvertently powered by a short circuit in the cargo door wires.

The incident involving a UAL Boeing 747 at JFK Airport on June 13, 1991, confirmed that electrical short circuits in the cargo door wiring could cause the door to open. In this case, the short circuits were in the fuselage-to-cargo door wiring bundle where the bundle was covered by a flexible conduit. Although N4713U did not have a flexible conduit installed at the forward door position, its wiring was routed over the top of the door hinge where exposure to damage could occur. That portion of the wiring from N4713U was not recovered from the sea. The wires located at the door hinge area are more susceptible to in-service damage from movement during the open/close cycle, as compared with the wires mounted on the door that are normally static.

Following the incident at JFK, UAL directed that the circuit breaker that terminates power to the cargo doors be pulled after the door is closed and before departure of every B-747 flight. UAL obtained approval for this practice from the FAA and requested Boeing and the FAA to make such a practice part of the approved manual for the airplane. Neither Boeing nor the FAA acted on UAL's request.

Nevertheless, the Safety Board believes that the FAA should initiate rulemaking to include design considerations for nonplug transport category aircraft cargo doors that would deactivate the electrical circuitry to the door actuators after the doors are closed and locked. The catastrophic nature of the loss of a cargo door dictates the need to provide additional redundancies and fail-safe features in the door mechanisms to supplement the hardware safety features.

2.6.3 Possibility of Electrical Malfunction

Due to the lack of physical evidence, the Safety Board was unable to conclude that an electrical short caused the cargo door actuator to move the latch cams to the nearly open position, allowing the door to separate when the cabin pressure exceeded the load-carrying capability of the door latches. Neither could this possibility be eliminated. A momentary actuation of the door open switch by someone on the ground in the presence of a faulty S2 switch could also have caused the latches to open through the closed lock sectors. However, no evidence has been found that someone actuated the switch after the door was initially closed and locked.

The Safety Board concludes that it was not possible for the cargo door to have opened electrically at the time of the loss of the door. There was no power to the ground handling bus to power the actuator, even if there had been an electrical short. Further, the Safety Board concludes that it is highly improbable that an electrical short could have caused the latches to open after the airplane was airborne. Although the ground handling bus could conceivably have been powered, failures of other components that were tested as functional would also have been necessary.

The Safety Board believes that the electrical operation of the latch actuators from the fully closed and locked position most likely occurred before the engines were started when the ground handling bus was powered. The precise source of the electrical actuation could not be determined. Once the engines were started, the possibility of an electrical short decreases significantly because the ground handling bus is disengaged from the APU when the engines start. There was no evidence that the flightcrew reengaged the ground handling bus.

Because the preaccident condition of the S2 master latch lock switch could not be determined, it could also not be determined whether its proper functioning would have prevented the accident. The Safety Board did not determine whether damaged cargo door wires or a malfunctioning S2 switch could have been found by UAL maintenance had they been more aggressive in troubleshooting the cargo door problem in the weeks prior to the accident.

2.7 Design, Certification, and Continuing Airworthiness Issues

The Safety Board's analysis of this accident went beyond the conclusions about how the door failed. The Safety Board also examined the initial design and certification of the B-747 cargo door, and the continuing airworthiness system that should have prevented this accident, to identify the breakdowns in this system that led to the accident. As is the case with most aviation accidents, there are many factors that led up to the actual failure of the door on flight 811.

The Safety Board found that there were multiple opportunities during the design, certification, operation, and maintenance of the forward cargo door for N4713U for persons to have taken actions that could have precluded the accident involving flight 811. The circumstances that led to this accident exemplify the need for human factors considerations in the promulgation of regulations, the application of regulatory policies, the design of airplane systems, and the quality of airline operational and maintenance practices.

The first opportunity to prevent this accident occurred during the design and certification of the B-747 cargo door mechanical systems, when the design was chosen and approved, which allowed for the overriding of the lock sectors by either mechanical or electrical actuation. It is apparent that the original design was not tested sufficiently to verify that the locking sectors in fact "locked" the latch cams in the closed position. This shortcoming should have become apparent during the initial certification testing and approval process. Later, it should have become apparent when Boeing applied for, and the FAA granted, an alternative method of compliance with the certification regulations (25.783 [e]) that permitted the elimination of operational practices that included a visual verification of the cargo door latch positions via view ports in the doors.

The failure mode analysis performed by Boeing, and the FAA's acceptance of its content in granting the exemption, probably were based on the assumption that the lock sectors would always prevent the master latch lock handle from being in a stowed position when the latch cams were not fully closed. This assumption was not valid, as evidenced by the findings in 1987 following the Pan Am incident that the lock sectors could not prevent the latch cams from being driven from the fully latched position with the master latch lock handle stowed, while a false indication was provided to the flightcrew that the cargo door was properly latched and locked. At the time that Boeing sought approval of the alternative compliance, Boeing and the FAA should have reviewed the design and required testing of the door latch/lock mechanisms to verify their integrity. Thus, the procedure for direct viewing of the latches via the view ports before the airplane could be dispatched should not have been eliminated without adequate verification that the lock sectors were totally effective.

The next opportunity for the FAA and Boeing to have reexamined the original assumptions and conclusions about the B-747 cargo door design and certification was after the findings of the Turkish Airline DC-10 accident in 1974 near Paris, France. The concerns for the DC-10 cargo door latch/lock mechanisms and the human and mechanical failures, singularly and in combination, that led to that accident, should have prompted a review of the B-747 cargo door's continuing airworthiness. In the Turkish Airlines case, a single failure by a ramp service agent, who closed the door, in combination with a poorly designed latch/lock system, led to a catastrophic accident. The revisions to the DC-10 cargo door mechanisms mandated after that accident apparently were not examined and carried over to the design of the B-747 cargo doors.

Specifically, the mechanical retrofit of more positive locking mechanisms on the DC-10 cargo door to preclude an erroneous locked indication to the flightcrew, and the incorporation of redundant sensors to show the position of the latches/locks, were not required to be retrofitted at that time for the B-747. Of similar concern is the fact that the cargo doors for the L-1011 required redundant latch/lock indication sensors at initial certification, during the approximate same time frame the DC-10 and B-747 were certificated.

More recently, when Boeing and the FAA learned about the circumstances of the Pan Am cargo door opening incident in March 1987, more timely and positive corrective actions should have been taken. The Safety Board believes that the findings of that incident investigation should have called into question the assumptions and conclusions about the original design and certification of the B-747 cargo door, especially the alternative method for verifying that the door was latched and locked that was sought by Boeing and was granted by the FAA. Since a B-747 cargo door opening in flight was considered to be an "unacceptable event", once a door did come open in flight, the FAA and Boeing should have acted much quicker to prevent another failure.

It took nearly 16 months from the date of the Pan Am Incident (March 10, 1987) until the FAA issued AD-88-12-04 (July 1, 1988). And then, the AD allowed 18 or 24 months, depending on the model B-747, from the date of its issuance for compliance with the terminating actions of the AD. The fact that Boeing had issued an Alert SB as a result of the Pan Am incident is an indication of the apparent urgency with which Boeing treated this issue. Alert SB's are issued for "safety of flight" reasons, while regular SB's deal with "reliability" and not necessarily safety of flight items. Despite this, the terminating action, issued as revision 3 to the Alert SB, on August 27, 1987, was not mandated by the FAA for 11 months.

The Safety Board found no evidence that the FAA or Boeing reassessed the original design and certification conclusions regarding the safety of the B-747 cargo door during this period. Several opportunities for preventive action were also missed by UAL during this period. First, UAL delayed the completion of the terminating actions of Alert SB 52A2206 (Rev 3 and AD-88-12-04. In fact, there was no evidence that UAL had intended to comply with the terminating action of the Alert SB, until it was mandated by the FAA.

It is understandable that an airline would not take its aircraft out of service to incorporate revisions that do not appear to be safety critical. Although by definition an Alert SB is safety related, there was no implication from Boeing's and FAA's actions regarding this matter that urgency was required. The airlines rely on the airframe manufacturers and the FAA to evaluate the need for urgent airworthiness actions that might take airplanes out of revenue service. In this case, UAL had scheduled completion of its B-747 fleet modifications in accordance with the terminating actions for AD-88-12-04 before the final allowable date; however, the schedule was based on other heavy maintenance schedules to prevent unnecessary down-time of its airplanes.

UAL personnel stated after the UAL 811 accident that its personnel did not fully appreciate the importance, or safety implications, of the terminating actions, or they would have incorporated the improvements much earlier. The usual difficulties in setting short suspense dates for performing terminating actions in AD's, such as parts availability, did not seem to exist in this case, because the parts were not complex components and probably could have been fabricated fairly quickly in-house by most airlines.

Human performance certainly contributed to UAL's failure to incorporate an important inspection step into its maintenance program as mandated by AD-88-12-04. When UAL obtained an advance draft copy of the forthcoming NPRM that eventually led to the AD, the airline began preparing its work orders to implement the forthcoming the AD requirements into its B-747 fleet (30 airplanes at the time). UAL developed its maintenance work sheets from the text of the draft NPRM, which was virtually identical to the text of the final rule. As a result of a clerical error, one of the important inspection steps required by the AD was omitted.

Apparently, UAL maintenance personnel never compared the work sheets they received with the actual requirements of the AD, or if they did, the omission was not detected. FAA inspectors responsible for oversight of UAL's maintenance program also did not detect this error because normal surveillance of AD compliance merely involved verifying the correctness of UAL's paperwork that listed the applicable AD's and compliance dates. The inspectors did not actually verify UAL's compliance action by shop visits, or by comparison of work sheets with AD provisions. These omissions by the UAL maintenance and quality assurance personnel, and the limitations of the FAA surveillance procedures were probably significant in setting the stage for the events that led to the actual cause of the door separation from N4713U.

Another matter of concern is the quality of UAL's trend analysis program. There was no indication that the repeated discrepancies with the forward cargo door on N4713U "raised a flag" within the UAL maintenance department. A quality assurance or trend analysis program should have detected an adverse trend and should have prompted efforts to resolve the repeated problems. If it had, any faults in the door electrical system or damage to mechanical components might have been detected.

In summary, the Safety Board concludes that there were several opportunities wherein Boeing, the FAA, and UAL could have taken action during the initial design and certification of the B-747 cargo door, as well as during the operation and maintenance of the cargo door installed on N4713U, to ensure the continuing airworthiness of the cargo door. The Safety Board further concludes that these deficiencies and oversights contributed to the cause of this accident.

2.8 Survival Aspects

The Hickam ARFF units and the airport's ARFF units operated on separate radio networks and thus they could not communicate directly on-scene by radio. This situation required them to communicate by voice. Although the two ARFF services had a common radio frequency (as per the Airport Emergency Plan), procedures for its use had not yet been developed. The Safety Board believes that such communication procedures should be expeditiously developed.

The use of camouflage paint schemes on military ARFF vehicles may be appropriate for military purposes; however, the Safety Board believes that camouflage is not appropriate for ARFF vehicles that are operated at a joint- use airport. It is obvious that these vehicles must be conspicuous to be seen by other responding vehicles and by persons who are involved in the accident, such as airport and airline personnel, crew and passengers, and off-airport firefighting and rescue vehicles.

The National Fire Protection Association Standards recommend for primary firefighting, rapid intervention and combined agent vehicles, that, "Paint finish shall be selected for maximum visibility and shall be resistant to damage from firefighting agents."4 Furthermore, Federal Aviation Regulation 14 CFR 139.319 (f) (2) requires emergency vehicles, "Be painted or marked in colors to enhance contrast with the background environment and optimize daytime and nighttime visibility and identification." Further guidance for the high visibility color of ARFF vehicles is provided in a Federal Aviation Administration Advisory Circular where the vehicle paint color is specified as, "lime yellow" Dupont No. 7744 UH or its equivalent.5

Because flight attendants are vital to the safety and survival of the passengers following a decompression, measures should be taken to prevent flight attendants from being incapacitated by hypoxia. The Safety Board believes that oxygen masks should be attached to the emergency oxygen bottles to avoid any delay in their use in order to be in compliance with the intent of 14 CFR 25.1447 (c)(4). Therefore, the FAA should direct its inspector staff to survey B-747 airplanes for compliance with 14 CFR 25.1447(c)(4), and correct deficiencies found.

In this accident, the use of megaphones was vital because of the inability to be heard over the public address (PA) system. Title 14CFR 121.309 (f)(1) requires one megaphone on each airplane with a seating capacity of more that 60 and less that 100 passengers; 14 CFR 121.309 (f)(2) requires two megaphones in the cabins on each airplane with a seating capacity of more than 99 passengers. As this decompression demonstrated, additional megaphones are necessary on wide-body and large narrow-body airplanes to ensure communication in the cabin during emergencies when the PA system is inoperative.

Had there been a need for an immediate evacuation, or a water ditching, rapid egress would not have been possible at doors 2-left and 2-right because they were blocked by open storage compartments and spilled contents. The possibility also exists that a compartment door could release during a hard landing or turbulence and swing down and injure a flight attendant. Thus, the Safety Board believes that improved latches should be installed and the downward movement of stowage compartments doors should be restricted to prevent the doors from striking a seated flight attendant or block the exit door.

The Safety Board believes that the problems with life preserver donning and adjustment demonstrated in this accident should be addressed by the FAA. The straps and fittings on life preservers need to be evaluated to determine where improvements can be made, and clearer donning instructions should be developed.

TSO-C13d, Life Preservers 1/3/83 prescribes the minimum performance standards for life preservers. With regard to donning, the TSO requires:

Donning. It must be demonstrated that an adult, after receiving only the customary preflight briefing on the use of life preservers, can don the life preserver within 15 seconds unassisted while seated. It must be demonstrated that an adult can install the life preserver on another adult, a child, or an infant within 30 seconds unassisted. The donning demonstration is begun with the unpackaged life preserver in hand.

Based on flight attendant interviews and information obtained from passengers these donning times were exceeded in many instances.

The Safety Board has made numerous recommendations to the FAA in the past regarding needed improvements in life preserver donning instructions, donning procedures, and timing of donning.6 The FAA has adopted most of the Safety Board's recommendations in its April 23, 1986, revision to TSO-C13e, Life Preservers, which now requires the wearer to be able to secure the preserver with no more than one attachment and make no more than one adjustment for fit. Also, donning tests are required for age groups of users starting with 20-29 years and ending with 60-69 years. At least 60% of the test subjects in each age group must be able to don then life preserver within 25 seconds unassisted with their seatbelts fastened starting with the life preserver in its storage package. TSO-C13e contains requirements that would have eliminated some of the problems that passengers had in this accident in correctly donning and adjusting their life preservers.

The Safety Board has recommended (A-85-35 through-37) to the FAA to amend 14 CFR 121, 125, and 135 to require air carriers to install life preservers that meet TSO-C13e within a reasonable time. The FAA adopted TSO-C13e on April 23, 1986, and originally had specified an effective date of April 23, 1988, after which all newly manufactured life preservers approved under the TSO system would have to meet the requirements of TSO-C13e. The objective of the cut off date was to introduce life preservers into the fleets with the higher performance level as specified in TSO-C13e by assuring that replacement articles met the higher standards. On March 3, 1988, the FAA rescinded the cut off date to seek further public comments of fleet retrofit in accord with the proposed rulemaking. See Section 4.0 for FAA action and status of the recommendations.

3. CONCLUSIONS

3.1 Findings

1. There were no flightcrew or cabincrew factors in the cause of the accident or injuries.
2. There were no air traffic control or weather factors in the cause of the accident.

3. The airplane had not been maintained in accordance with the provisions of AD-88-12-04 that required an inspection of the cargo door locking mechanisms after each time the door was operated manually and restored to electrical operation. However, this circumstance was determined not to be a factor in the accident.

4. All but one of the electrical components remaining with the airplane or found with the cargo door that were necessary to have malfunctioned in order to cause an inadvertent electrical opening of the cargo door after dispatch were found to function properly.

5. The forward cargo door lock sectors were found in the locked position (actually in an "over-locked" position) and jammed against the latch cams. The latch cams were found in the nearly open position.

6. The latch actuator manual drive port seal was found damaged from the forces involved in the separation of the door and did not indicate that the drive port had been used to open the door latches manually before the accident.

7. Electrical continuity tests indicated that the S2 master latch lock switch was in the "not locked" position when it was recovered with the cargo door. Because it had sustained damage from being submerged in the sea, its preaccident condition could not be determined.

8. An S2 switch functioning as found after recovery would permit electrical power to the door during ground operation so that additional failure modes or activation of the door control switch could result in movement of the latching cams.

9. All other switches associated with operation of the cargo door were found damaged from being submerged in the sea; however, they were determined to be properly installed and probably functional.

10. Short circuit paths in the cargo door circuit were identified that could have led to an uncommanded electrical actuation of the latch actuator; this situation occurred most likely before

engine start, although limited possibilities for an uncommanded electrical actuation exist after engine start while an airplane is on the ground with the APU running.

11. It was not possible for electrical short circuits to command the cargo door to open at the time of the loss of the door, and it is highly improbable that such an event occurred when the airplane was airborne during the short period while the APU was running.

12. Insulation breaches were found on recovered portions of the cargo door wires that could have allowed short circuiting and power to the latch actuator, although no evidence of arcing was noted. All of the wires were not recovered, and tests showed that arcing evidence may not be detectable.

13. An uncommanded movement of cargo door latches that occurred on another UAL B-747 on June 13, 1991, was attributed to insulation damage and a consequent short between wires in the wiring bundle between the fuselage and the moveable door. Because the S2 switch functioned properly on that airplane, movement of the latches would not have occurred after the door was locked.

14. UAL's maintenance trend analysis program was inadequate to detect an adverse trend involving the cargo door on N4713U. This circumstance was determined not to be a factor in the accident.

15. FAA oversight of the UAL maintenance and inspection program did not ensure adequate trend analysis and adherence to the provisions of airworthiness directives. This circumstance was determined not to be a factor in the accident.

16. The smooth wear patterns on the latch pins of the forward cargo door installed on N4713U were signs that the door was not properly aligned (out of rig) for an extended period of time, causing significant interference during the normal open/close cycle.

17. The rough heat-tinted wear areas on the latch pins of the forward cargo door installed on N4713U marked the positions of the cams at the time the door opened in flight.

18. The design of the B-747 cargo door locking mechanisms did not provide for the intended "fail-safe" provisions of the locking and indicating systems for the door.

19. Boeing's Failure Analysis, which was the basis upon which the FAA granted an alternative method of compliance with the provisions of 14 CFR 25.783(e), was not valid as evidenced by the findings of the Pan Am incident in 1987, and the accident involving flight 811.

20. Boeing and the FAA did not take immediate action to require the use of the cam position view ports following the Pan Am incident, and did not include this requirement in the provisions of the Alert Service Bulletins or AD-88-12-04.

21. There were several opportunities for the manufacturer and the FAA to have taken action during the service life of the Boeing 747 that might have prevented this accident.

22. The fact that the crash fire rescue vehicles responding to this accident did not use a common radio frequency led to problems in communication among the responding vehicles.

23. The camouflage paint scheme of the military fire rescue units led to reduced visibility of these units and resulted in at least one near-collision.

24. Megaphones were used in flight to communicate with passengers because of the high ambient noise level. However, more megaphones would have afforded better communication in all parts of the cabin.

25. Some flight attendants and passengers had difficulties tightening straps of their life preservers around their waists because of the fabric used, the design of the adjustment fittings, and the angle the straps were pulled.

26. Articles that fell to the floor from stowage bins above the

L-2 and R-2 exits and galley service items had to be cleared away from the exits before the emergency evacuation could be initiated.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

4. RECOMMENDATIONS

As a result of the investigation, including evidence from the recovered cargo door and a June 13, 1991, incident involving the uncommanded electrical operation of a cargo door on a UAL Boeing 747 at JFK Airport, the National Transportation Safety Board recommends that the FAA:

Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits. (Class II, Priority Action)
(A-92-21)

As a result of this investigation, on August 23, 1989, the Safety Board issued the following safety recommendations to the FAA:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams. (Class II, Priority Action)(A-89-92)

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently. (Class II, Priority Action)(A-89-93)

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions. (Class II, Priority Action)(A-89-94)

The FAA responded to Safety Recommendations A-89-92 through -94 on November 3, 1989. During its evaluation of Safety Recommendation A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with AD 88-12-04, cannot be overridden during mechanical or
least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this, Safety Recommendation A-89-92 has been classified as "Closed--Reconsidered."

The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all jetpowered transport-category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight. The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100 certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as "Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using nonplug doors and that the FAA should not be limiting this review to only those transports which are jetpowered.

On November 29, 1990, Boeing issued service bulletin number 747-52-2224 applicable to all 747-100, 747-200, and 747-300 airplanes to add a new "door latch" switch to all 747 cargo doors. In addition to the door warning switch that monitors the position of the pressure relief doors, the new door latch switch is activated by the latch cam bellcrank to separately sense the position of the latch cams. The existing "door closed" switch is also replaced with a double pole switch. The additional pole is used to separately sense the position of the door. Another single pole switch is also added to redundantly sense the position of the door. If any of these switches are not actuated, the warning light on the flight engineer's panel and a new light added to pilot's glareshield panel will be illuminated. The modification also requires installation of new cargo door control panels on the forward and aft lower cargo doors. The new panel incorporates an additional light to indicate proper door locking.

The FAA mandated the incorporation of this service bulletin within 18 months by AD 90-09-06, Amendment 39-6581, effective May 29, 1990.

Also, as a result of this accident, on May 4, 1990, the National

Transportation Safety Board issued the following safety recommendations to the FAA:

Amend 14 CFR 25.1447(c)(4) to require that face masks be attached to the regulators of portable emergency oxygen bottles. (Class II, Priority Action) (A-90-54)

Require, in accordance with the requirements of 14 CFR 25.1447 (c)(4), that a portable oxygen bottle be located at the flight attendant stations at exit door 5 right and at exit door 5 left in B-747 airplanes. (Class II, Priority Action) (A-90-55)

Require that no articles be placed in storage compartments that are located over emergency exit doors. (Class II, Priority Action) (A-90-56)

Amend 14 CFR 121.309(f) to require a readily accessible megaphone at each seat row at which a flight attendant is stationed. (Class II, Priority Action) (A-90-57)

Take corrective action to improve direct visibility to passengers from the upper level flight attendant jumpseat in the B-747 airplanes using eye reference data contained in Federal Aviation Administration report FAA-AM-75-2 "Anthropometry of Airline Stewardesses." (Class II, Priority Action) (A-90-58)

Issue an Airworthiness Directive to require that stronger latches be installed in oversized storage compartments that formerly held liferafts on all B-747 airplanes and also limit the distance that these compartments can be opened. (Class II, Priority Action) (A-90-59)

Demonstrate for each make and model of life preserver that it can be donned, adjusted, and tightened within the elapsed time required by TSO-C13d. Direct particular attention to the ease with which straps pass through adjustment fittings when the straps are pulled at all possible angles. (Class II, Priority Action) (A-90-60)

Establish a cutoff date of [within 1 year of this recommendation letter] after which all life preservers manufactured for passengercarrying aircraft would be required to meet the

specifications of TSO-C13e. (Class II, Priority Action) (A-90-61)
The FAA first responded to these safety recommendations in a July 26, 1990, letter. Further responses to various safety recommendations in the group came in letters dated October 26, 1990 (A-90-59); May 13, 1991 (A-90-58); September 23, 1991 (A-90-55, -56, and -59); and March 9, 1992 (A-90-59). The current status of each safety recommendation is:

A-90-54: "Open--Acceptable Response," pending outcome of potential rulemaking initiative by the FAA.

A-90-55: "Open--Unacceptable Response," pending a review by the FAA of B-747 airplanes for compliance with portable oxygen bottle placement and securement requirements and for modifications that do not meet the intent of the type certification.

A-90-56: "Open--Unacceptable Response," pending a reexamination by the FAA of the potential for contents of compartments spilling out during an emergency and obstructing passengers.

A-90-57: "Open--Unacceptable Response," pending the FAA's review of its position regarding a requirement for multiple megaphones on passenger airplanes.

A-90-58: "Closed--Reconsidered" as a result of the Safety Board's acceptance of the FAA position that the cabin jumpseat design on B-747's does not constitute an unsafe condition.

A-90-59: "Open--Acceptable Response," pending the issuance of an Airworthiness Directive to require stronger latches on oversized storage compartments on B-747 airplanes.

A-90-60: "Open--Acceptable Response," pending the implementation of the latest iteration of TSO-C13.

A-90-61: "Open--Unacceptable Response," pending inclusion in TSO-C13 (latest iteration) of a cutoff date after which all life preservers manufactured for passenger-carrying aircraft would be required to meet the specifications of the TSO.

The FAA's March 9, 1992, response to Safety Recommendation

A-90-59 included the final AD addressing this issue. The AD does meet the intent of the recommendation, which is now classified as "Closed--Acceptable Action."

Also as a result of this accident, on May 4, 1990, the Safety Board reiterated the following recommendations to the FAA:

A-85-35

Amend 14 CFR 121 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; ensure that 14 CFR 25 is consistent with the amendments to Part 121.

A-85-36

Amend 14 CFR 125 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; amend Part 125 to require approved flotation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR 25 is consistent with the amendments of Part 125.

A-85-37

Amend 14 CFR 135 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; Amend Part 135 to require approved floatation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR SFAR No. 23 is consistent with the amendments to Part 135.

In a November 28, 1988, letter to the FAA, the Safety Board recommended that a cutoff date January 1, 1989, be reestablished. Based on this accident, the Safety Board's again urges the FAA to establish a cutoff date by which life preservers meeting TSO-C13e would be introduced into the fleets within a reasonable time (A-85-36). The Safety Board recognizes that the FAA has complied with the part of this recommendation pertaining to the flotation-type seat cushions.

Safety Recommendations A-85-35 and -37 are being held in an "Open--Acceptable Action" status pending the publication of the final rule. Safety Recommendation A-85-36 is being held in an "Open--Unacceptable Action" status because Part 125 operations were not included in the FAA rulemaking action.

As a result of its investigation, on May 4, 1990, the Safety Board also recommended that the State of Hawaii, Department of Transportation, Airports Division:

Develop, in cooperation with the Department of Defense, procedures for direct radio communication between aircraft rescue and fire fighting vehicles operated by the State of Hawaii and Hickam Air Force Base that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-62)

Additionally, as a result of its investigation, on May 4, 1990, the Safety Board recommended that the Department of Defense:

Develop, in cooperation with the State of Hawaii Department of Transportation, procedures for direct radio communication between aircraft rescue and firefighting vehicles operated by Hickam Air Force Base and the State of Hawaii that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-63)

Comply with Federal Regulation 14 CFR 139.319(f)(2) and the guidance contained in Federal Aviation Administration Advisory Circular 150/5220-14 by using high visibility color for aircraft rescue and firefighting vehicles that operate at Honolulu International Airport. (Class II, Priority Action) (A-90-64)

The Department of Defense responded to Safety

Recommendations A-90-63 and -64 on August 17, 1990, citing the establishment of emergency radio communication ability between ARFF vehicles operated by Hickam Air Force Base and the State of Hawaii at Honolulu International Airport. Based on this action, Safety Recommendation A-90-63 was classified as "Closed--Acceptable Action" on December 12, 1990. With the establishment of the communications system as recommended, the Safety Board now classifies Safety Recommendation A-90-62 as "Closed--Acceptable Action."

Also, with regard to Safety Recommendation A-90-64, the Department of Defense pointed out that the Air Force has initiated a program to rep™ aint the vehicles over a 3-year period to spread out funding concerns. This safety recommendation is being held as "Open--Acceptable Response," pending the completion of the repainting program in 1993.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Member

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Member

JAMES L. KOLSTAD

Member

March 18, 1992

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Washington Headquarters of the National Transportation Safety Board was notified of the United Airlines accident within a short time after the occurrence. A full investigation team departed Washington, D.C. at 1400 eastern daylight time on the same day and arrived in Honolulu at 0030 Hawaiian standard time the next day.

The team was composed of the following investigation groups: Operations, Structures/Systems, Maintenance Records, Metallurgy, and Survival Factors. In addition, specialist reports were prepared relevant to the CVR, FDR and radar plots.

Parties to the field investigation were United Airlines, the FAA, the Boeing Commercial Airplane Company, the Air Line Pilots Association, the International Association of Machinists, and the Association of Flight Attendants.

2. Public Hearing

A 3-day public hearing was held in Seattle, Washington, beginning on April 25, 1989. Parties represented at the hearing were the FAA, United Airlines, the Boeing Commercial Airplanes Company, the Air Line Pilots Association, and the International Association of Machinists.

APPENDIX B

PERSONNEL INFORMATION

Captain David Cronin

Captain David Cronin, 59, was hired by UAL on December 10, 1954. The captain holds Airline Transport Pilot (ATP) Certificate No. 1268493 with airplane multiengine land ratings and commercial privileges in airplane single-engine land, sea and gliders. The captain is type rated in the B747, DC10, DC8, B727, Convair (CV) 440, CV340, CV240 and the learjet. The captain was issued a first class medical certificate on November 1, 1988, with no limitations.

The captain's initial operating experience (IOE) check out in the B747 occurred in December, 1985. The captain's latest line and proficiency checks in the B747 were completed in August and December, 1988, respectively. Training in ditching and evacuation was included with the proficiency check. The captain had flown a total of about 28,000 hours, 1,600 to 1,700 hours of which were in the B747. During the 24-hour, 72-hour and 30-day periods, prior to the accident, the captain had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 76 hours, 18 minutes, respectively.

First Officer Gregory Slader

First Officer Gregory Slader, 48, was hired by UAL on June 15, 1964. The first officer holds ATP Certificate No. 1528630 with airplane multiengine land ratings and commercial privileges in airplane single-engine land. The first officer is type rated in B747, DC10, B727, and B737. The first officer was issued a first class medical certificate on February 14, 1989, with no limitations.
The first officer's initial operating experience (IOE) check out in the B747 occurred in August, 1987. The first officer's latest proficiency check in the B747 was completed in October, 1988. Training on ditching and evacuation was included with the proficiency check. The first officer had flown a total of about 14,500 hours, 300 hours of which were in the B747. During the 24-hours, 72-hour and 30-day periods prior to the accident, the first officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Second Officer Randal Thomas

Second Officer Randal Thomas, 46, was hired by UAL on May 22, 1969. The second officer holds Flight Engineer Certificate No. 1947041 for turbo jet powered airplanes, issued July 18, 1969. The second officer holds commercial pilot certificate No. 1585899 with ratings and limitations of airplane single and multiengine land with instrument privileges. The second officer was issued a first class medical certificate on December 6, 1988, with no limitations.
The second officer's IOE check out in the B747 occurred in March, 1987. The second officer's latest proficiency check in the B747 was completed in October, 1988. Training in ditching and evacuation was included with the proficiency check. He had flown a total of

about 20,000 hours, about 1,200 hours of which were as second officer on the B747. During his 24-hour, 72-hour and 30 day-periods, prior to the accident, the second officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Flight Attendant and Chief Purser Laura Brentlinger

Flight attendant Laura Brentlinger, 38, was employed by UAL in May 1982; and had completed B747 recurrent training on September 19, 1988.

Flight Attendant and AFT Purser Sarah Shanahan

Flight attendant Sarah Shanahan, 42, was employed by UAL in August 1967; and had completed B747 recurrent training on October 10, 1988.

Flight Attendant Richard Lam

Flight attendant Richard Lam, 41, was employed by UAL on April 1970; and had completed B747 recurrent training on September 16, 1988.

Flight Attendant John Horita

Flight attendant John Horita, 44, was employed by UAL in June 1970; and had completed B747 recurrent training on November 1, 1988.

Flight Attendant Curtis Christensen

Flight attendant Curtis Christensen, 34, was initially employed by PAA in May 1978. He was subsequently employed by UAL in February 1986 when UAL purchased PAA Pacific Division. Flight attendant Chrisensen had completed B747 recurrent training on December 12, 1988.

Flight Attendant Tina Blundy

Flight attendant Tina Blundy, 36, was employed by UAL in May 1973; and had completed B747 recurrent training on October 28, 1988.

Flight Attendant Jean Nakayama

Flight attendant Jane Nakayama, 37, was employed by UAL in

August 1973; and had completed B747 recurrent training on December 6, 1988.

Flight Attendant Mae Sapolu

Flight attendant Mae Sapolu, 38, was initially employed by Pan American Airlines (PAA) in March 1973. She was subsequently employed by UAL in February 1986; when UAL purchased PAA Pacific Division. Flight attendant Sapolu completed B747 recurrent training on October 13, 1988.

Flight Attendant Robyn Nakamoto

Flight attendant Robyn Nakamoto, 26, was employed by UAL in April, 1986, and transferred to the Inflight Service Division in May, 1988. She was initially trained on the B747 in May 1988; and had not attended recurrent training.

Flight Attendant Edward Lythgoe

Flight attendant Edward Lythgoe, 37, was employed by UAL in December 1978; and had completed B747 recurrent training on October 21, 1988.

Flight Attendant Sharol Preston

Flight attendant Sharol Preston, 39, was employed by UAL in July 1970; and had completed B747 recurrent training on July 29, 1988.

Flight Attendant Ricky Umehira

Flight attendant Ricky Umehira, 35, was employed by UAL in November 1983; and had completed B747 recurrent training on November 15, 1988.

Flight Attendant Darrell Blankenship

Flight attendant Darrell Blankenship, 28, was employed by UAL in February 1984; and had completed B747 recurrent training on February 10, 1988.

Flight Attendant Linda Shirley

Flight attendant Linda Shirley, 30, was employed by UAL in March 1979; and had completed B747 recurrent training on November 3, 1989.

Flight Attendant Ilona Benoit

Flight attendant Ilona Benoit, 48, was initially employed by PAA in November 1969. She was subsequently employed by UAL in February 1986; and had completed B747 recurrent training on November 17, 1988.

Lead Ramp Serviceman Paul Engalla

Lead ramp serviceman Paul Engalla was employed by UAL in 1959. Because of his extensive ramp service experience, Mr. Engalla was selected as a ramp service trainer in 1986.

Ramp Serviceman Daniel Sato

Ramp serviceman Daniel Sato was employed by UAL in May 1987. Company records indicate that his proficiency in the opening and closing of B747 cargo doors and the operation of container loads was attained in September 1988.

Ramp Serviceman Brian Kitaoka

Ramp serviceman Brian Kitaoka was employed by UAL in November 1986. Company records indicate that his proficiency in the operation of container loaders was attained in November 1987. His proficiency in the opening and closing of B747 cargo doors was attained in October 1988.

Dispatch Mechanic Steve Hajanos

Dispatch mechanic Steve Hajanos was employed as an airplane mechanic by UAL on October 30, 1986. He holds FAA Airplane and Powerplants Certificate No. 362583850, issued November 14, 1981. He was formerly employed by Aloha Airlines as a maintenance supervisor and by World Airways as a mechanic and maintenance supervisor. He began his aviation career as an airplane mechanic in the United States Air Force.

APPENDIX C

AIRPLANE INFORMATION

Type of Date of Maximum Inspection Inspection Cycles Interval Service No. 1 Current 02/23/89 58,814:24 15,027 Note 1 Previous 02/23/89 58,809:02 15,026 Service No. 2 Current 02/22/89

58,802:35 15,024 65 Hours Previous 02/18/89 58,747:12 15,016 Note 2 A Check Current 02/14/89 58,710:14 15,009 350 Hours Previous 01/16/89 58,368:57 14,947 B Check Current 11/28/88 57,751:44 14,839 131 Days Previous 07/28/88 56,635:36 14,632 C Check Current 11/28/88 57,751:44 14,839 393 Days Previous 11/19/87 53,789:00 14,146 MPV Check Current 04/30/84 43,731:0 11,857 5 Years Previous 01/30/80 30,906:0

D Check Current 04/30/84 43,731 19,237 9 Years Previous 09/09/76 19,237 Note 1: Service No. 1 to be accomplished on through flights or at trip termination whenever time is less than 12 hours per Maintenance Manual Procedures BX 12-0-1-1.

Note 2: Aircraft with layover of 12 hours or more will receive a Service No. 2 not to exceed 65 flight hours between checks.

APPENDIX D

INJURY INFORMATION

Flight Crewmember.--The second officer sustained minor superficial brush burns to both elbows and forearms, during the evacuation.

Cabin Crewmembers.--The cabin crewmembers sustained the following injuries during the evacuation:

Flight attendant No. 1 sustained a strained left shoulder;

Flight attendant No. 2 sustained acute thoracic and lumbosacral strain;

Flight attendant No. 3 sustained a mild right bicep strain;

Flight attendant No. 4 sustained a left elbow contusion, left shoulder dislocation, and mild lumbosacral strain;

Flight attendant No. 5 sustained a left calf contusion;

Flight attendant No. 6 sustained a mild left elbow bruise;

Flight attendant No. 7 sustained mild left arm and lower back strain;

Flight attendant No. 8 sustained a soft tissue injury to the back;

Flight attendant No. 9 sustained abrasions to both palms and the left knee;

Flight attendant No. 10 sustained a fracture of the left tenth rib;
Flight attendant No. 11 sustained a minimal injury to the right middle finger PIP joint and left first MP joint;
Flight attendant No. 12 sustained a pulled muscle on the left side of the neck;
Flight attendant No. 13 sustained a comminuted fracture of the right ulna and radius;
Flight attendant No. 14 sustained a mild thoracic back strain;
Flight attendant No. 15 sustained a non-displaced fracture of C-6, a cerebral concussion, a fracture of the proximal right humerus, and multiple lacerations;
A flight attendant, flying as a passenger, sustained mild lumbosacral strain, a laceration of the right little finger, and a left elbow abrasion.
Passengers.--Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH, and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally injured in the accident.
Passengers seated in the indicated seats sustained the following injuries:
Seat
7C - Barotrauma to both ears
9C - Half-inch laceration to the upper left arm, superficial abrasions to left arm and hand, barotrauma to both ears
9E - Superficial abrasions and contusions to the left hand, mild barotrauma to both ears
10B - Superficial abrasions to the left elbow and left middle finger
10E - Superficial abrasions to the torso and left forearm, bruising of the left hand and fingers
11E - Laceration on the right ankle tendon, multiple bruises
11F - Slight contusion of the right shoulder
13D - Barotrauma to both ears

13E - Bleeding in both ears
13H - Contusion to the left periorbital area
14A - Laceration in the parietal occipital area, barotrauma to both ears
15J - Comminuted fracture of the lateral epicondyle of the left distal humerus (about 5mm separation)
16B - Superficial abrasions to the right arm
16J - Barotrauma to both ears
16K - Right temporal abrasions
26A - Barotrauma to both ears
26B - barotrauma to both ears
26H - Barotitis to both ears, low back pain, irritation to the right eye due to foreign bodies
27A - Barotrauma to the right ear
28J - Superficial abrasions and a contusion to the left hand, mild barotrauma to both ears

1The flap track canoe fairings are numbered 1 through 8, from left outboard to right outboard.

2For ease in reference, the following numbering was used to relate forward cargo door frames to fuselage body stations (BS): frame 1--BS 567.10, frame 2--BS 580.95, frame 3--BS 596.75, frame 4--BS 608.15, frame 5--BS 623.96, frame 6--BS 636.02, frame 7--BS 651.50, frame 8--BS 662.90.

3 The "used" switch is the switch through which electricity passes; the "unused" switch does not have electricity pass through it.

4NFPA 414 - Aircraft Rescue and Fire Fighting Vehicles, National Fire Protection Association, 1984, Batterymarch Park, Quincy, MA 02269.

5Airport Fire and Rescue Vehicle Specification Guide, AC 150/5220-14, March 15, 1979, Federal Aviation Administration, Washington, D.C. 20591.

6 Air Carrier Overwater Emergency Equipment and Procedures" (NTSB/SS-85/02)

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:49 PM PDT
To: Sterns@trial-law.com
Subject: **AI 182 AAR**

Canadian Aviation Bureau canadien Safety Board de la sécurité aérienne AVIATION OCCURRENCE AIR INDIA BOEING 747-237B VT-EFO CORK, IRELAND 110 MILES WEST 23 JUNE 1985 1.0 INTRODUCTION

Air India Flight 182, a Boeing 747-237B, registration VT-EFO, was on a flight from Mirabel to London when it disappeared from the radar scope at a position of latitude 51°O'N and longitude 12°50'W at 0714 Greenwich Mean Time (GMT), 23 June 1985, and crashed into the ocean about 110 miles west of Cork, Ireland. There were no survivors among the 329 passengers and crew members. The depth of the water at the crash site is about 6,700 feet.

At 0541 GMT, 23 June 1985, CP Air Flight 003 arrived at Narita Airport, Tokyo, Japan, from Vancouver. At 0619 GMT a bag from this flight exploded on a baggage cart in the transit area of the airport within an hour of the Air India occurence. Two persons were killed and four were injured. From the day of the occurrences, there have been questions about a possible linkage between the events.

This Submission examines the information available to the Canadian Aviation Safety Board (CASB) with respect to the circumstances surrounding the AI 182 accident. The sources of information include: information made public to the Indian Inquiry as a result of the RCMP investigation; the flight data recorder (FDR), cockpit voice recorder (CVR) and Shannon ATC tape recording analyses by Canadian, United Kingdom, and Indian authorities; the medical evidence obtained from Dr. Hill of the Accident Investigations Branch of the United Kingdom; and the evidence obtained by examination of the wreckage recovered, the wreckage distribution pattern, photographs, and videotapes of the wreckage on the ocean bottom.

2.0 EXAMINATION

2.1 Vancouver

On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight East Indian accent.* He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vancouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

On the same date at approximately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

On 20 June 1985 at about 1210 PDT (1910 GMT), a male appearing to be of East Indian origin purchased the tickets with cash from a CP Air ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to M. Singh. The telephone contact number was also changed. The final itinerary was as follows:

a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22 June 1985

*See Appendix A for chronology of events.

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22 June 1985

b) L. Singh - CP 003 Vancouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 (local time in Tokyo), 23 June 1985

On 22 June 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy East Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that he was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

On Saturday morning, 22 June 1985, a CP Air passenger agent worked check-in position number 26 at the CP Air ticket counter, Vancouver International Airport, and recalls dealing with a passenger booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto he could not interline his baggage. The passenger insisted and, as the line-ups were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that M. Singh checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage. The flight manifest for CP 003 shows that on the same day the person using the name of L. Singh with a ticket to Bangkok also checked in through the same counter, was assigned seat 38H, and checked one piece of baggage.

A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as M. and L. Singh did not board these respective flights.

2.2 Toronto

Air India Flight 181 from Frankfurt arrived at Toronto on 22 June 1985 at 1430 EDT (1830 GMT) and was parked at gate 107 of Terminal 2. All passengers and baggage were removed from the aircraft and processed through Canada Customs. Passengers continuing on the flight to Montreal were given transit cards, and on this flight 68 cards were handed out. These transit passengers are required to claim their luggage and proceed through Canada Customs. Prior to entering the public area, there is a belt which is designated for interline or transit baggage. Transit passengers deposit their luggage on this belt which carries it to be reloaded on the aircraft. This baggage was not subjected to X-ray inspection as it was presumed to have been screened at the passengers' overseas departure point. When the transit passengers checked in to proceed to Montreal, their carry-on baggage was subjected to the normal security checks in place on this date. Passenger and baggage security checks were conducted by Burns International Security Services Ltd. and all passenger and baggage processing for both off-loading and on-loading was handled by Air Canada staff.

Air India Flight 181 was composed of the following:

- passengers continuing to Montreal (68)
- passengers from connecting flights

AC 102 (Saskatoon) 2
AC 106 (Edmonton) 4
AC 192 (Winnipeg) 1
AC 170 (Winnipeg) 4
AC 136 (Vancouver) 10
CP 060 (Vancouver) 1 Standby (M. Singh)

- passengers originating at Toronto
- diplomatic bags from the Vancouver India Consul General via AC 508
- produce cargo from India
- cargo in the form of 5th pod engine components loaded in the aft cargo compartment.

It should be noted that some passengers from India book flights to Montreal with their intended destination being Toronto. The reason is that the fare to Montreal is cheaper and therefore some passengers get off the flight in Toronto, claim their luggage and leave without reporting a cancellation of the trip to Montreal. It has been established that 65 of the 68 transit passengers reboarded the flight to Montreal.

Air India personnel were in charge for the overall operation at Toronto regarding the unloading and loading of both passengers and cargo. Although the actual work was performed by various companies under contract, Air India personnel oversaw the operation. The Air India station manager was away on vacation on 22 June 1985. The evidence does not clearly establish who had been assigned to replace the station manager and assume his duties.

Air Canada had stored in a hangar an engine that had failed on a previous Air India flight from Toronto on 8 June 1985. Air Canada received a message from Air India stating that the failed engine was to be mounted as a 5th pod on Flight 181/182 on 22 June 1985. The engine was prepared for loading and component parts were crated for loading into the aft cargo compartment. On 22 June, the component parts were taken from the hangar and placed outside to be delivered to the aircraft by MEGA International Air Cargo. The component parts were placed just inside the airport fence separating the restricted and unrestricted areas. The installation began immediately upon the arrival of Flight 181 and was completed at 1530 EDT (1930 GMT). The front engine cowling was crated but would not fit through the aft cargo door. The crating was rearranged, and the door stops on the cargo door were removed to permit the loading of the crate and the remaining engine parts were loaded on pallets. Due to problems with loading the 5th pod and component parts, the departure was delayed from 1835 EDT (2235 GMT) to 2015 EDT (0015 GMT, 23 June).

CP Air Flight 060 arrived in Toronto at 1610 EDT (2010 GMT) and docked at gate 44, Terminal 1. A number of passengers on this flight were interlined to other flights including passenger M. Singh wait-listed on Air India Flight 181/182. It has been established that this passenger did not board Flight CP 060 but did check baggage onto the flight. This baggage was to be interlined to the Air India flight departing from Terminal 2. In this case, CP Air employees would have off-loaded all baggage from CP 060 and deposited the baggage at Racetrack 6 on the ring road of Terminal 1 to be transported to the Air Canada sorting room at Terminal 2.

Consolidated Aviation Fuelling and Services (CAFAS) is a company which is contracted to pick up and deliver baggage from one terminal to the other. The CAFAS driver on duty at the time recalls picking up a bag from a CP Air flight originating in Vancouver and destined for Air India at Terminal 2. As this piece of luggage did not turn up as found luggage, it is deduced that normal practice was followed, and the luggage was interlined and loaded on AI 181/182.

MEGA International Air Cargo is a firm that handled air cargo and containers for Air India. Since the flight was carrying a 5th engine and component parts, no commercial cargo could be loaded at Toronto. MEGA delivered the engine component parts to be loaded in the cargo compartment by Air Canada employees. Later, MEGA received two diplomatic bags and delivered these to the aircraft. The bags were loaded into the valuable goods container (see Appendix B). These bags were not subjected to X-ray or any other security checks.

All checked-in baggage for AI 181/182 was to be screened by an X-ray machine which was located in Terminal 2 at the end of international belt number 4. This location would permit all baggage from the check-in counters and interline carts to be fed through the X-ray machine before being loaded. It has been established that this machine worked intermittently for a period of time and stopped working during the loading process at about 1700 EDT (2100 GMT). Rather than opening the bags and physically inspecting them, the Burns security personnel performing the X-ray screening were told by the Air India security officer to start using the hand-held PD-4 sniffer.

One Burns security officer checked the bags with the sniffer while another put stickers on the bags and forwarded them. The security officer forwarding the baggage recalls the sniffer making short beeping noises not long whistling ones. The security officer who used the sniffer claims it never went off, and the only time any sound was made was when it was turned on and off. At those times, it would emanate a short beep (refer to section 2.8 for further information regarding the PD-4 sniffer).

Burns International Security had a contract with Air India for the security of the aircraft while it was docked. The security arrangements contracted from Burns were as follows:

- security at the bridge door leading to the aircraft;
- security inside the aircraft from the time the passengers disembarked upon flight arrival until flight departure;
- security guards assigned the physical inspection of all carry-on baggage in the departure room; and
- security guards in the international baggage make-up room conducting screening of baggage using an X-ray machine and a hand-held PD-4 sniffer.

The statements taken from Burns security personnel in Toronto indicated that a significant number of personnel, including those handling passenger screening, had never had the Transport Canada passenger inspection training program or, if they had, had not undergone refresher training within 12 months of the previous training.

As a result of official requests made by Air India in early June 1985 for increased security for Air India flights, the RCMP provided additional security as follows:

- one member in a marked police motor vehicle patrolling the apron area;
- one member in a marked police motor vehicle parked under the right wing from time of arrival until push-back;
- one member on foot patrol at Air India check-in counter; and
- one member at the loading bridge during boarding.

In addition, all RCMP members working in that particular area of Terminal 2 were aware of the Air India flight and would check in with the assigned personnel during their patrols in the area of the aircraft and check-in/boarding lounges. Uniformed members are to patrol and monitor security within the airport premises as detailed in section 2.5 below.

Passenger check-in was handled for Air India by Air Canada under contract with Air India. The check-in included passengers originating in Toronto and interline passengers but did not include the transit passengers to Montreal. The check-in passengers were numbered using a security control sheet in accordance with instructions from Air India;

however, the check-in and interline baggage was not numbered, and no attempt was made to correlate baggage with passengers. Hence, any unaccompanied interline baggage would not have been detected.
The flight and cabin crew had been in Toronto for the week prior to this flight and were to take the aircraft to London where they would be replaced by another crew. The crew members themselves and their carry-on baggage were not subjected to any security checks; however, their checked-in baggage was screened in the same manner as other baggage.

2.3 Montreal

Air India Flight 181 from Toronto arrived at Mirabel International Airport at about 2100 EDT (0100 GMT, 23 June) and parked in supply area number 14 at 2106 EDT (0106 GMT). The 65 passengers destined for Montreal along with three Air India personnel deplaned and were transported by bus to the terminal building. The remaining passengers remained on board as transit passengers and were not permitted to disembark at Montreal. Air Canada baggage handlers off-loaded four containers of cargo, three containers of baggage and a valuables container. Two diplomatic pouches from the Indian High Commission in Ottawa were delivered to the aircraft by MEGA International Cargo. One pouch weighing one kilogram was hand-delivered to the flight purser for storage in a valuables locker within the cabin and the other pouch was loaded into the valuables container.
During the check of the aircraft at Montreal, the second officer pointed out to an Air Canada mechanic that a rear latch on the fan cowl for the 5th engine did not appear to be properly secured. The mechanic examined the latch and found it well secured, but the handle was not flush and was hanging about five degrees. The mechanic applied high-speed tape to the latch handle for aerodynamic smoothness. This repair was examined by the second officer who was satisfied with the work. No records were completed by Air Canada in connection with this temporary repair.
At about 1730 EDT (2130 GMT), Air Canada, which is Air India's contracted agent, opened its check-in counter to passengers who would

be flying on Air India Flight 182. Burns security personnel were also assigned at this time to screen the checked baggage. Passenger tickets were checked, issued a number, and copies of the tickets were removed and retained by Air Canada. Boarding passes were then issued and affixed to the numbered tickets. Also attached to the ticket booklets were numbered tickets which corresponded to each piece of checked baggage. The numbered checked baggage was sent to the baggage area by Air Canada personnel to be security-checked by Burns security personnel. The passengers for AI 182 after checking in were free to enter the departure area. At the entrance to the departure area, Burns security staff used X-ray units and metal detectors to screen passengers and carry-on baggage. At about 2100 EDT (0100 GMT), the passengers proceeded to gate 80 where they gave their boarding passes and numbered tickets to an Air Canada agent. The agent kept the numbered flight tickets and checked the numbers against the passenger list. Also, at gate 80, a secondary security check was done on passengers by a Burns security officer using a metal detector. Hand-carried baggage was subjected to further physical and visual checks. A total of 105 passengers boarded the flight at Mirabel Airport; there were no interline passengers.

Between 1900 (2300 GMT) and 1930 EDT (2330 GMT), Burns security personnel identified a suspect suitcase using the X-ray machine. The suitcase was placed on the floor next to the machine. The Burns security supervisor told Air India personnel that a suspect suitcase had been located and was advised within 15 to 20 minutes to wait for the Air India security officer who would be arriving on the flight from Toronto. Subsequently, a second suspect suitcase was identified and a little later a third. The three suitcases were placed next to the X-ray machine.

Between 1930 (2330 GMT) and 1945 (2345 GMT), all the Burns security personnel at the X-ray machine were assigned to other duties and the three suspect suitcases remained in the baggage area without supervision. At about 2140 (0140 GMT), the Air India security officer went to the baggage room and inspected the three suitcases with the X-ray machine and a sniffer that was in the possession of the security officer. The Air India security officer decided to keep the three suitcases and, if further examination proved negative, send them on a later flight. At approximately 2155 (0155 GMT), the Air Canada Operations Centre supervisor contacted the airport RCMP detachment regarding the suspect suitcases. At about 2205 (0205 GMT), an RCMP member located the suitcases in the baggage room and requested that an Air India representative be sent to the baggage room. About five minutes later, the Air India security officer contacted the baggage room by telephone and advised that he could not come to the room immediately. The Air India security officer arrived in the baggage room at about 2235 (0235 GMT) and, when asked to determine the owners of the suitcases, informed the RCMP member that the flight had already departed [2218 (0218 GMT)]. The three suspect suitcases were later examined with negative results. The remainder of the checked baggage which cleared the security check was identified by a green sticker. The baggage was then forwarded to Air Canada personnel who loaded the baggage in containers to be placed on board the aircraft. A later check with Canada Customs and Air Canada at Mirabel revealed no unclaimed baggage associated with AI 181/182. A similar check at Dorval Airport was conducted with negative results.

No record was kept as to the location and number of individual pieces of checked-in luggage. Records were kept as to the location of the containers according to destination, where loaded and the number of pieces of luggage in each container (see Appendix B).

The Mirabel Detachment of the RCMP provided the following security at the airport on 22 June 1985:

- one member in a police vehicle for airside security;
- one member on patrol in the arrival and departure areas;
- one member on general foot patrol throughout the terminal; and
- one member as a telecommunications operator in the detachment office.

In addition, due to the increased threat to Air India flights, the RCMP provided the following supplementary coverage to Air India Flight 181/182 on 22 June 1985:

- one member in a police vehicle escorted the aircraft to and from the runway and the terminal building and remained with the aircraft while it was stationary;

- one member in a police vehicle remained at the entrance to the ramp;
- two members patrolled the area of the ticket counter and access corridors, and one of these members also served in a liaison capacity with the airline representatives.

2.4 International Standards and Recommended Practices

International security standards and recommendations to safeguard international civil aviation against acts of unlawful interference are listed in ICAO Annex 17 to the Convention on International Civil Aviation. Suggested security measures and procedures are amplified in the ICAO Security Manual for Safeguarding Civil Aviation Against Acts of Unlawful Interference.

Annex 17 requires contracting States of which Canada is one to "take the necessary measures to prevent weapons or any other dangerous devices, the carriage or bearing of which is not authorized, from being introduced by any means whatsoever, on board an aircraft engaged in the carriage of passengers."

In addition to other recommendations, Annex 17 recommends that contracting States should establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage, cargo, mail and stores to be carried on board aircraft.

The Security Manual specifies that,

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Recently, ICAO has proposed amendments to Annex 17. These proposals arise from a decision taken by the Council in its 115th Session on 10 July 1985. The Council instructed its Committee on Unlawful Interference, as a matter of urgency, to review the entirety of Annex 17 and to report on those provisions which might be immediately introduced, upgraded to Standards, strengthened or improved. Among the proposed amendments is the following upgrading in the Standards:

- Each contracting State ensure the implementation of measures at airports to protect cargo, baggage, mail stores and operator's supplies being moved within an airport to safeguard such aircraft against an act of unlawful interference.

2.5 Canadian Law

In terms of Canadian statutory requirements, the Civil Aviation Security Measures Regulations and the Foreign Aircraft Security Measures Regulations made pursuant to the Aeronautics Act require specified owners or operators of aircraft registered in Canada or specified owners or operators who land foreign aircraft in Canada to establish, maintain, and carry out security measures at airports consisting of:

- systems of surveillance of persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- systems of searching persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas that are inaccessible to any person other than a person who has been searched and the personnel of the owner or operator;
- a system that provides, at airports where facilities are available, for check-points at which persons intending to board the aircraft of an owner or operator can be searched;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas in which cargo, goods and baggage that have been checked for loading on aircraft are inaccessible to persons other than those persons authorized by the owner or operator to have access to those areas;
- a system of identification that prevents baggage, goods and cargo from being placed on board the aircraft if it is not authorized to be placed on board by the owner or operator; and
- a system of identification of surveillance and search personnel and the personnel of the owner or operator.

Specified carriers including Air Canada, CP Air, and Air India were required to provide a description of their security measures to the Canadian Minister of Transport.

An Order-in-Council on 29 September 1960 established that the RCMP was responsible for the direction and administration of police functions at major airports operated by Transport Canada. The duties of the Police and Security Detail at these designated airports include the following:

- carry out policing and security duties to guard against unauthorized entry, sabotage, theft, fire or damage;
- enforce federal legislation;
- respond to violations of the Criminal Code of Canada, Federal, Provincial, and Territorial statutes, and perform a holding action pending arrival of the police department having primary criminal jurisdiction;
- man guard posts; and
- provide a police response in those areas of airports where pre-board screening takes place.

Section 5.1(9) of the Aeronautics Act states that "The Minister may designate as security officers for the purposes of this section any persons or classes of persons who, in his opinion, are qualified to be so designated." Pursuant to this section Transport Canada has established criteria for persons or classes of persons that are designated as security officers in a Schedule registered on 11 April 1984. The criteria also specify that a security guard company and its employees will meet Transport Canada requirements provided that the company:

- is under contract with a carrier to conduct passenger screening under the Aeronautics Act and Regulations;
- is licensed in the province or territory;
- complies with the security guard criteria as follows in that the guard must:
  - be 18 years or older,
  - be in good general health without physical defects or abnormalities which would interfere with the performance of duties,
  - be licensed as a security guard and in possession of the licence while on duty, and
  - meet the training standards of Transport Canada consisting of successfully completing the Transport Canada passenger inspection training program, attaining an average mark of 70 per cent, and undergoing refresher training within 12 months from previous training;

- uses a comprehensive training program which has been approved by Transport Canada and is capable of being monitored and evaluated;
- keeps records showing the date each employee received initial training and/or refresher training and the mark attained; and
- provides supervision to ensure that their employees maintain competency and act responsibly in the conduct of searching passengers and carry-on baggage being carried aboard aircraft.

2.6 Canadian Security Procedures

In accordance with the Canadian Aeronautics Act and pursuant regulations, air carriers are assigned the responsibility for security. Transport Canada provides the following security services for the air carriers using major Canadian airports, including the international airports in Vancouver, Toronto and Montreal:

- security and policing staff including RCMP airport detachments;
- specific airport security plans and procedures;
- secure facilities (e.g., secure areas, pass identification systems, etc.); and
- security equipment and facilities (e.g., X-ray detection units, walk-through metal detectors, hand-held metal detectors, explosive detection dogs).

As of 22 June 1985, the following general security measures were in place at Canadian airports:

- metal detection screening of passengers; and
- X-raying of carry-on baggage.

Checked baggage was not normally subject to any security screening. A few air carriers such as Air India had extra security measures in place because of an assessed higher threat level (see section 2.7 below).

On 23 June 1985, Transport Canada required additional security measures to be implemented by all Canadian and foreign air carriers for all international flights from Canada except those to the continental United States. These measures required:

- the physical inspection or X-ray inspection of all checked baggage;
- the full screening of all passengers and carry-on baggage; and
- a 24-hour hold on cargo except perishables received from a known

shipper unless a physical search or X-ray inspection is completed. Further, on 29 June 1985, Transport Canada directed that all baggage or cargo being interlined within Canada to an Air India flight was to be physically inspected or X-rayed at the point of first departure and that matching of passengers to tickets was to be verified prior to departure.

2.7 Air India Security Program in Canada

In accordance with the Foreign Aircraft Security Measures Regulations, Air India had provided the Minister of Transport with a copy of its security program. It included measures to:

- establish sterile areas;
- physically inspect all carry-on baggage by means of hand-held devices or X-ray equipment;
- control boarding passes;
- maintain aircraft security;
- ensure baggage and cargo security; and
- off-load baggage of passengers who fail to board flights.

Under these procedures established by Air India, passengers, carry-on baggage, and checked baggage destined for AI 181/182 on 22 June 1985 were subjected to extra security checks. A security officer from the Air India New York office arrived in Toronto on 22 June 1985 to oversee the security operation at Toronto and Montreal.

On 17 May 1985, the High Commission of India presented a diplomatic note to the Department of External Affairs regarding the threat to Indian diplomatic missions or Air India aircraft by extremist elements. Subsequently, in early June, Air India forwarded a request for "full and strict security coverage and any other appropriate security measures" to Transport Canada offices in Ottawa, Montreal and Toronto, and RCMP offices in Montreal and Toronto.

2.8 PD-4 Sniffer

On 18 January 1985, prior to the inaugural Air India flight out of Toronto on 19 January, a meeting on security for Air India flights (Toronto) was held with representatives from Transport Canada, RCMP and Air India. At this meeting, a PD-4 sniffer belonging to Air India was produced. It was explained that it would be used to screen checked baggage as the X-ray machine had not yet arrived. At that time, an RCMP member tested its effectiveness. The test revealed that it could not detect a small container of gunpowder until the head of the sniffer was moved to less than an inch from the gunpowder. Also, the next day the sniffer was tried on a piece of C4 plastic explosives and it did not function even when it came directly in contact with the explosive substance. It is not known if this was the same sniffer used on 22 June 1985.

2.9 Medical Evidence

Medical examination was conducted on the 131 bodies recovered after the accident. This comprises about 40 per cent of the 329 persons on board. It should be noted that assigned seating is based on preliminary information. Also, the exact position of passengers is not certain because it is not known if passengers changed their seats after lift-off. On the information available, the passengers were seated as follows:

Passengers:*

	Seats Available	Occupied	Bodies Identified
Zone A	16	1	0
Zone B	22	0	0
Upper Deck	18	7	0
Zone C	112	104 + 2	29
Zone D	86	84 + 1	38
Zone E	123	105 + 3	50
SUB-TOTAL	377	301 (+6 infants)	117
Crew:			
Flight Deck	3	3	0
Cabin	19	19	5
TOTAL	399	329	122

There were 30 children recovered and they showed less overall injury. The average severity of injury increases from Zone C to E and is significantly less in C than in Zones D and E.

Flail pattern injuries were exhibited by eight bodies. Five of these were in Zone E, one in Zone D, two in Zone C and one crew member. The

significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.
There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evenly
*See Appendix C for interior seating arrangement.
distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).
Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 in Zone D, 11 in Zone E, 2 crew and 1 unknown), and 16 had little or no clothing.
Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).
There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).
There is a general absence of signs indicating the wearing of lap belts. Pathological examination failed to reveal any injuries indicative of a fire or explosion.
2.10 Flight Recorders and Shannon Air Traffic Control (ATC) Tape Analyses
VT-EFO was equipped with a Fairchild A100 Cockpit Voice Recorder (CVR) and a Lockheed 209E Digital Flight Data Recorder (DFDR). These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the aft pressure bulkhead. The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor.
The Shannon Air Traffic Control Centre was in contact with VT-EFO and recorded radio communications with the aircraft. At the time of the accident, 5.4 seconds of noise was recorded, and the transponder signal

seen on the radar scope was lost from the aircraft. This signal which displays aircraft altitude showed no deviation before disappearing from the radar scope.

2.10.1 Analysis by National Research Council, Canada

From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder. The initial waveform of the cockpit area microphone signal is not consistent with the sharp pressure rise expected with detonation of an explosive device close to the flight deck, but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, the possibility that it originated from such a device elsewhere in the aircraft cannot be excluded.

By correlating the oscillograph records of the CVR and the Shannon ATC VHF recording, it was estimated that the unusual sounds recorded on the ATC tape started 1.4 ± 0.5 seconds after the start of the sudden sound detected by the cockpit area microphone and lasted intermittently for 5.4 seconds. It was felt the closeness in time of the two noises indicated the 5.4 seconds recorded on the ATC tapes originated from AI 182. The ATC recording that followed the cockpit area microphone sounds appeared at first to contain a series of short intermittent sounds. Listening to the sounds, it also appeared that a human cry occurred near the end of the recording. Spectral analysis of these sounds and comparison with voice imitations revealed that the recorded sounds do not contain all the pitch harmonic frequencies normally associated with voice sounds. The origin of these sounds has not been determined.

An examination of the DFDR showed no abnormal variations before the accident. With the spare engine, this aircraft was restricted to altitudes below 35,200 feet and indicated airspeeds less than 290 knots. During the last 27 minutes of the flight, the computed airspeed did gradually increase to nine knots above this limit in the first part of this period and the power was readjusted several times. The speed fell below the 290 knot limit at about 07h:09m GMT as recorded by the DFDR; power was increased again at about 07h:10m causing the aircraft to accelerate to six knots above the limit by the time the accident occurred at 07h:13m:59s. The observed excursions outside the specified limits are not considered significant.

The aircraft was flown with 1.5-degree left-wing-down with 4.2 degrees clockwise control wheel as compared to the aircraft without the 5th engine installation. Also, 9.4 per cent of right rudder pedal was applied giving a 1.1-degree right deflection of the upper and lower rudders. Considering the carriage of the 5th engine on the left side, these figures are not considered abnormal.

When synchronized with the other recordings, it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR.

Irregular signals were observed over the last 0.27 inches of the DFDR tape. Laboratory tests indicated that the irregular signals most likely occurred as a result of the recorder being subjected to sharp angular accelerations about the lateral axis of the recorder, causing rapid changes in tape speed over the record head. This equates to an angular acceleration on the recorder about the aircraft's longitudinal axis in a left-wing-down sense. Therefore, these tests indicate that the digital recorder was subjected to a sharp jolt separate from any violent motion of the aircraft.

The other possibility for the irregular signals is that the Flight Data Acquisition Unit which generated the serial digital data signal and which is located in the electronics bay under the cabin floor forward of the cargo compartment could have suffered some damage or had an intermittent power supply that caused it to generate the irregular signals.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom

The AIB analysis was restricted to the CVR and the Shannon ATC tape. The correlation of the CVR and ATC tapes showed that the ATC recording started after the CVR had stopped recording and 1.1 ± 0.4 seconds from the start of the sudden sound. The total duration of the signal on the ATC tape was 5.4 seconds.

An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Evidence of the presence of audio warning signals buried amongst the noise was investigated with negative results. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.

The analysis of the ATC tape audio determined three or four words could be heard at the beginning of the transmission, but extensive filtering did not allow the sounds to be transcribed. Two bursts of tone occurred during the first second. The spectrum of the tone does not coincide with any B747 audio warning. The transmission is chopped until at about 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound is similar to that heard in other accidents where there has been a rapid increase in airspeed. Toward the end of the transmission a crying sound was heard; however, a study of the noise indicates a human cry would contain more harmonics. The origin of this sound was not determined. Knocking sounds were also heard during the transmission. These were initially thought to be due to hand-held microphone vibration, but this was discounted because of the frequency of the sounds. Almost identical sounds were heard on the DC-10 CVR after the explosive decompression had occurred. Their source was not identified. On the DC-10, the pressurization audio warning sounded 2.2 seconds after the decompression. No such warning was identified on the ATC tape.

*Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization. A loud noise is associated with this event but not necessarily an explosion.

Every aircraft provides a different signature when the press-to-transmit button is released. These signatures were compared with transients which occurred during the open microphone transmission. There is a close match with the previous AI 182 signatures. Therefore, it is almost certain that the ATC tape recording originated from AI 182.

The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182. It further states there is strong evidence to suggest a sudden explosive decompression of undetermined origin occurred. Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. However, the AIB report is of the opinion that the device would have to be small not to be detected as it is considered that a large high-explosive device could not fail to be detected on the CVR.

2.10.3 Analysis by Bhabha Atomic Research Centre (BARC), India

The BARC analysis was restricted to the CVR and the Shannon ATC tape.

Channel 3 of the recording which corresponded to the cockpit area microphone showed the first indication of a rising audio signal. The signal level rises from the ambient level in the cockpit by about 18.5 decibels in approximately 45 milliseconds. The signal starts falling and stabilizes at a level about 10 decibels higher than ambient for about 375 milliseconds. The total duration of the signal is about 460 milliseconds.

The timings of the CVR and the Shannon ATC tape were correlated, and it was determined that the explosive sound on the CVR coincided with the beginning of the series of audio bursts on the ATC tape. The report concluded that the sounds recorded on the ATC tape emanated from AI 182 at the time of the occurrence.

The noise on the CVR was compared with an explosion which caused the crash of an Indian Airlines B737. In this occurrence, the explosive sound recorded on the cockpit area microphone showed a rise time of about 8 milliseconds. It was also determined that the explosion occurred 8 feet from the microphone. The report concluded that the rise time is a measure of the distance from the cockpit area microphone to the source of an explosion. Hence, the exact location in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the cockpit judging from the rise time of 45 milliseconds.

The report concluded that the series of audio bursts on the ATC tape were most probably generated by the break-up of AI 182 in mid-air.

2.11 Aircraft Structures Examination

The examination of aircraft structures consisted of the following areas: floating wreckage, wreckage mapping and surveying, wreckage distribution, photographic and video interpretation of wreckage, wreckage recovery and initial examination, and examination of recovered wreckage.

2.11.1 Floating Wreckage

During the search, aircraft wreckage was sited and recovered by several search vessels. The wreckage was transported to Cork, Ireland, where preliminary examination was conducted. This examination took place in June and July, 1985.

The wreckage consisted mainly of various leading edge skin panels of the left and right wings, left wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canoe fairing pieces, landing gear wheel well doors, pieces of elevator and aileron, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggage, suitcases, personal effects and a number of internal fittings. The floating wreckage constitutes about three to five percent of the aircraft structure.

The wreckage was then transported from Ireland to Bombay, India where it underwent further examination by the Floating Wreckage Structures Group which then produced a report which was submitted to the Indian Inquiry. The report concluded:

- There was no evidence of fire damage.
- There was no evidence of lightning strike damage.
- The cabin floor panels from the forward and rear sections of the

aircraft separated from the support structure in an upward direction (floor to ceiling) pulling free from the attaching screws and, in some cases, breaking the vertical web of the seat track/floor beams.

- The position of the leading edge flap rotary actuator and the damage to the flap structure indicated that the leading edge flaps were in the retracted position.
- The six spoiler actuators found were in the retracted position. The lower surface of all the spoiler panels showed signs of spanwise skin splits with the edges curled into the core of the honeycomb. The report concluded that this was possibly due to the loading of the spoilers by being deployed in flight at high speed, resulting in compression on the lower surfaces. This, in turn, caused splitting of the lower skin into the honeycomb.
- The right wing root leading edge, number 3 engine inboard fan cowling, the right inboard midflap inboard leading edge, and the right stabilizer root leading edge all exhibited damage possibly due to objects striking the right wing and stabilizer before water impact.

In addition to the above conclusions, the following significant information regarding the floating wreckage is noted in the report:

- The aircraft was carrying a -7Q engine at the 5th pod and a -7J 5th pod kit in the aft cargo compartment. In all there were 14 engine fan cowls (four in the aft cargo compartment). Out of these 14 fan cowls, nine, including six from the working engines and three from the aft cargo compartment, and two additional pieces of fan cowls were found. Five of the fan cowls from the working engines showed folding damage lines at about the three and nine o'clock positions. The number 3 engine inboard fan cowl had severe impact damage on its leading edge and had small outward puncture holes but no penetration through the outer skin in the lower centre region. The two fan cowls of the -7J 5th pod kit stowed in the aft cargo compartment showed severe damage. One piece was cut at one corner in an arc of about 20 inches diameter and its external skin was peeled back.
- The cockpit entry door and the side bulkhead panel were found relatively intact but had come out of their attachments.

- Twelve toilet doors out of 16 were found and were relatively intact but had come out of their attachments.
- Cabin interior panels and overhead bins of the main and upper decks which were recovered exhibited only minor damage.
- The wooden boxes which contained the fan blades of the 5th pod engine were loaded in container 24L in the forward cargo compartment and were found broken apart exhibiting no burn marks.
- One passenger oxygen bottle and one portable oxygen bottle were recovered and showed no sign of damage.

Mr. V.J. Clancy, an aviation explosives expert representing Boeing Aircraft Corporation, prepared a preliminary report based on his examinations of certain items of recovered and floating wreckage. Mr. Clancy's report notes the following with respect to floating wreckage:

- A foam-backed floor panel which showed a small number of perforations was recovered. Mr. Clancy recommended that it should be X-rayed and a detailed examination completed.
- One of the lavatory doors had, into its inner surface, a number of fragments of glass mirror - presumably from breakage of a mirror normally fitted into the lavatory. Most of the fragments, buried edgeways, were oriented parallel to each other. The remainder were approximately at right angles to the others. Mr. Clancy concluded that it would be improbable that any reliance could be placed on the penetration by mirror fragments as being indicative of an explosion.
- Three steel oxygen cylinders which were stowed in the forward cargo compartment were recovered. One had been dented apparently by the impact of an object measuring about one to two centimetres. The depression had a maximum depth of about four millimetres.
- A few suitcases recovered among the floating wreckage were examined. Mr. Clancy felt that one might provide useful information. It was of red plastic material with a blue lining. Mr. Clancy reported that plastic material has been found to retain identifiable traces of explosive after long immersion in the sea. Also, the lining which was severely tattered resembled that of one found after an explosion in an aircraft in Angola.

- A wooden spares box was found on the foreshore of Wales. It was of the kind used on the aircraft. It was charred on one side and partially on the bottom. The depth of charring suggested that the burn time was three to four minutes. This box was normally stowed in the aft cargo compartment; however, on this flight it may have been stowed in the forward compartment.
- Two pieces of the cover of an overhead locker originating above either door 2R or 4R were also found on the foreshore. They were partially damaged and blackened by fire. Mr. Clancy concluded that this indicated the presence of fire.
- Two pieces of U-section alloy channel partially filled with plastic foam were found on the foreshore. The alloy was of a kind not used in aircraft structure; however, it could have been from some fitting supplied by a sub-contractor. Also, since the pieces were found near an area where practice firings at targets are carried out off the west coast of the United Kingdom, it could have come from some other source. One piece of the alloy bore marks ("mooncraters") typical of an attack by very high velocity fragments such as produced by an explosion. X-rays showed the presence of a few small particles buried in the foam which Mr. Clancy recommended should be extracted and examined. He also felt that this provided the strongest single indication of an explosion and that it was essential to determine if these pieces came from the aircraft or any of the equipment or cargo aboard the aircraft.

The CASB in its examination of the floating wreckage noted the following:

- The fan cowls of the number 4 engine had a series of five marks in a vertical line across the centre of the Air India logo on the inboard facing side of the fan cowl. These marks had the characteristic airfoil shape of a turbine blade tip. It is possible that a portion of the turbine parted from the number 3 engine and struck the cowl of the number 4 engine.
- The upper deck storage cabinet which was located on the left side had unusual damage to its bottom. A large rounded dent in the bottom inboard edge of this stiff cabinet structure revealed smooth stretching without breakthrough. The damage did not seem to be achievable by

inertia or impact forces as the cabinet except for the bottom was undamaged. The damage was considered by a CASB investigator to be compatible with the spherical front of an explosive shock wave generated below the cabin floor and inboard from the cabinet; however, it is not known if this damage could be caused by some other means.

- The right wing root fillet which faired the leading edge of the wing to the fuselage ahead of the front spar had a vertical dent similar to that which would have resulted had the fillet run into a soft cylindrical object with significant relative velocity. The paint on the inboard chord appeared to be scorched brown in the centre areas of three honeycomb panels. It has been determined that sudden heat can turn these panels brown, but it is not known if other reasons for the discolouration exist. The fillet abutted the fuselage side at the aft end of the forward cargo compartment.
- There was blackened erosion damage to the bottoms of some seat cushions. The damage had an appearance similar to that which would have been caused by an explosive device. It is not known if marine life feeding on the cushions or some other cause could have produced the same effect.
- The charred wooden spares box contained some sand and small shellfish. The flesh from the shellfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

An electronic device was found among some floating wreckage and was forwarded to the Bhabha Atomic Research Centre for analysis. There was some concern that it could have been used to detonate an explosive device. The device was forwarded to the RCMP who in conjunction with the CASB determined it to be an item manufactured for use in radiosondes (weather balloons) and was not modified as a detonating device.

2.11.2 Wreckage Mapping and Surveying

The Canadian Coast Guard Ship (CCGS) John Cabot was given the task of mapping the wreckage on the ocean floor. On 19 July 1985, the Cabot with a SCARAB deep submersible on board departed Cork. On arrival at the site, and based on surface wreckage distribution and bottom side scan sonar plots, four transmitters were placed on the sea bed. These transmitters provided signals for the ALLNAV navigation system used to accurately plot the sea bed wreckage.

Based on all the data available, the SCARAB was launched on 24 July 1985 to begin the bottom search in position 51°01.9'N 12°41.0'W.

During the mapping, stage areas were designated for search and each progressive area was determined based on the information gained during the search. The search was conducted using sonar and video. Wreckage found was recorded on video tape and on 35mm positive film.

The first object plotted on the sea bed was a torn suitcase located at lat 51°02.63'N, long 12°53.15'W and was the most westerly object located. This suitcase has not been recovered, nor has it been positively identified as having come from the accident aircraft.

As the search progressed eastward, the first positive identification of aircraft wreckage was made at lat 51°02.9'N, long 12°49.93'W. Slowly, over a period of about 90 days, a detailed bottom wreckage plot was developed.

While mapping was in progress, some of the wreckage was revisited to obtain additional data. During the transit through areas already searched, wreckage not previously plotted was found, and, in some areas, the density of wreckage physically precluded 100 per cent coverage.

Components and major structural items were identified from all sections of the aircraft and when the mapping of the sea bed ended, most of the aircraft had been found and photographed. Although positive identification of each piece of wreckage could not be made, it was decided in late October 1985 that the search phase was essentially completed and wreckage recovery could begin. A bottom wreckage distribution plot is contained separately in an envelope as Appendix F.

2.11.3 Wreckage Distribution

The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling on the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled.

Although badly damaged, sections 41, 42 and 44*, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been plotted or photographed.

Sections 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the westernmost identified aircraft component located at lat 51°02.90'N and long 12°50.1'W. The wreckage extended in a line about 110 degrees True to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern.

A?? third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southeast orientation. One of the operating engines was displaced 0.5 nautical miles to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

*See Appendix D for location of aircraft sections and aircraft body stations (BS).

2.11.4 Photographic and Video Interpretation of Wreckage

2.11.4.1 Photographic Interpretation

All wreckage sighted was recorded on video tape and all major items were recorded on 35mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage patterns. For example, the sine wave bending of target 7* appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into account.

2.11.4.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

2.11.4.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gear were in the 'up' position at the time of impact.

2.11.4.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

*See Appendix E for location of targets on aircraft.

2.11.4.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

2.11.4.6 Section 42

Portions of section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers.

All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

2.11.4.7 Section 44

Section 44, containing the aircraft structure between body station (BS) 1000 and BS 1480 including that area where the fuselage and wings were mated was located in the same general area as the forward sections of the aircraft. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one-third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gear were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

2.11.4.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northernmost area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

2.11.4.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of BS 1480 and, for purposes of this Submission, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were identified (targets 35, 37, 73 and 296), and one portion of the bulkhead was never located. Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognizable as having come from a specific area of the aircraft.

Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from BS 1600 to BS 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

The tail cone and the auxiliary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure of air or water.

The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabilizer was missing and the auxiliary spar was exposed. There was localized damage to the right-hand root of the leading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

2.11.4.10 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from sections 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42, and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat-belts were not fastened.

2.11.5 Wreckage Recovery and Initial Examination

During the wreckage mapping, some small items were recovered, and an unsuccessful attempt was made to recover a portion of the forward cargo door. On completion of the sea bed survey, an offshore supply ship, Kreuztrum, chartered by the National Transportation Safety Board (NTSB), joined John Cabot for a wreckage recovery operation. Prior to the commencement of the wreckage recovery, the structures group met at the Boeing facility in Seattle, USA and reviewed the video tapes and photographs of the wreckage. Based on their findings, a list of items was identified as being most desirable for recovery. The priority list was prepared by a group in Cork, Ireland, headed by Dr. V. Ramachandran. On 8 October 1985, the John Cabot sailed, and on 9 October 1985, the Kreuztrum sailed for the accident site. The following target numbers and items were recovered during the mapping and wreckage recovery stages of the investigation: 7, 8, 35, 47, 117, 193, 223, 245, 287, 296, 299, 362/396, and 399 (as the location on the aircraft of some of the targets was not known when Appendix E was created, some are not shown in the appendix). The first officer's seat, some suitcases and small debris were also recovered using a metal frame basket. Initial examination of the wreckage was carried out in Cork and then it was transported to Bombay for detailed examination.

2.11.6 Examination of Recovered Wreckage

Although all the recovered wreckage was examined, only those items exhibiting characteristics which provided some evidence as to what may have happened to the aircraft during its final moments of flight are discussed. CASB engineering personnel and other participants examined the recovered wreckage at Cork and Bombay. The observations made during their examinations are discussed below.

2.11.6.1 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from BS 1480 to 1860 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear, and the torn edge was buckled in waves, like the trace of a sine wave. On the right side, between the one-quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at BS 1480. The skin tear located at about BS 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distorted and elongated.

The left and right trunnion vertical support fittings located at BS 1480 were examined optically using the stereomicroscope. Both trunnions were fractured through the three bolt holes. The right fracture characteristics were consistent with an overload mode of failure. Although most of the left fracture surface was also characterized by overload features, there were heavily corroded areas where the fracture mode could not be confirmed through optical examination. One lug fracture was sectioned from the left trunnion and prepared for scanning electron microscope (SEM) examination. After the corroded area was cleaned, the examination revealed some ductile characteristics on the fracture surface. There was no evidence of intergranular fracture observed to suggest a stress corrosion cracking mode of failure, nor was there any evidence of progressive failure observed. The corrosion appeared to have developed after the accident.

2.11.6.2 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from BS 1860 to 1960 and from stringer 46L to 46R. A small section from the aft end along the belly skin splice at stringer 46L was removed for examination. SEM examination revealed that the fracture was characterized by slightly elongated ductile dimples along its length, including areas adjacent to the edges of the rivet holes. On the aft edge of each rivet hole examined, a distinctive shear lip was observed. These features are consistent with an overload mode of failure along the skin splice with an apparent direction of failure from aft to forward.

2.11.6.3 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 o'clock position. The piece from 12 to 1 o'clock had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 o'clock position, the outer edge showed sinusoidal buckling, and the edge sector at 9 o'clock was partially collapsed and its edge was turned under. Samples taken for optical stereomicroscope and SEM examination revealed that the fracture characteristics were consistent with an overload mode of failure. The examination suggested a general direction of failure from the aft to the forward edge of the rear pressure bulkhead panel.

2.11.6.4 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occupied the 7 to 9 o'clock position. Optical and SEM examination were undertaken on this item.

The fracture along the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation. Representative fracture samples were cut from the left-hand and right-hand edges of the fracture surfaces. Optical and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

2.11.6.5 Target 47 - Aft Cargo Compartment

This portion of the aft cargo compartment roller floor was located between BS 1600 and BS 1760. Based on the direction of cleat rotation on the skin panel (target 7) and the crossbeam displacement on this structure, target 47 moved aft in relation to the lower skin panel when it was detached from the lower skin. No other significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

2.11.6.6 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between BS 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

2.11.6.7 Target 399 - Left-Hand Side Triple Seat with Tray Arms

It would appear that this section was from row 18, seats A, B and C, the first set of triple seats aft of door 2L. The notable damage to this unit was as follows: front leg aisle side buckled and crushed in place; front leg window side buckled and crushed in place; forward edge tube to seat broken and bent downwards at joint with fore and aft tube between window and centre seats; and fore and aft tube between centre and aisle seat broken at start of T-connection to rear edge of seat tube. The damage suggests that the failures resulted from vertical loading. All the life-jackets were in place.

2.11.6.8 Target 399 - Fuselage Side and 2R Entry Door

The fuselage segment was located between BS 780 and 940. This piece was badly damaged and buckled inwards along a line through the lower door hinge. There were 12 holes or damaged areas on the skin generally with petals bending outwards. The curl on a flap around a hole had one full turn. This curl was in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal. When this target was recovered from the sea, along with it came a few hundred tiny fragments and medium-sized pieces. One of the medium-sized pieces recovered with this target was a floor stantion about 35 inches long. It was confirmed that this stantion belonged to the right side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the stantion.

Scientists from the Bhabha Atomic Research Centre, the National

Aeronautical Laboratory and the Explosives Research and Development Laboratory in India conducted a metallurgical examination of certain items of wreckage. Their report on target 399 concluded that:

- the curling of the metal on the floor channel was indicative of a shock wave effect;
- the large number of tiny fragments from the disintegration of nonbrittle aluminum was a characteristic indication of explosive forces; and
- the indications of punctures, outward petalling around holes, curling of metal lips, reverse slant fracture, formation of spikes at fracture edges and certain microstructural changes all were indicative of an explosion.

2.11.6.9 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segment was located between BS 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

2.11.6.10 Target 362/396 - Lower Skin Panel - Forward Cargo Area

This section of skin panel was located between BS 720 and 860 and is just below target 399. The skin was badly crumpled and torn and had several punctures. It was pulled free from a large mass of debris which included some mangled cargo floor beams and roller trays. Some of the punctures had a feathered or spiked profile, with spikes angled at approximately 45 degrees to the edge. Other puncture holes gave clear indication of being formed by underlying stiffeners at impact. Two of these holes contained pieces of web stiffener. Most of the punctures were the result of penetrations from inside.

In the preliminary report of Mr. V.J. Clancy, representing Boeing, the following observations regarding target 362/396 were made:

- There were about 20 holes in the lower skin panel clearly resulting from penetration from inside.
- In addition to the fact that perforation was from inside, there were certain features which suggested that they were made by high velocity fragments such as those produced by an explosion. Mr. Clancy's report describes these features as follows:
- the presence of toothed or spiked edges at some parts of the metal

which has petalled out from the perforations;
(Tardif and Sterling, Canadian Aeronautics and Space Journal, 1969, 15, 1, 19-27, obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.)

- the presence of marked curling (in some cases of more than 360 degrees) of some of the petals;

(Tardif and Sterling stated that such curling was a feature of explosively produced fragments.)

- the virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal;
- the virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object, thereby suggesting that the production of at least many of the perforations were separate independent events; and
- the presence of one perforation (identified as number 14) resembling a "bullet hole" that was clearly punched out - a type of hole usually associated with a high velocity missile.
- There was evidence that the forward part of the skin panel had been folded back inward along the line of station 760 and then bent back again along a line slightly forward of this station.
- Such folding, perhaps violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces, thus producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.
- One hole (identified as number 13) was almost certainly caused by a slipping wire rope used as a sling.
- Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken of this area for further examination for evidence of fire or explosives.
- A large number (several hundred) of small fragments were recovered. These varied in size from an inch or less to a few inches. They included fragments broken out of sheet metal, and these were reported to be from

the same area as T362.

- The production of a large number of small fragments is generally regarded as an indication of an explosion.
- One piece, which was isolated, was about an inch square of sheet alloy with characteristic spikes on one edge similar to those described by Tardif and Sterling.

The following is an excerpt from the report by Mr. V.J. Clancy wherein he gives his opinion and conclusions regarding target 362.

"Opinion

The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

A more detailed study, metallurgical and fractographic, is required.

The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

The single "bullet hole," No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

If the forward part of this item was forcefully and rapidly folded back to impact on the other part, it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility.

The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some

other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.
The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."
Mr. Clancy concluded that:
"there is strong circumstantial evidence that an explosion occurred but neither individually nor collectively do the several pointers give the degree of confidence necessary for a firm and final conclusion, at this time."
With respect to target 362/396, in his report Mr. Clancy recommended:
"that firing trials be carried out projecting various size missiles at targets similar to the material of T362 to obtain reference samples for laboratory comparison with the perforations in T362."
The Indian report, in addition to the observations made by Mr. Clancy, noted the following with respect to the metallurgical examination:
- The microstructure in the various areas examined on target 362/396 confirmed explosive loading in this part of the aircraft.
- The holes and other features observed in targets 362/396 and 399 must have been due to shock waves and penetration by fragments resulting from an explosion inside the forward cargo hold.
- The chemical nature of the explosive material was not identified. No part of an explosive device, its detonator or timing mechanism was recovered.

2.11.6.11 Examination of Wreckage in India with CASB Participation

The examination of the targets recovered did not reveal any pre-existing defect, premature cracking or pre-impact corrosion damage associated with any of the failures.

3.0 DISCUSSION

3.1 Initial Event

From the correlation of the recordings of the DFDR, CVR and Shannon ATC tape, the unusual sounds heard on the ATC tape started shortly after the flight recorders stopped recording. The conversations in the cockpit were normal, and there was no indication of an emergency situation prior to the loud noise heard on the CVR a fraction of a second before it stopped recording. The DFDR showed no abnormal variations in parameters recorded before it stopped functioning. The only unusual observation was the irregular signals recorded over the last 0.27 inches of the DFDR tape. Laboratory tests indicated the possibility that these signals resulted from the recorder being subjected to a sharp disturbance at the time it stopped recording. The other possibility for the irregular signals on the DFDR is that they were caused by a disturbance to the Flight Data Acquisition Unit in the main electronics bay. Since there was an almost simultaneous loss of the transponder signal, this indicates the possibility of an abrupt aircraft electrical failure. The medical evidence showed a general absence of signs indicating that seat-belts were fastened. From the video and photographic examination of the wreckage on the bottom, it was ascertained that the majority of seats located did not have the seat-belts fastened. The above evidence indicates that the initial occurrence was sudden and without warning. The abrupt cessation of the data recorder could be caused by airframe structural failure or the detonation of an explosive device as the initial event. The millisecond noise on a CVR as observed in this case is usually, as described in the available literature, the result of the shock wave from detonation of an explosive device. However, in this case, certain characteristics of the noise indicate the possibility that the noise was the result of an explosive decompression. There is some disagreement regarding the cause and location of the source of the noise heard on the CVR, that is, whether the noise resulted from an explosive device or an explosive decompression and whether the noise originated from the rear or closer to the front of the aircraft.

3.2 Passenger/Flight Deck Area

From the examination of the wreckage recovered and wreckage on the bottom, there is no indication that a fire or explosion emanated from the cabin or flight deck areas. The medical examination of the bodies also showed no fire or explosion type injuries. However, pieces of an overhead locker coming from above door 2R or 4R had been blackened by fire. There was blackened erosion damage to the bottoms of some seat cushions, showing damage possibly from an explosive device, and the upper deck storage cabinet had a large rounded dent in the bottom inboard edge which might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet. It should be noted that the pieces of the overhead locker were found on the Welsh shore some time after the accident, and it is not known if the pieces were subjected to a fire after the accident. Also, it is not known if the damage to the seat cushions and the upper deck storage cabinet could have been caused by other means. Nevertheless, the above evidence suggests that some areas of the passenger cabin may have been subjected to minor fire and explosive damage possibly emanating from below the cabin floor.

3.3 Aircraft Break-up Sequence

The medical evidence showed a proportion of the passengers with indications of hypoxia, decompression, flail injuries and loss of clothing. The incidence of hypoxia and decompression indicates that the aircraft experienced a decompression at a high altitude. The flail injuries and loss of clothing indicate a proportion of the passengers were ejected from the aircraft before water impact. The severity of injuries increased from Zones C to E and was significantly less in Zone C than in Zones D and E.

The wreckage of the forward portion of the aircraft up to and including the aircraft body wheel well area and the wings was lying about 0.8 miles north of the vertical and horizontal stabilizers. Hence, it is likely that the aft portion of the aircraft separated from the forward portion before striking the water. In addition, the wreckage found west of longitude 12°48' consisted of suitcases and aft cargo compartment lower skin panels. There was also a wide scatter of sections 46 and 48 in an east-west direction, whereas the wreckage of the forward portion was mainly localized within a relatively small area.

The higher severity of injuries in the aft end of the passenger cabin appears to coincide with the break-up of the aft end, sections 46 and 48 of the aircraft. The fact that items from the aft cargo compartment were found further west than the tail section indicates that the aft cargo compartment ruptured first during the break-up sequence of the aft end.

The forward portion of the aircraft was highly localized, which indicates that it struck the water in one large mass.

3.4 Aircraft Structural Integrity

As described earlier, the sudden nature of the occurrence indicates the possibility of a massive airframe structural failure or the detonation of an explosive device.

3.4.1 Aircraft Break-up

The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer before water impact. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.

The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile to the west indicating that there was some break-up of the number 3 engine before water impact.

The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction. Also, passenger seats viewed and recovered exhibited that they had been subjected to an upward force from below. They showed that the seats to the rear in sections 46 and 48 had their back legs buckled, and the seats toward the front had both front and back legs buckled. This indicates the vertical force was greater at the front than the rear of the aircraft. It is possible that this vertical force on the floor was caused by the force of the water during impact, but the rear of the aircraft broke up before impact and therefore any vertical loading on the floor in this area is unlikely to have occurred at impact. Twenty-three passengers also showed evidence of vertical impact injuries. These could have been caused from a force from below during flight or at water impact. Sixteen of these passengers had little or no clothing indicating that some may have been ejected before water impact. Therefore, there is some indication that the upward force on the floor may have occurred in flight and was more severe toward the front.

3.4.2 Aft Pressure Bulkhead

The localized impact mark found on the leading edge of the right horizontal root leading edge is indicative of an object striking the stabilizer in flight before water impact. This suggests that the loss of the tail plane was not the first event. The horizontal and vertical stabilizers were found separated and each was intact and in good condition. Items from the aft cargo compartment were found further to the west of the tail plane. The absence of the type of damage to the tail plane as was found in the Japan Airlines (JAL) Boeing 747 accident where the aft pressure bulkhead failed and which took place shortly after this occurrence, and the rupture of the aft cargo compartment before the loss of the tail indicate that there was not an in-flight failure of the aft pressure bulkhead. In addition, examination of the recovered portions of the bulkhead shows evidence of overload failures from the rear to front only and no evidence of any pre-existing defect, premature cracking or pre-impact corrosion damage.

3.4.3 Target 7 - Lower Fuselage Skin Panel

Target 7 which extends from BS 1480 to 1860 shows a break at the joint at BS 1480. The forward keel joint splice plate is bent and the keel joint holes are distorted and elongated. Some of the fracture surface was heavily corroded. An in-flight failure in this area would cause a massive failure of the aircraft's structural integrity. Further examination showed the fractures to be overload, and there was no evidence of an intergranular type fracture to suggest a stress corrosion cracking mode of failure. The corrosion was concluded to be post-impact and, therefore, there is no evidence to suggest an in-flight failure in this area as the initial event.

3.4.4 Structural Failure

The examination of the floating and recovered wreckage and the analysis of the photos and videos of the wreckage on the bottom failed to indicate any evidence of a failure of the primary or secondary structure as a result of a pre-existing defect. The initial event has been established as sudden and without warning. The abrupt cessation of the flight recorders indicates the possibility of a massive and sudden failure of primary structure; however, there is evidence to suggest that there were ruptures in the forward and aft cargo compartments prior to any failure of the primary structure in flight. Therefore, available evidence tends to rule out a massive structural failure as the initial event.

3.4.5 Explosive Device

A violent explosion occurring within an aircraft in flight usually leads to a complicated break-up mode and sequence of failure. Fractures of metal caused by an explosion are normally different in character to those caused by overstressing or crash impact forces. Shattering of metal into very small and numerous fragments and minute deep penetration of a metal surface are not usually found in aircraft accident wreckage. The size and characteristics of these particles often accompanied by rolled edges, surface spalling, pitting or evidence of heat are indicative of an explosion.

Of the floating wreckage, there is little to indicate the possibility of an explosion:

- the lining in one suitcase was severely tattered;
- although the wooden spares box was burned, this could have happened after the occurrence;
- although pieces of an overhead locker were damaged by fire, it is not known if the burning happened at the time of the occurrence;
- although the pieces of U-section alloy clearly indicated evidence of

an explosion, it is quite possible that these pieces were not associated with the aircraft;

- the bottoms of some seat cushions show indications of a possible explosion;
- the inside of the right wing root fillet appears to have been scorched; and
- the deformation of the floor of the upper deck storage cabinet might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet.

It is not known if the suitcase came from the aft or forward cargo compartment, and the location of the seats from which the cushions came is also unknown.

The scorching of the right wing root fillet and the damage to the upper deck cabinet suggest, if there was an explosion, it emanated from the forward cargo compartment.

From the examination of the recovered wreckage, the following deductions can be made:

- Target 47, which is a portion of the aft cargo compartment roller floor, shows no indications characteristic of an explosion emanating from the aft cargo compartment.
- Target 362/396, which is a lower skin panel from the forward cargo compartment is badly crumpled and torn and has about 20 punctures resulting from penetration from inside. It appears that some folding occurred on water impact which brought stringers or stiffeners from the aircraft structure into forceful contact with the internal surface of the panel producing most of the penetrations. However, there are certain punctures which indicate no evidence of impact marks on the inside surface and show evidence of being produced by high velocity fragments. Part of the inner surface of the skin panel appeared to have been blackened by soot from a fire.
- Target 399, consisting of a piece of the skin and stringers on the right side in the area of the forward cargo compartment contained holes and several hundred metal fragments. The damage to the floor stantion and the presence of the fragments are consistent with an explosion.

The examination of the recovered wreckage contains no evidence of an explosion except for targets 362/396 and 399 which contain some evidence that an explosion emanated from the forward cargo compartment.

An explosion in the forward cargo compartment would explain the loss of the DFDR, CVR and transponder signal as the electronics bay is immediately ahead of the cargo compartment.

3.5 Security Aspects

There is a considerable amount of circumstantial and other evidence that an explosive device caused the occurrence. Therefore, it is reasonable to examine the security measures in place on 22 June 1985. The evidence indicates that if there was an explosion, it most likely occurred in the forward cargo hold, not the passenger and flight deck areas or exterior to the fuselage. Although an explosive device could have been placed in a cargo hold in a number of ways, the available evidence points to the events involving the checked baggage of M. and L. Singh in Vancouver. The investigation determined that a suitcase was interlined unaccompanied from Vancouver via CP Air Flight 060 to Toronto. In Toronto, there is nothing to suggest that the suitcase was not transferred to Terminal 2 and placed on board Air India Flight 181/182 in accordance with normal practice. The aircraft departed Toronto for Mirabel and London with the suitcase unaccompanied. Similarly, a suitcase was interlined unaccompanied on CP Air Flight 003 from Vancouver to Tokyo to be placed on Air India Flight 301 to Bangkok. The explosion of a bag from CP 003 at Narita Airport, Tokyo, took place 55 minutes before the AI 182 accident. Therefore, the nature of the link between the two occurrences raises the possibility that the suitcase which was unaccompanied on AI 182 contained an explosive device.

3.5.1 Canadian Security Situation

Canadian security arrangements in place prior to 23 June 1985 met or exceeded the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand luggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

In Canada, the Department of Transport (Transport Canada) is responsible for establishing overall security standards for airports and airlines, and for the provision of certain security equipment and facilities at airports. By regulation, air carriers are responsible for applying security standards for passengers, for baggage and cargo and for ensuring security within individual aircraft. The RCMP provides airport physical security and responds to criminal incidents.

Air carriers contract for or otherwise provide the personnel who operate the security check-points through which passengers and their carry-on baggage enter the secure area of the airport terminal. These personnel also operate security equipment for the screening of cargo, passengers and checked baggage. Usually, air carriers use the service of private security firms. Transport Canada has established certain standards required for licensed security guards, such as the successful completion of the Transport Canada passenger inspection training program and annual refresher training. As stated earlier, a significant number of the security guards did not meet the criteria with respect to the completion of the training program and refresher training. In addition, the criteria do not require training for the screening of cargo and checked baggage.

ICAO Annex 17 recommends that contracting States establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage or cargo intended to be carried on board aircraft. For all Canadian airlines, Canadian regulations before 23 June 1985 required a system of identification that prevented baggage, goods and cargo from being placed on board an aircraft if it was not authorized to be placed on board by the airline operator. However, if someone were to purchase a ticket, check in baggage and not board the aircraft, the baggage would in all likelihood have been authorized by the airline to be placed on board the aircraft. Therefore, it was possible to interline baggage unaccompanied and this explains how a suitcase was interlined to AI 181/182 from CP 060. It is not the normal practice of airlines to interline baggage if there is not a confirmed reservation to the destination. In this case, the ticket agent allowed the suitcase to proceed; however, if there had been a confirmed reservation, the suitcase would have been interlined unaccompanied without question.

3.5.2 Air India Security

Air India, as required by Canadian regulation, had a security program. Because of the threat level assessed against the airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and received extra security from Transport Canada and the RCMP for the month of June 1985. For Air India Flight 181/182, Air India provided a security officer from its New York office to oversee the security arrangements at Toronto and Mirabel. The security program at each airport was under the overall supervision of the respective Air India station managers. In Toronto, it was not clear who, if anyone, was undertaking this function.

It is not known if the suitcase interlined from CP 060 was screened before or after the X-ray machine broke down in Toronto. Although baggage not examined by X-ray was screened by a PD-4 sniffer, there are indications that the sniffer could have been ineffective in detecting explosives, especially plastics. Rather than using the sniffer, it would have been more effective to open all bags and physically inspect them. Even though a number of security personnel were not adequately trained in the screening of passengers and baggage, it is not known whether more training would have prevented an explosive device from being placed on board.

Although airline procedures required baggage to be accompanied, the agents checking in passengers in Toronto used a passenger security numbering system but did not number checked-in baggage, and baggage was not correlated with passengers. Therefore, the interlined unaccompanied suitcase from CP 060 was not detected. At Mirabel, checked-in passengers and baggage were numbered so that the number of passengers checking in baggage could be correlated with the number of passengers boarding the aircraft. Had a passenger-baggage correlation been carried out in Toronto, the suitcase from CP 060 would have been detected. The airline procedures would have prevented the placement of the suitcase on the aircraft.

Once loaded on the aircraft, the suitcase would have been placed in container 11L and 12L (see Appendix B) if in the forward cargo compartment, in container 44L or 44R if in the aft cargo compartment, or in position 52 if in the bulk cargo compartment. It could not be determined in which cargo compartment the suitcase was loaded.

Therefore, although the procedures were in place to prevent an explosive device from being placed on board the aircraft in checked-in baggage, there was a breakdown in the X-ray machine used to screen baggage, and there are indications that the PD-4 sniffer was inadequate. Also, the security numbering system used in Toronto was ineffective in preventing unaccompanied interlined baggage from being placed on board the aircraft.

4.0 CONCLUSIONS

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion.

4.2 Other Findings

Even though they may not be causal or related to the accident, the following additional conclusions can be drawn from the investigation with respect to certain security arrangements and their application pertaining to this flight:

1. In compliance with the International Civil Aviation Organization Annex 17 to the Convention on International Civil Aviation, the Department of Transport of Canada has made regulations requiring foreign aircraft operators who land in Canada to establish, maintain, and carry out certain security measures at airports.

2. In accordance with these regulations, Air India submitted a security program to the Minister of Transport which included security measures with respect to aircraft, cargo, baggage, and passengers.

3. On 22 June 1985, an unaccompanied suitcase was interlined from Vancouver to Toronto on CAP Flight 060 for transfer in Toronto to Air India Flight 181/182.

4. The baggage loaded in Toronto was screened through an X-ray machine process but, during the course of this procedure, the X-ray machine broke down.

5. After the X-ray machine breakdown, an explosives detector was used to screen the baggage; the baggage was not opened and physically examined.

6. The effectiveness of the explosives detector is in doubt.

7. It is not known whether the unaccompanied suitcase interlined from Vancouver was screened before or after the X-ray machine broke down.

8. The security numbering system used in Toronto did not prevent unaccompanied interlined baggage from being placed on board the aircraft.

9. The normal procedures for interlining baggage in Toronto indicate that the unaccompanied suitcase was loaded on Air India Flight 181/182.

REPORT OF THE COURT INVESTIGATING
ACCIDENT TO AIR INDIA BOEING 747 AIRCRAFT VT-EFO,
"KANISHKA" ON 23RD JUNE 1985

HON'BLE MR. JUSTICE B. N. KIRPAL JUDGE, HIGH COURT OF DELHI
ASSESSORS
DR. V. RAMACHANDRAN MR. J. S. GHARIA
CAPT. J. S. DHILLON MR. J. K. MEHRA
CAPT. B. K. BHASIN
SECRETARY
MR. S. N. SHARMA

FEBRUARY 26, 1986

CONTENTS

INTRODUCTION

1.1.1 On the morning of 23rd June, 1985 Air India's Boeing 747 aircraft VT-EFO (Kanishka) was on a scheduled passager flight (AI-182) from Montreal and was proceeding to London enroute to Delhi and Bombay. It was being monitored at Shannon on the Radar Scope. At about 0714 GMT it suddenly disappeared from the Radar Scope and the aircraft, which has been flying at an altitude of approximately 31,000 feet, plunged into the Atlantic Ocean off the south-west coast of Ireland at position latitude 51° 3.6'N and Longitude 12° 49'W. This was one of the worst air disasters wherein all the 307 passengers plus 22 crew members perished.

1.1.2 The fact that emergency had arisen was first noticed by Shannon Upper Area Control (UAC) after the aircraft had disappeared from the Radar Scope. The control gave a number of calls to the aircraft but there was obviously no response. Thereafter various messages were transmitted and that is how the rest of the world came to know of the

accident.
1.1.3 Shannon Control at 0730 hours advised the Marine Rescue Coordination Centre (MRCC) about the situation which appeared to have arisen. MRCC, in turn, explained the situation to Valencia Coast Station and requested for a Pan Broadcast. Thereafter ships started converging on the scene of the accident and they commenced search and rescue operations.
1.1.4 The aircraft in question - Kanishka, was named after the most powerful and famous king of the Kushanas who perhaps ruled in India from AD 78 to AD 103. Besides being a great conqueror, he was an ardent supporter and follower of Budhism - a religion which preaches non-violence. Emperor Kanishka, however, met a violent end. After 25 years of reign he was killed by some of his own subjects. His life was thus brought to an abrupt end.
1.1.5 It is indeed ironical that the Jumbo Jet which bore the name 'Kanishka' also met with a violent and a sudden end on that fateful morning of 23rd June, 1985.

INITIAL ACTION TAKEN BY THE GOVERNMENT OF INDIA

1.2.1 Initial intimation of the accident was received by Air India who, in turn, communicated the same to Mr. H.S. Khola, Director of Air Safety, Civil Aviation Department, New Delhi. The Accident Investigation Branch of United Kingdom also sent information to the Director General of Civil Aviation, New Delhi to the effect that the accident had taken place on international waters and as such it was India which was the authority to investigate the accident in accordance with the provisions of ICAO Annex 13.
1.2.2 Thereupon Order No. AV.15013/8/85-AS dated 23rd June, 1985 was issued by the Director General of Civil Aviation whereby Mr. H.S.Khola was appointed Inspector of Accidents for the purpose of carrying out the investigation into the aforesaid air accident. This appointment was made under Rule 71 of the Aircraft Rules, 1937.
1.2.3 While search and rescue operations were underway at the site of the accident, a team of officials headed by Dr.S.S. Sidhu, Secretary, Ministry of Tourism & Civil Aviation rushed from India to Cork. The

said team was joined by Mr. Kiran Doshi, the Indian Ambassador to Ireland, and also by two officers of the Indian Navy who were attached to the Indian High Commission at London. Subsequently two Medical Experts from India also joined the said Team.

1.2.4 The Indian Team arrived at Cork, Ireland on 24th June, 1985. Representatives of the Governments of United States of America, Canada and United Kingdom also reached there that day. They were met by the representatives of the Government of Ireland.

1.2.5 The members of the Team saw the rescue and salvage operations being conducted. They also visited the Cork Regional Hospital and had discussions with Irish and other Authorities with a view to release the bodies of the victims which were being brought to Cork.

1.2.6 For facilitating the process of investigation the Inspector of Accidents after consulting the representatives of the aforesaid Governments formed the following groups:

a. Structures, Power Plant and Systems Group.

b. Operations Weather & ATS Group.

c. Medical and Human Factor Group.

d. Search & Rescue Group.

The aforesaid groups were required to collect evidence and to submit their respective reports to the Inspector of Accidents.

1.2.7 The bodies which were being recovered were brought to the Cork Regional Hospital for identification and post-mortem. At that time it was considered proper that apart from the two medical experts from India, Wing Commandor Dr.I.R. Hill, who is an expert in aviation pathology should also be called from United Kingdom.

1.2.8 It was also being speculated that the accident may have occurred due to an explosion on board the aircraft. In order to see whether there was any evidence of an explosion which could be gathered from the floating wreckage which was being salvaged, the Government of India requisitioned the services of Mr. Eric Newton, a Specialist in the detection of explosives sabotage in aircraft wreckage.

1.2.9 In order to coordinate and guide the operations of the various ships working at the crash site, a control centre was set up at Cork

Airport on 30th June, 1985.
1.2.10 The control centre was manned by representatives of the Governments of Ireland, Canada and United States. The Indian Naval Officers from the High Commission at London were overall in-charge of this centre. After the flight recorders had been recovered the centre continued to function, but the representatives of the United States departed.

1.2.11 For retrieving the Cockpit Voice Recorder (CVR) and Digital Flight Data Recorder (DFDR), a cable ship named Leon Thevenin was engaged which had on board Submersible Robot (Scarab) which was fitted with a Sonar receiver and TV Cameras. The aforesaid ship was engaged and after an intensive search CVR and the DFDR (more popularly known as 'the black boxes') were located and retrieved on 10th July and 11th July, 1985 respectively.

1.2.12 The Government of India, in exercise of the powers conferred by Rule 75 of the Aircraft Rules, 1937 vide Notification No. AV. 15013/10/85-A, dated 13th July, 1985, directed that a formal investigation of the accident be carried out. Mr Justice B.N. Kirpal, Judge of the Delhi High Court, was appointed as the Court to hold the said investiation. The Central Government also appointed Dr. V. Ramachandran of National Aeronautical Laboratory, Bangalore; Mr. J.S. Gharia of Explosive Research and Development Laboratory, Pune; Captian J.S. Dhillon, retired Director of Operations, Air India, Bombay; Mr. J.K. Mehra, retired Manager (Technical Training), Indian Airlines, Hyderabad and Captain B.K. Bhasin, Deputy Managing Director of Indian Airlines, New Delhi to act as Assessors of the said Investigation. The Court was required to make its report to the Central Government by 31st December, 1985, which date was later extended to 28th February, 1986.

1.2.13 Mr. S.N. Sharma, Director of Airworthiness, Civil Aviation Department, was appointed as Secretary to the Court vide Ministry of Tourism & Civil Aviation letter No. AV/15013/10/85-A, dated 22nd August, 1985. The appointment was to take effect from 13th July, 1985.

ACTION TAKEN BY IRELAND, INCLUDING THE CORK

REGIONAL HOSPITAL

1.3.1 The accident had occurred on the Atlantic Ocean approximately 100 miles south-west of the coast of Ireland. It is the Air Traffic Control at Shannon, Ireland who first became aware of the tragic event.

1.3.2 On coming to know of the accident, various authorities in Ireland took immediate action. The Shannon ATC asked the Marine and Rescue Coordinating Centre there to take emergency action. Thereupon MRCC, Shannon asked Valantia Coast Radio Station (CRS) for a PAN broadcast requiring all the vessels in areas 51N/1250W to keep a look out for the wreckage of an aircraft. The PAN broadcast was repeated and all ships were directed to proceed to the site of accident which was determined as 5101.9N/1242.5 W.

1.3.3 Irish authorities also took great pains in rendering every possible assistance to the Indian and other authorities. Some of the wreckage which had floated in to the west coast of ireland was transported to Cork where a boat house had been hired by the Government of India. The wreckage which was placed in the said boat house was protected from any outside interference by the local Gardai (police).

1.3.4 Irish ships proceeded to the scene of accident and helped in search and rescue operations. The ATC at Shannon gave details about the accident, in so far as they were aware of it, and copies of the ATC tapes were supplied. Aer Lingus, national airline of Ireland, provided assistance by making available its local engineering facilities to the coordinating centre at Cork and also to the other authorities.

1.3.5 Cork is a city having a population of approximately 1,34,000. One of the hospitals which was opened in 1978 is the Cork Regional Hospital which had been set up to meet the needs of the people. This 600-bed hospital was designated for the purposes of the Major Accident Plan of the Southern Health Board and thus became the appropriate centre for the reception of the casualities of the Air India disaster. Since the hospital first opened, it had dealt with a number of major accidents involving road, rail and marine incidents. The Major Accident Plan of the Southern Health Board sets out formally, the strategy and procedure which the hopital is required to follow while deailing with major accidents.

1.3.6 On the morning of 23rd June, 1985 at approximately 11.20 A.M. the hospital was put on alert following the disappearance of the Air India Flight 182 off the south-west coast of Ireland. The first message which was communicated to the hospital indicated that it was unlikely that there would be any survivors. The key hospital personnel were alerted and a meeting was arranged in the hospital for the purposes of discussing and making arrangements for the receipt of the bodies on the basis of the information which was available at that time.

1.3.7 On being informed that there were no survivors in the accident and that the hospital should be prepared to receive a large number of bodies, then, in accordance with the Major Accident Plan, mortuary facilities were improvised by appropriating the gymnasium attached to the Deparatment of Rheumatology. Subsequently it became evident that additional mortuary and postmortem facilities would be needed. In order to decide where the second mortuary was to be located, the hospital had to take into cosideration the following factors:-

(a) The number and the condition of the bodies;

(b) The period during which the bodies would be retained;

(c) The hospital would be required to provide an on-going service for in-patients, out-patients and serious accident and emergency cases;

(d) To avoid unnecessary internal transport problems, the bodies should be near the Post-Mortem and Pathology Departments; and

(e) To facilitate traffic flow in the hospital curtilage and to to aviod unduc public access.

The hospital authorities accordingly located the second mortuary in a recreational room adjoining the gymnasium.

1.3.8 Two rooms were put at the disposal of the Garda (Police) authorities for use as Garda Control Rooms in the hospital. Telecommunications lines were set up immediately for their assistance as the Gardai was responsible for the forensic and identification procedures in regard to the bodies brought to the hospital.

1.3.9 A small Co-ordinating Group was set up consisting of the Chief Executive Officer of the Southern Health Board, Medical Co-ordinating

Officer, Press Liaison Officer, a Senior Registrar who knew about Indian customs and traditions and a Hospital Administrator. This small Co-ordinating Group, whose membership never changed, worked together and were capable of assessing situations, making decisions, liaising with other agencies and services and undertaking with other agencies and services and undertaking responsibility for hospital press releases. Apart from individual contact between members, the Group had a standing arrangement to meet every morning and afternoon. In the late evening, the Group, met the Garda, Hospital Pathologists and key staff members for a general review of progress and to decide the tasks and objectives for the following day.

1.3.10 Within a few hours, the Co-ordinating Group realised that the hospital was a world focal point of the international media, and was required to:

a. Accommodate 131 bodies;

b. Provide pathological and Radiological services for each body;

c. Co-operate with the Garda in their forensic work;

d. Cater for relatives of the victims;

e. eet representatives of foreign Governments; and

f. Keep press agencies informed.

Thus began an operation which demanded a quick and dedicated response from all staff working in close cooperation with the Gardai. At the same time, the hospital was required to continue functioning in the delivery of normal in-patient and out-patient services. The Major Accident Plan, apart from alerting staff, provided the framework and basis for many decisions taken as events evolved. An additional advantage in the practical implementation of the Plan was the fact that the hospital had staff experienced in dealing with previous emergency situations and could marshal the extensive manpower resources available.

1.3.11 The hospital authorities also made the following arrangements:-

a. They briefed Government Ministers and Officials and other dignitaries who visited the hospital. They were taken round the hospital and were explained the arrangements which had been made.

b. Some of the services which were being provided at the hospital were either discontinued or postponed.

c. Bodies were received at the hospital and arrangements were made on their arrival to numerically label and certify as dead all the 131 bodies which were initially received. All the bodies, at that stage, had been individually placed in special purpose body bags. Initially, bodies were placed on tables, but, it was subsequently decided that it would be much easier for all concerned to place the wrapped bodies on polythene covered floors.

d. Arrangements were made for carrying out of the post-mortem examinations. Three Pathologists from other city Hospitals were recruited to augment the existing staff. Dr. Harbison, State Pathologist, was in charge of this aspect of the operation. All the post mortem were completed by 27th June, 1985.

e. For the preservation of the bodies five refrigerated containers with a capacity to hold 140 bodies were hired. These containers were fitted with timber shelving.

f. Government Information Service was located in the Matron's Office.

g. The Army provided troops for the unloading of the bodies from the helicoplers at Cork Airport. They also supplied and erected two large tents for storing bodies after post mortem and embalming. Under Garda escort transport of all the bodies which were recovered was undertaken by the

Army and these arrangements were co-ordinated by Chief Ambulance Officer.

h. Embalming was carried out in the hospital and bodies were then coffined and the coffins with appropriate number plaques were subsequently laid out in the numerical order on the floor when all the post mortems had been completed.

I. All the embalmed bodies were x-rayed (whole body). The examination was completed on 28th June, 1985.

j. A provision was made for a 24 hour extended catering service to meet the needs of staff, Gardai, Army and other personnel involved including visiting relatives.

k. A simple plan was devised for dealing with the relatives. This was a sensitive task bearing in mind the varying religious beliefs, customs and cultures generally of the visiting relatives. Their main function was to provide moral and emotional support to the relatives.

l. As identification progressed, special arrangements were made to assist the relatives. They were met by teams of councellors from the Hospital as soon as they disembarked at Cork Airport and subsequently at the Hospital. The relatives had the same Counsellor and Garda Officer throughout the identification procedure. An interesting development noted was that each family group of relatives, their Counsellor and Garda officers formed a single family unit transcending cultural barriers. On subsequent visits, families appeared lost if their own Counsellor was not immediately available to them. Usually, the Counsellor and the Garda officers accompanied the relatives, at their own request, for visual identification.

m. When plans were being formulated to receive the relatives, it had been hoped to discourage them from coming to the Hospital until such time as progress had been reported on the identification process. Practical experience subsequently proved this strategy to be inappropriate for a number of reasons. Apart from facilitating the collection from relatives of salient information on the victims, the most fundamental reason was the underestimation of the abiding wish of the relatives to be physically and psychologically as close as possible to their deceased dear ones. Moreover, it was the express wish of almost all relatives on arriving at Cork Airport to proceed directly to Cork Regional Hospital; there, they were given an informal talk by Air India and Garda representatives on the progress of the investigation and the methods of identification. Many of the relatives visited the hospital daily and remained there throughout each day.

n. Coach trips were arranged to Bantry Bay for the relatives; Bantry Bay is the nearest landmark from the site of the crash. Relatives visited the seaside to pay their last respects to the departed souls. These were solemn occasions when each relative prayed in his/her own way. Rose petals and wreaths were immersed in the sea in keeping with Indian traditions. The visit gave them mental satisfaction and in the early days following the crash, helped in diverting their attention while the investigative procedures were being completed.

o. A small number of visiting relatives had personal medical problems and they were treated at out-patient and in-patient levels at the Hospital.

p. Cork/Kerry Tourism Organisation helped to co-ordinate the accommodation of relatives between a number of hotels. Approximately seven hotels were used within a radius of twenty miles of the city for this purpose.

g. A number of press conferences were held. The Chief Executive Officer, directed that press photography and television filming be not allowed within the hospital in deference to the privacy of patients and in respect for the relatives wishes.

r. Responsibility for the identification of bodies rested with the Garda Authorities and the conditions under which bodies were released are summarised as follows :-

(I) Satisfactory identification

(ii) Consent of the Coroner

(iii) Proper authentification of the person claiming each body

All bodies arriving at Cork Regional Hospital had already been numerically labelled by the Garda Authorities. To prevent confusion, the bodies were then given identical numbers under the hospital major accident labelling system and this proved to be very helpful later during identification, investigations and recordings. A routine was established for examining and recording information about each body. Teams consisting of a doctor, nurse, clerical officer and Garda made the necessary examination, labelling and recording each body and such details as :-

a. Sex

b. Adult or child

c. Clothing

d. Jewellery and personal effects
e. Injuries
f. Obvious scars

Death was confimed in all cases. Each body was fingerprinted and photographed by Garda Technical Bureau Staff. Each body was subjected to autopsy, forensic and dental examination. All bodies were embalmed and following embalming, were photographed and x-rayed. This procedure was completed in respect of all the bodies by the evening of the fifth day of the crash. The data from these investigations was collated on an Interpol form (pink) for each body. Similar ante-mortem information was obtained from the relatives about each victim on a separate Interpol form (yellow). When the information on the pink and yellow forms matched beyond doubt, a positive identification was made. It might be noted that the photographs originally taken by the Garda Technical Bureau Officers of each body were matched with photographs of the 131 embalmed bodies. When a positive identification was made, the relatives were shown photographs of the deceased. These photographs were available for inspection by Saturday, 29th June. As positive identification progressed,

personal effects were added to the identification process and finally, visual identification took place. For obvious forensic reasons, positive identification was necessarily slow and meticulous and, in fact, was made more difficult by reason of the fact that only 131 bodies out of the 329 passengers and crew were recovered. All 131 bodies were identified, the first positive identification was made on 27th June and the last on the 6th August. Each coffin had affixed to it a metal plaque clearly indicating the number assigned in the first instance to the body it contained. The bodies when identified were released by the Garda Authorities through the undertaker. The Coroner directed that a reasonable time would have to elapse before unidentified bodies could be disposed off an this was to be by way of burial. The final date for this purpose was fixed for 3rd August, 1985, but, this date was subsequently extended to 6th August, 1985, to coincide with the date of the Civic Commemoration Ceremony.

(s) Bodies of victims for identification were brought individually to separate viewing rooms, suitably decordated with flowers and with incense burning. Visual identification was performed in private by the relatives and moreover, it allowed them to pay their last respects in their own religious beliefs. An adjoining room was also made available where they could grieve in private. Subsequently, it was learnt that these arrangements were much appreciated by the relatives who articulated this appreciation by commenting that the arrangements provided were as near as possible to the funeral rites observed in their domestic communities. The relatives were of the opinion that the special arrangements made conveyed a deep personal and individual response to the dignity of each victim which might otherwise be lost with such a large number of bodies.

(t) Procedures were laid down which were required to be followed and observed for the purposes of preventing infection.

(u) On 6th August, 1985 an interdenominational service was held in the morning. In the evening on that day a Civic Commemoration Ceremony was held which was attended by a large number of persons.

(v) A formal inquest was held by the Coroner in the Courthouse, Cork, which commenced on 17th September, 1985 and ended on 23rd September, 1985. The Coroner's Jury returned a verdict in accordance withmedical and pathological evidence.

ACTION TAKEN BY THE COURT

1.4.1 Despite the fact that Mr. H.S. Khola had been appointed as the Inspector of Accidents under Rule 71 of the Aircraft Rules, the Government thought it proper to appoint Mr.Justice B.N. Kirpal as the Court to investigate into the circumstances of the accident.

1.4.2 The appointment of the Court was made under Rule 75 of the Aircraft Rules, which is as follows :-

"75. Formal Investigation - Where it appears to the Central Government that it is expedient to hold a formal investigation of an accident it may, whether or not an investigation or an inquiry has been made under rule 71 or 74, by order direct a formal investigation to be held and with respect to any such formal investigation the following provisions shall apply namely

(1) The Central Government shall appoint a competent person (hereinafter referred to as "the Court"), to hold the investigation, and may appoint one or more persons possessing legel, aeronautical, engineering, or other special knowledge to act as assessors, it may also direct that the Court and the assessors shall receive such remuneration as it may determine.

(2) The Court shall hold the investigation in open court in such manner and under such conditions as the Court may think fit most effectual for ascertining the causes and circumstances of the accident and for enabling the Court to make the report hereinafter mentioned.

(3) (i) The Court shall have, for the purpose of the investigation, all the powers of a Civil Court under the Code of Civil Procedure, 1908 and without prejudice to those powers the Court may :-

(a) enter and inspect, or authorise any person to enter and inspect, any place or building, the entry or inspection whereof appears to the court reguisite for the purpose of the investigation; and

(b) enforce the attendance of witness and compel the production of documents and material objects; and every person required by the Court to furnish any information shall be deemed to be legally bound to do so within the meaning of section 176 of the Indian Penal Code.

(ii) The assessors shall have the same powers of entry and inspection as the Court.

(4) The investigation shall be conducted in such manner that, if a charge is made or likely to be made against any person, that person shall have an opportunity of being present and of making any statement or giving any evidence and producing witness on his behalf.

(5)Every person attending as a witness before the Court shall be allowed such expenses as the Court may consider reasonable: Provided that, in the case of the owner or hirer of any aircraft concerned in the accident and of any person in his employment or of any other person concerned in the accident, any such expenses may be disallowed if the Court, in its discretion, so directs.

(6)The court shall make a report to the Central Government stating its findings as to the causes of the accident and the circumstances thereof and adding any observations and recommendations which the Court thinks fit to make with a view to the preservation of life and avoidance of similar accidents in future, including, a recommendation for the cancellation, suspension or endorsement of any licence or certificate issued under the rules.

(7)The assessors (if any) shall either sign the report, with or without reservations, or state in writing their dissent therefrom and their reasons for such dissent, and such reservations or dissent and reasons (if any) shall be forwarded to the Central Government with the report. The Central Government may cause any such report and reservation or dissent and reason (if any) to be made public, wholly or in part, in such manner as it thinks fit."

1.4.3 The Court, which is appointed under Rule 75, does not act as a 'Commission of Inquiry' which is usually appointed under the Commissions of Inquiry Act to inquire into any definite matters of public importance. The role of the Court, on its appointment under Rule 75 of the Aircraft Rules, is essentially that of an Investigator. It is for this reason that no procedure has been prescribed in the Rules which the Court is required to follow. While carrying out its functions, the Court is not only required to comply with the provisions of the Aircraft Act, and the Rules framed thereunder, but it must necessarily also keep in view the provisions of ICAO Annex. 13.

1.4.4. As an Investigator, investigating into an accident, the Court had to perform multi-farious duties and functions. Before referring to them, it would be pertinent to point out that whereas an Inspector of Accidents, who is appointed under Rule 71, would normally be belonging to the Civil Aviation Department and would have all the machinery available to him for conducting the investigation, the Court, when it is appointed to hold an investigation under Rule 75, lacks the basic infrastructure to conduct the investigation of such a magnitude. Assessors are appointed to assist the Court but the actual investigation work cannot be carried out by them. Despite these handicaps, the investigation continued smoothly primarily due to the fact that whenever directions were issued by the Court to any of the participants before it or to the Civil Aviation Department or any other Organisations, the directions of the Court were readily complied with. On a few occasions it also became necessary to require the Assessors to conduct the investigation, which they did with the help of other organisations.

1.4.5 As an Investigator, the first task which was undertaken was to see that the tapes from the Cockpit Voice Recorder, which had been salvaged, were recoverd from the recorders and subsequently analysed. Requisite directions were issued and the tapes were removed from their respective recorders on 16th July, 1985. This operation was carried out at the Air India workshop at Santacruz in the presence of the accredited representatives of Lockheed (manufactures of DFDR), Fairchild (manufacturers of CVR), Boeing Airplane Co., Canadian Air Safety Board (CASB), National Transportation Safety Board, USA (N.T.S.B), Air India and Government of India. The tapes so recovered were subsequently played and analysed.

1.4.6 On an appointment being made under Rule 75 the Court would become incharge of overall investigation of the accident. In that capacity, and in order to effectively discharge its functions, it became necessary for the Court to undertake the following tasks :-

(a) For getting first hand information, the Court had to personally inspect the wreckage which had been recovered and was housed in a boat yard in Cork. While in Cork opportunity was also taken to go to the Cork Regional Hospital and to have discussions with and be briefed by the hospital staff. A trip was also made to Shannon with a view to see and understand the working of the Secondary Radar System which was in use there. On this visit the original ATC tape, which contained communication betwen Kanishka and the ATC, was also heard.

As it was suspected that there may be a link between the blast which had taken place at Narita Airport on 23rd June, 1985 and the accident to Air India's flight 182, it was felt necessary to inspect the site of the bomb blast at Narita Airport.

On the aforesaid visit to Tokyo, the site where the blast had taken place was inspected which gave some, though very vague, idea of the detonating power of the blast. While in Tokyo meetings and discussions were also held with the police and Aviation Authorities. The Court also had the advantage of being able to meet members of the team investigating into the Japan Airlines Flight JL 123 accident which had occurred near Tokyo on 12th August, 1985. Similarities and dissimilarities between the two accidents were, to some extent, noticed and some information was exchanged.

Information was received, that some floating wreckage had been picked on the coast of England and it was possible that some of the places, which were so received, should be subjected to further detailed chemical and metallurgical examination. In order to decide this, it became necessary to visit RADRE, Kent, U.K. As a result of the inspection and the discussions there, it was decided by the Court that the pieces so recovered should be sent to BARC at Bombay for further analysis.

(b) Directions had to be given, from time to time, with regard to the mapping and salvaging of the wreckage which was being effected. It had to be decided as to how, and in what areas, the Scarab should continue to map the wreckage and take video films and still photographs. Based on the information received therefrom and after discussions with the experts, both Indian and foreign, a list was drawn up indicating the items which had to be salvaged. As the weather was likely to be unpredictable, with a possibility of its deteriorating rapidly, a priority list of items to be salvaged had also to be prepared, and this was done. In view of the fact that the Canadian ship John Cabot and the Scarab had a limited capacity, with regard to the size and weight of pieces which could be lifted from the bottom of the ocean, decision had also to be taken with regard to the deployment of another ship. As a consequence thereof a ship 'Kreuzturm' was also engaged in salvage operations.

(c) Directions had also to be given assigning work and duties to different teams of persons. As an Investigator, the Court was incharge of the entire work of investigation which was being carried out in different parts of the world. It not being possible for the Court itself to undertake all the tasks, decisions had to be taken as to how the investigating work was to progress and who would carry out the directions issued from time to time. For example, immediately after reaching Cork on 25th July, 1985 it was felt necessary that a team should be immediately sent to Canada in an effort to get relevant information from there in connection with the flight AI 182. Accordingly, a team of 3 persons headed by Mr. H.S. Khola was directed to proceed to Canada immediately. As a result of the efforts put in by this team, and with the considerable amount of cooperation, help and assistance rendered by the Canadian Authorities valuable information was received by the Court having direct bearing on the investigation. Yet another example in this regard was of requiring Dr. V. Ramachandran, one of the Assessors and an expert in Metallurgy, to be stationed on board the salvage ships during the recovery operations. The procedure which had to be followed by him was also determined. Information about the progress of the salvage operations was communicated on telephone to the Court at all times of day and night. On receipt of such information further instructions, when ever necessary, used to be issued.

(d) Discussions were held with the Indian experts in order to understand some of the complicated questions which had arisen during the investigation.

In an effort to be able to fully appreciate the effect of decompression, the Court visited the Institute of Aviation Medicine at Bangalore where explsoive decompression was simulated for the Court's benefit. Discussions were also held with other experts of aviation medicine who were also given copies of the post-mortem reports for their opinion. National Aeronautics Laboratory was also visited in Bangalore where meeting was held with experts in aerodynamics, structure and metallurgy. Visits to Bombay where more frequent and necessary so that the Court could get first hand information with regard to the work which was being done at BARC.

The investigation involved looking into matters concerning aviation, electronics, medicine etc. Not being familiar with these branches, the discussions which were held, were of immense help and assistance to the Court who had to understand all the evidence and information which it was gathering.

(e) The accident had attracted world wide attention. Right from the start of the investigation by the Court when the recorders were first opened in Bombay on 16th July, 1985 till the conclusion of the hearing, the Press and the TV were eager for information. It was felt that rather than the media resorting to speculation of getting wrong information, the Court itself or its representative should, as and when necessary, brief the media. In this connection interviews were given, both in India and abroad, which were broadcast over the television and printed in the Press. As a result of this, correct information was disseminated with regard to the progress of the investigation without disclosing the Court's opinion on the evidence which had been received.

(f) Finally, the Court had to conduct the formal investigation in Court. For this purpose it laid down the procedure which would be followed. Rule 75 of the Aircraft Rules required that the investigation would be in open court. It was, however, felt that in this particular case it would be advisable that some evidence should be obtained in Camera. The Court, accordingly, recommended that necessary amendment should be made in Rule 75 so that the Court was given the power to hold certain proceedings in camera when the circumstances so warranted. The suggestion of the Court was accepted and that resulted in Rule 75(2) being amended and, as a result thereof, the Court was given the power to hold proceedings in camera if the stipulated conditions existed.

COMMENCEMENT OF FORMAL INVESTIGATION

1.5.1 The object of setting up a court to investigate into an accident is primarily to find out the causes and circumstances of the accident and thereafter to make recommendations. Such an investigation is not in the nature of an adversary litigation between the participants before the Court. As such it should be the endeavour of all the participants to assist the Court in arriving at a correct conclusion.

1.5.2 Under Rule 75 of the Aircraft Rules, the procedure which has to be followed in the investigation of an accident is to be determined by the Court itself. While laying down the procedure which is required to be followed, the endeavour of the Court has necessarily to be to adopt such procedure which would help the court in being able to complete its task satisfactorily, and in the shortest possible time. Whenever an accident takes place, it is of utmost importance that the cause of the accident must be ascertained at the earliest so that if any remedial measures are to be taken then those steps should be taken without any undue delay.

1.5.3 In the present case, there were a number of factors which had to be kept in view while determining the procedure whichshould be followed. The accident had occurred over international waters and approximately at a distance of about 5000 miles from the place where the investigation was to be conducted, namely, New Delhi. The ill fated flight itself had commenced from Canada, and this meant that most of the evidence would only be available there. Matters were not simplified by the fact that the debris itself was lying at the bottom of the ocean, 2 miles under water. It became apparent, at the very beginning, that to recover the entire debris would be a superhuman task and it will not be possible to do so within the limited time span which was available.

1.5.4 It was thought that it would be of assistance if all the participants got together so as to determine what procedure should be followed. The procedure had to be such which would give an effective opportunity of hearing to all the participants, without in any way unduly prolonging the investigation.

1.5.5 The Court decided that, in order to obtain the views, it would be necessary and advisable to have a Pre-hearing Conference.

1.5.6 The first decision which had to be taken was as to who were to be given a participants status. Keeping inview the provisions of Annex 13, participants status was given to Governments of Ireland, Canada, USA and India. Similar status was also given to Boeing Airplane Co. and Air India. As there might have been some similarities or dissimilarities between the present accident and the accident of the Japan Airlines Boeing 747-SR and also because there may have been a possibility of the present accident being linked with the explosion which had taken, place at Narita Airport, Tokyo on 23rd June, 1985, an Observer's status was given to the Government of Japan.

1.5.7 Notices for holding of the Pre-hearing Conference on 16th September, 1985 were accordingly issued on 29th August, 1985. The agenda for the Conference was to be as follows :-

a. To make suggestions to the Court for its consideration, regarding the procedure to be followed in the conduct of the formal proceedings in the Court.

b. To draw up a tentative list of witness.

c. To draw up a tentative list of exhibits.

d. To determine the areas to be inquired into

e. To fix a date for the commencement of the public hearing.

f. Any other matter with the permission of the Court.

1.5.8 Except for the Government of Japan, all the other participants were represented at the said Pre-hearing Conference. After discussions had been held between the Court and the Participants, some decisions were arrived at regarding different items of the agenda.

1.5.9 Firstly the following points were framed, indicating the areas to be inquired into by the Court:

a. Whether the accident was caused by a structural failure?

b. Whether the accident was caused by some human effort?

c. Whether the accident was caused by some criminal act?

d. Whether the accident was caused by an external non-criminal act?

e. Based on the evidence on record, what steps should or can be taken so as to ensure greater air safety.

1.5.10 It was further decided that, as suggested by all the participants, at least critical portions of the wreckage should be recovered.

1.5.11 With regard to the recording of the evidence it was decided that evidence will, in the first instance, be taken by filling affidavits or by filling statements alongwith affidavits. Copies of the same were to be supplied to the other participants for their consideration. These affidavits were to be filed on or before 18th October, 1985 and a second Pre-hearing Conference was to take place on 30th October, 1985 at New Delhi when it was to be decided as to which of the persons should be called for cross-examination. It was determined that it is only thereafter that hearing would commence in open court.

1.5.12 A tentative list of witnesses was also drawn up and it was decided that on the next date names of more witnesses may be added and, furthermore, the participants would be free to file any affidavits which they deem fit including affidavits in rebuttal.

1.5.13 Another important decision which was taken at the Pre-hearing Confence was that a Structural Group was formed consisting of (1) Mr. H.S. Khola or his nominee (2) Representative of the Canadian Government (3) Representative of NTSB, USA (4) Representative of Boeing Airplane Co., USA (5) Representative of Air India. This group was entrusted with the task of examining and analysing, initially in Seattle, USA, the video films and the still photographs of the wreckage. This group was also to indicate and decide the items of priorities of wreckage which had to be recovered. The report of this group was required to be submitted by 18th October, 1985. The report of the work done at Seattle was in fact submitted only on 25th October, 1985. This group was also given the liberty to associate any other experts or persons from Boeing or any other Authority. The group was also to inspect the floating wreckage which had already been salvaged and any further wreckage which would be salvaged.

1.5.14 Although the affidavits by way of evidence had to be filed by 18th October, 1985, it was only the Government of Ireland who filed an affidavit by at date. On behalf of the Government of India, an application was filed asking for more time. The reason stated was that the affidavit which had to be filed was to be of Mr. H.S. Khola but he was out of India as he was heading the structures group which was evaluating the video films and photographs at Seattle. The Court had no option but to grant further time to the Union of India to file its affidavits and this necessarily resulted in the adjournment of the Pre-hearing Conference which had been fixed for 30th October 1985.

1.5.15 As the salvage operations were reaching a critical point it became necessary for the Court to go to Cork on 27th October, 1985. Taking advantage of the presence of the Court in Cork, other participants also came there. Besides them, representatives of CP Air and Air Canada also arrived. At one of the informal meetings between the Court and the representatives of the participants, applications were filed by CP Air and the Air Canada, inter alia, praying that they should be permitted to participate in the investigation. It might be mentioned here that CP Air had interlined one of the passangers from Vancouver to AI-182, while Air Canada was the handling agents in Canada of Air India. After hearing the participants it was decided that participant status should also be given to these two viz., CP Air and Air Canada.

1.5.16 The participant had all filed their affidavits by way of submissions. The Court indicated that formal hearings would be held for the purpose of cross-examining some of the witnesses about three weeks after the receipt of all the reports of the various groups. While in Cork, in the first week of November, 1985 some of the salvaged pieces of the wreckage were brought there. After they were inspected by all the participants and their advisers, who were present in Cork, it was decided by the Court that further detailed metallurgical and other examination of those pieces would be done at BARC, Bombay. In order that there should be no undue delay the Court decided that a Group be constituted consisting of expert representatives of all the participants and also the nominees of the Court. This group was asked to carry out metallurgical and other examination of some of the critical pieces salvaged and give its report to the Court. The group consituted as a 'Committee of Experts' was as under :-

a. Mr. A.J.W. Melson, Canadian Aviation Safety Board, Canada.
b. Mr. R.K. Phillips, Canadian Pacific Air, Canada.
c. Mr. T. Swift, Federal Aviation, Administration, USA.
d. Mr. R.Q. Taylor, Boeing Commercial Airplane Co., USA.
e. Mr. J.P. Tryzl, Boeing Commercial Airplane Co., USA.
f. Mr. J.F. Wildey II, National Transportation Safety Board USA.
g. Mr. S.N. Seshadri, Bhabha Atomic Research Centre, India (Coordinator).

1.5.17 The parties were informed in Cork that the report of Mr. H.S. Khola, Inspector of Accidents, would be available by about 8th November, 1985. It was then decided that the statements of the first batch of witnesses should be recorded from 20th November, 1985. It was also agreed that if some of the reports of the experts were not received, further examination of the witness may have to postponed.

1.5.18 After receipt of the report from Mr. Khola. on the 8th November, 1985, a notice of the holding of the Public Hearing was issued to all the participants. This notice indicated that the hearing would commence on 20th November, 1985. In the meantime, a Public Notice was also published in the daily "Times of India" in Delhi and Bombay editions on 21st October, 1985 in which it was stated as follows :-

NOTICE AIR INDIA KANISHKA ACCIDFNT INVESTIGATION

The Government of India, vide Notification dated 13th July, 1985, appointed Hon'ble Mr. Justice B.N. Kirpal as a Court to investigate into the accident to Air India's Boeing 747 aircraft VT-EFO (KANISHKA) near the Irish Coast on 23rd June, 1985, when the aircraft was engaged on a scheduled passenger flight from Montreal to Bombay via London and New Delhi.

Any person having direct knowledge, who may desire to make representation concerning the circumstances or causes of the accident, may do so in writing in the form of an affidavit duly attested by an Oath Commissioner or a Notary Public and address the same to the undersigned so as to reach him within 15 days of the publication of this Notice.

S.N. SHARMA SECRETARY COURT OF INVESTIGATION COURT NO.10,DELHI HIGH COURT SHERSHAH ROAD NEW DELHI - 110 003

Pursuant to the aforesaid public notice no affidavit was received from any one.

1.5.19 The public hearing commenced on 20th November, 1985 and the first session concluded on 28th November, 1985. During this period statements of Mr. H.S. Khola, Wing Commander Dr. I.R. Hill and Sgt. Atkinson of R.C.M.P., Canada were recorded.

1.5.20 Till that date, report on the examination of the salvaged pieces had not been received. It was anticipated that the report would be available by mid December, 1985. In order to give the parties sufficient time to study the reports of all the experts it was decided that further evidence would be recorded from 22nd January, 1986.

1.5.21 After the reports were received from BARC; AIB; Farnborrough; NTSB; USA; and Mr. Bernard Caiger of CASB, Canada and the copies of the same had also been received by all the participants, recording of evidence commenced from 22nd January, 1986 and concluded on 30th January, 1986. In all statements of 13 witnesses were recorded.

1.5.22 At this stage it will be pertinent to make a few observations with regard to the procedure which was laid down for recording of evidence etc. As already indicated, most of the evidence was such which was not available in India. As a Court investigating the accident under the provisions of Aircraft Rules, it had no jurisdication to compel attendance of any witness from abroad. The Court also had no jurisdication, either under the Rules or under the provisions of Annex 13, to require any witness to be examined in a country other than the one in which the Court is holding the investigation. The Court was informed that, if called upon, some of the persons who were outside India may not be inclined to testify before the Court.

1.5.23 Faced with the aforesaid difficulty it became necessary, therefore, to evolve a procedure which would enable the Court to get the requisite information. As long as the Court was satisfied that the information which was being received was one which had been truthfully given by a person, it was immaterial as to the manner in which the information was received. It is for this reason that it was decided that evidence will, in the first instance, be given by way of affidavits. It was also provided that the statements could also be filed along with affidavits. This latter course was permitted so as to enable some of the statements, which had been recorded by members of the Royal Canadian Mounted Police, to be placed before the Court. These statements, of course, had to be accompanied, as they were, with the affidavits of the persons who had recorded the statements.

1.5.24 At one stage, by a formal application in writing, Air India had protested against this procedure being followed. By order dated 22nd

November, 1985, an objection by Air India to the filing of the statements accompanied by affidavits, was dealt with by the Court in the following words :-

"With regard to the affidavits which have been filed by the Government of Canada, I would only like to observe in the Pre-hearing Conference on 16th September, 1985, it was decided that "Evidence will, in the first instance, 1985 be taken by filing affidavits or by filling of Statements along with affidavits." It was understood that if it is not possible to file affidavits of the persons who are in a position to give information then affidavits may be filed of other persons who may have recorded the statements of the persons who are in a position to give information. This is not an adversary litigation where one of the parties may lose because of lack of proof. One of the objects of setting up a Court to investigate into an accident is to find out the causes of the accident and to make recommendations. It is necessary for this purpose to get information which may be relevant. It is true that strictly speaking the statements which are annexed to the affidavits may not be admissible as evidence in a Court of Law when there is a litigation between the parties but considering limitations which we have, namely, where a Court like the present has no jurisdication to enforce the attendance of any witness who is outside this country and furthermore, the Court has no jurisdication to compel any one to give information, the procedure which was adopted was thought to be the most practical one for obtaining information in connection with the accident. Under the circumstances, the affidavits which have been filed along with the statements which have been annexed thereto which give information with regard to the accident, have to be taken on record."

1.5.25 Another advantage of following the aforesaid procedure was that the time which would have been taken in Court in examining of the witnesses was considerably reduced. After the participants had filed affidavits, the same were to be secrutinised and it was then to be decided as to which of the deponents or persons should be called for examination in Court. Effectiveness of this procedure which was adopted is apparent from the fact that though affidavits by way of evidence were filed in

Court, ultimately only 13 witnesses had to be examined in Court and sitings were held in Court only on 14 days.

1.5.26 Written arguments were filed on the forenoon of the 4th February, 1986 and oral arguments were heard in the afternoon of that day. No written arguments or oral submissions were made by the Government of Ireland, CP Air or Boeing Company.

1.5.27 Mr. I.G. Whitehall, councel for the Government of Canada took exception to some of the submissions which were contained in the written submissions filed by Air India. Mr. Whitehall contended that the Court had opined that it will not go into the question of responsibility of the unfortunate accident and therefore, there was no; justification for Air India to include in its written submissions numberous passages which tended to fix responsibilities.

1.5.28 By the order dated 4th February, 1986, it was made clear that it was not the intention of the investigation to apportion blame if any lapse had been committed and, therefore, the Court would ignore any written submissions which tended to apportion blame or responsibility for any lapse of any participants. It might here be mentioned that such a question had earlier arisen while the statement of Sgt. Atkinson was being recorded. The Court had then held that it will not go into the question as to who was responsible for the accident. It was in view of this order that no evidence was led by any of the parties on the question as to who may have been responsible for any possible lapse which could have led to this accident.

2.1 Flight Preparation

2.1.1. Air India Boeing 747 aircraft VT-EFO 'Kanishka' was operating flight AI-181 (Bombay-Delhi-Frankfurt-Toronto-Montreal) on 22nd June, 1985. From Montreal it becomes AI-182 from Mirabel to Heathrow Airport, London enroute to Delhi and Bombay. The aircraft arrived at Toronto from Frankfurt at 1830 Z and was parked at gate No. 107 Terminal 2 at L.N. Pearson International Airport. In accordance with the Canadian regulations, all the passengers and their baggage were off loaded to complete the customs and immigration checks. Transit cards were handed out to 68 transit passengers destined to Montreal who disembarked at Toronto for customs and immigration checks.

2.1.2. The flight from Toronto to Montreal was made up of the following:-

(I) Passengers originating at Toronto and their baggage.

(ii) Transit passengers, and their baggage, continuing their flight to Montreal.

(iii) Two diplomatic bags from Indian Consulate General, Vancouver via Air Canada Cargo Flight, and some Air India Mail.

(iv) Fifth Pod engine and its associated parts.

(v) Interline passengers and their baggage from connecting flights as detailed below:-

a) Air Canada flight AC-102
from Sasktoon - 2 Passengers

b) Air Canada flight AC-106
from Edmonton - 4 Passengers

c) Air Canada flight AC-170
from Winnipeg - 1 Passenger

d) Air Canada flight AC-170
from Winnipeg - 4 Passengers

e) Air Canada flight AC-136
from Vancouver - 10 Passengers

2.1.3. One passenger by name 'M. Singh', checked in at Vancouver on Canadian Pacific flight CP-060 (Vancouver-Toronto) of 22nd June 1985, and got his one piece of baggage interlined to Air India flight AI-181
even though he had no confirmed reservation on AI-181. This passenger, however, did not board the flight CP-060 at Vancouver and also did not check-in for Air India flight AI-181/182 at Toronto.

2.1.4 The checking-in of passengers for Air India flight AI-181/182 at Toronto began at 1830 Z. The checking-in of the passengers was carried out by Air Canada personnel who are the handling agents for Air India, and was supervised by Air India personnel. The Air Canada personnel indicated the computer sequeritial numbers (security numbers) on the passenger boarding card stubs. At about 1930 Z announcement was made for the primary security check of passengers and their hand baggage. The passengers passed through the Door Frame Metal Detector and their hand baggage was checked through X-Ray machine. The passengers were also subjected to physical security check with the help of Hand Held Metal Detectors. The transit passengers to Montreal and their hand baggage were also subjected to these security checks, while their checked in baggage, after clearance by the Canadian Customers authorities was placed by the passengers themselves on the conveyor belt while they were still in sterile area. In this way there was personal identification by the passengers of all checked in baggage, except the baggage which had been interlined to this flight.

2.1.5 The flight was closed for check-in at about 2150 Z. There were 10 'NO SHOWS' and 4 'GO SHOWS'. The security checked passengers remained in the holding area gate No. 107 till boarding was announced at about 2210 Z. At the boarding gate secondary security check of the passengers and their hand baggages was carried out. The passengers were frisked with the help of Hand Held Metal Detectors and their hand baggages were opened and physically checked.

2.1.6 The security numbers on the stubs were circled on the pre-numbered Security Control Sheet to ensure that all the checked-in passengers have boarded the aircraft. Passenger boarding was completed by 2300 Z. Traffic/Sales representative of Air India verified the Security Control Sheet with the number of stubs collected and the number of passengers checked-in.

He found that all the 202 passengers, who had checked-in, had boarded the aircraft.

2.1.7 As stated earlier, 68 transit passengers had disembarked at Toronto for completing the customs and immigration checks. However, only 65 of these passengers re-boarded the aircraft as per transit cards collected at the boarding gate. It is in evidence that almost every flight of Air India to Canada, two or three transit passengers do not re-board the flight at Toronto. Some Toronto passengers travelling to India buy their tickets "Montreal-India-Montreal" instead of "Toronto-India-Toronto", for which the fare is higher, and they travel by bus to Montreal to catch the Air India flight to India. On their return journey, when they get down at Toronto for customs and immigration checks, they simply do not re-board the flight even though their reservations are upto Montrteal. These passengers sometimes inform Air India personnel at Toronto about their not re-boarding the aircraft. On 22nd June, 1985, however, no such passenger informed Air India personnel.

2.1.8 There was a crew change at Toronto. The flight and cabin crew members who took over the flight AI-181/182 had been laid over in Toronto for the week prior to the accident flight and were scheduled to take the flight upto London where they were to be relieved by another set of crew. Capt H.S.Narendra was the Commander of the flight, with Capt S.S.Bhinder as co-pilot and Mr.D.D.Dumasia as the Flight Engineer. In addition there were 19 cabin crew members. All the crew members reported together at the airport at 2130 Z. As per the practice existing at that time, the flight crew and cabin crew members were not subjected to frisking checks and their hand baggage were also not security checked. Their checked-in baggage was, howevewr, security checked along with the other checked-in baggage of passengers.

2.1.9 The interline baggage was brought to the international baggage make-up area by the Air Canada staff but, as mentioned earlier, it was not personally identified and matched with the passengers.

2.1.10 The checked-in baggage of the originating passengetrs and crew members of AI-181/182 was sent on a conveyer belt to the baggage make-up area. All the checked-in baggage along with the interline baggage was required to be security checked on the X-ray machine which was located in the baggage make-up area at the end of international belt No.4.

2.1.11 It has been reported that the X-ray machine worked intermittently for some period and at about 2045Z it broke down and there was no picture on the screen. The Machine could not be repaired on that day as it was a week-end and no technician could be contacted. Air India's Security Officer then advised that the rest of the baggage be checked with a PD-4 explosive detector provided by him. He also demonstrated the use of the PD-4 detec- tor to the concerned personnel.

It has been reported that about 60 to 70 baggages were checked and cleared by the PD-4 detector.

2.1.12 The security checked baggage was loaded in the containers by the Air Canada personnel. The loading of the baggage in containers was over by about 2230 Z. The ramp personnel of Air Canada carried the container and loaded them in the aircraft.

2.1.13 From March, 1985, after the introduction of Air India flight AI-181 through Toronto, diplomatic bags from Indian Consulate General at Vancouver were being sent to India by Air India flight from Toronto. Accordingly, two diplomatic bags, duly sealed and escorted, were delivered to Air Canada office at Vancouver on 21st June and they arrived at Toronto by Air Canada flight AC-580. One of the bags Sl.No. 49 contained 13 empty large diplomatic bags while the other bag Sl.No. 50 contained diplomatic mail. The total weight of the bags was 13.8 Kgs.

2.1.14 In addition to the above, a few envelopes containing some flight documents addressed to Accounts Office, Air India, Bombay, and one envelope addressed to Commercial Headquarters, Air India, Bombay from Air India Town Office in Toronto, were collected by Messrs Mega International.

2.1.15 The aircraft was refueled by CAFAS with 14,602 litres of fuel.

2.1.16 On 8th June No. 1 engine of Air India Boeing 747 aircraft VT-EGC had failed during take off. The failed engine was to be ferried to Bombay on flight AI-181/182 of 22nd June.

2.1.17 The failed engine and the associated parts were placed in Air Canada Engineering Hangar at Toronto airport since June 8,when the aircraft was brought to the engineering hangar for engine replacement. Air India had requested Air Canada on 15th June for preparing the failed engine for installation as fifth pod mounting of the aircraft on 22nd June.

2.1.18 On 15th June Air India deputed one of their foremen to Toronto to bring back the failed engine. From 17th to 21st June, Air Canada technicians prepared the failed engine for installation as fifth pod. This preparation involved removal of cowlings, fan blades, locking of compressor rotors etc. Air Canada Engineering/Maintence personnel loaded the aircraft/engine parts on 4 pallets and one container. These pallets and container were then delivered at 0100 Z on 22nd June by Air Canada personnel to Messrs Mega International cargo warehouse at Toronto Airport within restricted airport area. (Messrs Mega International Cargo Warehouse at Toronto Airport within restricted airport area. (Messrs Mega International is the cargo handling agent of Air India at Toronto). The fifth pod engine was transported by Air Canada directly from their premises to the 'Kanishka' aircraft for mounting it on the fifth pod.

2.1.19 Installation of the engine on the fifth pod began immediately on arrival of flight AI-181 at Toronto on 22nd June and the work was completed by 1930 Z. One of the mechanics of Air Canada installed the Mach Air Speed Warning Switch in the Main Equipment Centre as part of the fifth pod engine installation.

2.1.20 The pre-loaded four pallets and one container were brought to the aircraft by M/s Mega International personnel from their warehouse in the afternoon of 22nd June for loading them into the aircraft cargo compartment at positions assigned by the Air Canada load agent. Difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fitting from the aft cargo compartment door cut-out. After removal of the fittings, the cowl could be loaded. All the removed fittings were then reinstalled.

2.1.21. On account of the delay in loading the cowls, departure of the flight was delayed by one hour and twentyfive minutes.

2.1.22 Maintenance Manager of Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft and no snag was observed by him. The commander duly accepted the aircraft.

2.1.23 Senior Flight Despatcher, Air India, Toronto did the flight despatch of AI-181/182 for sectors Toronto-Montreal-London. He briefed the flight crew members about flight plan, weather, Air Traffic Control and fuel requirements. The flight plans for the sectors Toronto-Montreal-London were duly accepted and signed by the Commander.

2.2 Progress of the Flight

2.2.1. The Aircraft took off from Toronto Runway 24L at 0016 Z on 23rd June, 1985. The Maintenance Manager, Security Officer and Passenger Service Supervisor of Air India travelled on board the aircraft for their duties at Montreal. In all there were 270 passengers on board in addition to 22 crew members.

2.2.2. The route from Toironto to Montreal was V-98/JHL-594/MSS/ V 203/FRANX at flight level 290. The flight was uneventful and the aircraft landed at Montreal at 0110 Z. No snag was reported by the flight crew. The aircraft was parked at Cluster 1 Bay No.114.

2.2.3 Sixtyfive passengers destined to Montreal along with the three Air India personnel mentioned above deplaned at Montreal. The remaining 202 passengers, who had joined the flight at Toronto, remained on board the aircraft as transit passengers were not allowed to disembark at Montreal.

2.2.4 Baggage handlers off loaded three containers of baggage, one valuable container and four cargo containers from the aircraft.

2.2.5 Transit Check 'C' of the aircraft was carried out at Montreal. The Flight Engineer also carried out his pre-flight inspection and found that rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to an Air Canada Technician who flaired the handle and applied the high speed tape. There was no other snag observed during the inspection. The personnel of CAFAS refueled the aircraft with 96,000 litres of fuel. Total fuel on board at the time of take off from Montreal was 104,000 Kgs. which was adequate for 8 hours 40 minutes of flying. The commander accepted the aircraft and signed the 'Certificate of Acceptance' of the aircraft.

2.2.6 At approximately 2130 Z Air Canada personnel opened the passenger check-in counter for flight AI-182 (The flight AI-181 terminates at Montreal and the flight from Montreal to London-Delhi-Bombay is designated as AI-182). The checked-in baggage was sent to the baggage make-up area. Between 2300-2350 Z, a suspect suitcase was identified as the X-Ray showed what appeared to be some wires next to the suitcase opening. The suitcase was placed on the floor next to the X-Ray machine. Subsequently two more suspect suitcases were located. These suitcases were also placed next to the X-Ray machine to await the arrival of the Air India Security Officer who was to arrive on Air India flight AI-181 from Toronto. The remainder of the checked-in baggage, which cleared the security check, was loaded in containers by Air Canada personnel for loading on board the aircraft.

2.2.7 Two diplomatic pouches from the Indian High Commission, Ottawa were brought to Mirabel. After the flight arrived, one of the pouches of Category 'A' weighing 1 Kg. was given to the Flight Purser. The other Category 'B' pouch weighing 9 Kgs. was placed in an valuable container 14R.

2.2.8 No other cargo was accepted for this flight except a small package (weighing less than 1 Kg) containing medicines for cancer treatment of a patient in New Delhi. This parcel was received at 1530 Z on 21st June and was loaded in container 14R by Messrs Mega International on 22nd June, more than 24 hours after its receipt.

2.2.9 Five baggage containers, one valuables container and two empty containers were loaded in the aircraft.

2.2.10 The checked-in passengers with their hand baggage went to the departure sterile area. At the entrance to the departure sterile area security staff used X-Ray units and metal detectors to check passengers and their hand baggages.

2.2.11. At approximately 0100 Z, 23rd June, after the primary security check was completed, the passengers proceeded to boarding gate No.80. At this lcoation the secondary security check was done on passengers using hand held metal detectors. Hand baggages were also subjected to further physical and visual check by them.

2.2.12. A total of 105 passengers boarded the flight AI-182 at Mirabel Airport. It was determined that all the passengers who had checked-in, boarded the aircraft. There was no interline passenger. At Montreal there were five 'NO SHOWS' and two 'GO SHOWS'. In all 307 passengers were on board the aircraft. The flight plan and the load and trim sheet, however, indicated 303 passengers as four of the 6 infants were not included in the passenger list.

2.2.13. The seating distribution of the passengers was as given below:-

Zone/Class Total number of Seats Occupied seats Zone 'A' - First Class 16 1 Zone 'B'- Club Class 22 - Upper deck - Club class 18 7 Zone 'C' - Economy Class 112 104+ 2 Zone 'D' - Economy Class 86 84+ 1 Zone 'E' - Economy Class 123 105+ 3 377 301+ 6 (Infants)

2.2.14 The seating distribution of the 19 cabin crew members was as follows:-

Two at door L1 and two at door R1
Two at door L2 and two at door R2
Two at door L3 and one at door R3
Two at door L4 and one at door R4
One at door L5 and one at door R5
One in crew rest area, Zone 'A'
One in jump seat upper deck
One crew rest area upper deck.

2.2.15 The three suspected suit cases were not loaded on the aircraft and were detained in the baggage make-up room. After the names of the passengers to whom the suit cases had belonged had been identified the same were transferred to the decompression chamber of E1 A1 Airline where they were examined, with the aid of a Police Explosive Dog, with negative results. The suit cases were kept overnight in the said chamber and when they were opened it was found that they contained no explosive items.

2.2.16. No unclaimed baggage pertaining to the Air India flight was recovered either at Toronto or at Mirabel or Dorval Airport in Montreal.

2.2.17. The flight plan for the sector Montreal to London was filed on telephone by the Air India Flight despatch from Toronto to Dorval ATC Centre. He requested for route SHERBROOKE-COLOR-NAT XRAYBUNTY-MERLY-EXMOR-IBLEY-SAMTN-HAZEL-OCKHAM-LONDON at flight level 290 upto COLOR and flight level

330 thereafter. The reporting points on Track XRAY on that day were COLOR, 47N/50W, 49N/40W, 50N/30W, 51N/20W, 51N/15W, 51N/08W and BUNTY.

2.2.18 The aircraft took off from Montreal at 0218 Z. Its estimated time of arrival at London was 0833 Z. The CVR and the ATC tapes show that the flight was normal and quite uneventful. Suddenly at about 0714 Z, when the flight was being monitored by the Air Traffic Controller at Shannon, with the help of secondary surveillance radar, the aircraft disappeared from the radar scope. Subsequently, the ATC at Shannon got the know that the aircraft had met with an accident and its wreckage was sighted about 110 miles west south-west of Cork, Ireland.

PERSONNEL INFORMATION

2.3.1 Pilot-in-Command (Capt. H.S. Narendra)

2.3.1.1 Cap.t H.S. Narendra (age 561/2 years, date of birth 25th November, 1928) joined Air India on 1st October, 1956. He held ALTP Licence No. 247 valid upto 29th October, 1985 and FRTO No. 478 valid upto 23rd October, 1985. He was released as a Co-pilot on Boeing 707 aircraft on 21st July, 1960 and as a Commander on Boeing 707 aircraft on 17th September, 1964.

2.3.1.2 For conversion as Pilot-in-Command on Boeing 747 aircraft, Capt. Narendra had undergone ground training at Boeing Airplane Company, USA and simulator and aircraft flying training at Bombay in 1972. He completed his route checks for Pilot-in-Command endorsement between December, 72 and January, 73. He became a Commander on Boeing 747 aircraft on 14th February, 1973.

2.3.1.3 Details of Capt. Narendra's flying experience and licence renewal checks are as given below:

a. Total flying experience : 20, 379:15 hours

b. Flying experience on B-747 as

(i) Pilot-in-Command : 6,364.50 hours

(ii) Co-pilot : 123:45 hours

c. Day flying experience
on B-747 aircraft : 3,980:00 hours

d. Night flying experience

on B-747 aircraft : 2,508:35 hours

e. Flying experience during

(i) last 6 months : 301:45 hours

(ii) last 3 months : 159:40 hours

(iii) last 30 days : 68:45 hours

(iv) last 7 days : 9:00 hours

He had last flown as Pilot-in-Command on flight AI 181 (Frank- furt to Toronto) on 15th June, 1985.

f. Date of last licence renewal and IR check : 8 May, 1985

g. Date of last route check : 24 March, 1985

h. Date of last medical examination at CME, Delhi : 29 April, 1985

i. Date of last simulator refresher course : 19 December, 1984

j. Date of ground technical refresher course : 6/7 May, 1985

k. Date of last flight safety refresher course : 25 July, 1984

l. Rest period before operating the accident flight : 1 week

2.3.1.4 Records indicate that on 29th June, 1966, Captain Narendra was declared medically unfit for 2 months to reduce his weight by 10 Lbs. In February, 1973 he was advised to wear corrective by-focal glasses while flying. In May, 1975 he was again declared medically unfit for 3 months.

2.3.1.5 Capt. Narendra was earlier involved in the following two incidents:

(a) On 25th August, 1984, while operating flight AI-1100 from London to Delhi, there was a deviation of the aircraft by about 170 nautical miles from the track over Rahimyar Khan in Pakistan. He was given necessary INS refresher and Route checks with particular emphasis on cross checking procedure.

(b) On 6th December, 1984, while operating flight AI-124 Delhi-Bombay, the aircraft was observed approaching runway 32 at Bombay Airport when runway in use was 27. Captain Narendra was given simulator training for a series of approaches and landings and visual circuits from right hand and left hands seats for approaches and landings on runway 27 at Bombay Airport.

2.3.1.6 Captain Narendra was not involved in any accident previously.

2.3.2 Co-pilot (Capt. S.S. Bhinder)

2.3.2.1 Capt. S.S. Bhinder (age 411/2 years, date of birth 30th November, 1943) joined Air India on 12th October, 1977. He held ALTP Licence

No. 940 valid upto 25th July, 1985 and FRTO Licence No. 2290 valid upto 2nd February, 1986.

2.3.2.2 Capt. Bhinder was released as a Co-pilot on Boeing 707 aircraft on 18th November, 1978 and as a Co-pilot on Boeing 747 aircraft on 17th May, 1980.

2.3.2.3 Details of his flying experience and licence renewal checks are as given below:

a. Total flying experience : 7,489:00 hours

b. Experience on B-747
aircraft as Co-pilot : 2,469:30 hours

c. Day flying experience
on B-747 aircraft : 1,426:15 hours

d. Night flying experience
on B-747 aircraft : 1,043:15 hours

e. Flying experience during

(i) last 6 months : 157:45 hours

(ii) last 3 months : 65:00 hours

(iii) last 30 days : 20:15 hours

(iv) last 7 days : 9:00 hours

He had last flown as Co-pilot on flight AI-181 (Frankfurt to Toronto) on 15th June, 1985).

f. Date of last licence
renewal check : 25th March, 1985

g. Date of last IR check : 23rd November, 1984

h. Date of last route check : 9 April, 1985

i. Date of last medical
examination at CME
Delhi : 14 January, 1985

j. Date of last simulator
refresher course : 16 July, 1984

k. Date of last ground technical
refresher course : 8/9 October, 1984

l. Date of last flight
safety refresher course : 3 December, 1984

m. Rest period before operating
the accident flight : 1 week.

2.3.2.4 Records indicate that Capt. Bhinder was not involved in any accident earlier.

2.3.3 Flight Engineer (Mr. D.D. Dumasia)

2.3.3.1 Flight Engineer Mr. D.D. Dumasia (age 57 1/2 years, date of birth 10th October, 1927) joined Air India on 27th December 1954. He held flight Engineer's Licence No. 37 valid upto 6th December, 1985. Mr. Dumasia was released as a Flight Engineer on Boeing 707 airecaft on 16th December, 1963 and on Boeing 747 aircraft on 6th February, 1974. He had a total flying experience of 14,885 hours out of which 5,512:35 hours were on Boeing 747 aircraft.

2.3.3.2 Last medical examination of Mr. Dumasia was completed on 1st October, 1984 at CME Delhi. He had completed simulator refresher course on 14th February, 1985, ground technical refresher course on 14/15th January, 1985 and flight safety refresher course on 13th August, 1984.

2.3.4 Cabin Crew

2.3.4.1 A total of 19 cabin crew members were on duty on Flight AI-181/182 on 23rd June, 1985. Their brief details are as given below:

Sl.No. Names Designation Flight Safety course completed on 1. Mr. S.L. Lazar Inflight Supervisor 1/2 April, 1985 2. Mr. K.M. Thakur Flight Purser 18 February, 1985 3. Mr. Inder Thakur Flight Purser 9/10 May, 1984 4. Mr. Shukla Flight Purser 23 January, 1985 5. Mr. S.P. Singh Flight Purser 15 January, 1985 6. Mr. N. Vaid Asst. Flight Purser 2/3 May, 1985 7. Mr. B.K. Sena Asst. Flight Purser 3 December, 1984 8. Mr. N. Kashipri Asst. Flight Purser 12/13 Sept., 1984 9. Mr. J.S. Dinshaw Asst. Flight Purser 17/18 Dec., 1984 10. Mr. K.K. Seth Asst. Flight Purser 11/12 February, 1985

11. Miss Raghavan Airhostess 13 July, 1984 12. Miss S. Ghatge Airhostess 10/11 April, 1985 13. Miss R. Bhasin Airhostess 11/12 February, 1985 14. Miss L. Kaj Airhostess 17/18 April, 1985 15. Miss P. Dinshaw Airhostess 17/18 Dec., 1984 16. Miss S. Lasarado Airhostess 15/16 April, 1985 17. Miss E.S. Rodricks Airhostess 10/11 June, 1985 18. Miss S. Gaonkar Airhostess 3/4 April, 1985 19. Miss R.R. Phansekar Airhostess 29/30 April, 1985 AIRCRAFT INFORMATION

2.4.1 General

2.4.1.1. Boeing 747-237B 'Kanishka' aircraft VT-EFO was manufactured by Messrs Boeing Company under Sl.No. 21473. The aircraft was acquired by Air India on 19th June, 1978. Initially, it came with the expert Certificate of Airworthiness No. E-161805. Subsequently, the Certificate of Airworthiness No. 1708 was issued by the Director General of Civil Aviation, India on 5th July, 1978. The C of A was renewed periodically and was valid upto 29th June, 1985. From the beginning of June, 1985, C of A renewal work of the aircraft was in progress. The aircraft had the Certificate of Registration No. 2179 issued by the DGCA on 5th May, 1978. The commercial flight of 'Kanishka' aircraft started on 7th July, 1978.

2.4.1.2 The aircraft was maintained by Air India following the approved maintenance schedules. It had logged 23634:49 hours and had completed 7525 cycles till the time of accident.

2.4.1.3 The aircraft was fitted with four P & W JT9D-7J engines having thrust rating of 48650 pounds. The hours and cycles logged by

the engines since new till the time of accident are as given below:
Engine No.1 : P662927-7J - 29,663:26 Hrs (9422 cycles)
Engine No.2 : P695610-7J - 20,810:28 Hrs (6031 cycles)
Engine No.3 : P695602-7J - 21,992:31 Hrs (6564 cycles)
Engine No.4 : P662926-7J - 32,332:15 Hrs (11295 cycles)

2.4.1.4 All the DGCA mandatory modifications and inspections applicable to the subject aircraft had been compiled with. No major component installed on this aircraft and its engines had exceeded the stipulated life period.

2.4.1.5 The last quarter Periodic Check of the aircraft was carried out on 24th May, 1985, at 23274:53 hours and 7439 cycles. Subsequent to this check, two Check 'B' schedules were carried out. The last Check 'B' was carried out on 17th June, 1985, at 23564:14 hours and 7510 cycles and was valid for 200 flying hours.

2.4.1.6 The aircraft had flown 359:56 hours and 86 cycles since last quarter Periodic Check and 70:35 hours and 15 cycles since last Check 'B' till the time of accident.

2.4.1.7 The last Flight Release Certificate was issued on 24th May, 1985 on completion of quarter Periodic Check and was valid for 1100 hours or 150 days elapsed time whichever occurred first. After the last departure from Bombay on 21st June, 1985, the aircraft had flown for 22:34 hours till the time of crash.

2.4.1.8 Mr. Rajendra, Maintenanace Manager, Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft at Toronto on 22nd June, 1985 and no snag was observed by him. No snag was reported by the flight crew during the flight from Toronto to Montreal. Transit Check 'C' of the aircraft for the flight AI-182 was carried out at Montreal by Mr. Rajendra and three Air Canada technicians. The flight engineer also carried out his pre-flight inspection and found that the rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to Mr. P. Bayle, Air Canada technician who faired the handle and applied high speed tape. No other snag was observed during the inspection.

2.4.2 Previous Incidents and Snags

2.4.2.1 A maintenance Group was formed with representatives from Air India and Airworthiness Directorate with Mr. R.K. Paul, Senior Air Safety Officer as the Group Leader to scrutinise the maintenance documents and various defects experienced on this aircraft. The report submitted by the Group (Attachment 'B') indicates that the aircraft was involved in six incidents since the last C of A renewal, details of which are given below

(I) On 13th July, 1984 at Dubai -- flight AI-868 The aircraft returned after aborting take off due to no rise in the EPR and N1 on No.1 engine (Sl.No. 695612). The engine front and rear were checked and found OK. Slight wetness was noticed in the bleed outlets. No external oil leak was noticed. Oil quantity was topped up. The chip detectors and oil filter were found OK. EVC Ph filter was found OK. EVC linkage wes exercised. The engine was run up and its operation was found satisfactory. The snag was suspected to be due to lack of pressurising air at low N1.

(ii) On 18th July, 1984 at Delhi -- flight AI-105 The right hand side fuselage skin between stations 480 and 500 in line with lower portion of forward cargo door cut-out was damaged by high lift. The same was repaired at Delhi. Permanent repair was carried out at Bombay. The repairs were accomplished using guidelines given in the Boeing Structural Repair Manual.

(iii) On 12th August, 1984, at Rome -- flight AI-135 The aircraft landed with No. 2 engine (Sl.No. 662826) shut down in flight due to oil pressure and oil quantity droping. On motoring the engine, oil leak was observed from metal line between F C O C and L O P switch at the switch end. The line was found cracked which was welded and refitted. The line was subsequently replaced at Bombay.

(iv) On 24th October, 1984, at London -- flight AI-104 There was total loss of No.1 hydraulic system fluid. The fluid leak was traced to inlet pressure adapter of flap control module in the left hand body gear wheel well. Two of the four bolts holding the adaptor on the flap control module had sheared. The hydraulic pump, seal, back-up ring and case drain filter were replaced. The flap control module was replaced when

the aircraft arrived at Bombay.
(v) On 14th February, 1985, at Delhi -- flight AI-164 On arrival the leading edge honey comb of the left hand aft trailing edge flap was found damaged about 18 inches in length due foreign object damage. Necessary repair was carried out at Delhi. The aft flap was replaced at Bombay.
(vi) On 28th May, 1985, at Dubai -- flight AI-103 On arrival, the left hand wing to fuselage botton fairing forward rubber seal with strip was found turn off. Temporary repair was carried out at Dubai. Permanent repair was carried out subsequently at Bombay.
2.4.2.2 The flight snags recorded in the flight report books of the aircraft during the 4 1/2 month period prior to the accident were scrutinised by the Maintenance Group and the only significant repetitive defect observed was "R2 door not going to manual". On ground checks by the aircraft maintenance engineers, the operation of the selector was, however, found normal.
2.4.2.3 Prior to operating the accident flight, the aircraft arrived at Toronto from Frankfurt. Capt. R.K. Spencer was the commander of the flight. The flight crew had reported the following three snags:
(I) HF system No. 2 had a lot of distortion
(ii) E P R L indicator unserviceable in 'Go around' mode
(iii) Hydraulic system No.1 pressure indication unserviceable (This snag was carried forward from Delhi).
2.4.2.4 The Auxiliary Power Unit (APU) was unserviceable ex-Bombay and had been released under M E L.
2.4.2.5 For rectification of the above stated snag No.1, Shri Rajendra, Air India's Maintenance Engineer at Totonto checked the connections of the transreceiver and reracked the unit. No snag was reported on this system on Toronto-Montreal sector.
2.4.2.6 Snag No. 2 was carried forward.
2.4.2.7 Regarding the third snag, Mr. Rajendra has stated that the indicator showed 4000 P S I pressure even with no pump running. He therefore, interchanged No.1 and No.3 indicators. The snag, however, persisted. He then replaced transmitter No.1 with a spare transmitter

from the aircraft SE box and the snag was rectified. No rectification work was however, recorded by the AME in the Flight Report Book. No snag was reported on this system on Toronto-Montreal sector.

2.4.3 Installation of 5th Pod Engine

2.4.3.1 On 8th June, 1985, No.1 engine of Air India Boeing 747 aircraft VT-EGC operating flight AI-181 failed during take off at Toronto. The aircraft returned and the engine was replaced by a loaned engine from Air Canada. The removed engine was a P & W JT9D-7Q type (Sl. No. P702353-7Q).

2.4.3.2 Air India had planned to bring back the failed engine of VT-EGC aircraft to Bombay, as fifth pod on their flight AI-181/182 of 22/23 June, 1985 and had sent an Engineer along with the necessary kit to Toronto on 15th June, 1985. The engine borrowed from Air Canada on 8th June, 1985, was flown back to Toronto as a fifth pod engine on flight AI-181 of 22nd June, to return it to Air Canada.

2.4.3.3 Shri C.D. Kolhe, Controller of Airworthiness, Bombay examined the aspects relating to installation of the 5th Pod engine, loading of its components and certification of the related work. Shri Kolhe's report indicates that the failed engine and the associated parts were kept in the Air Canada engineering hanger at Toronto airport since June 8 when the aircraft was brought to the hanger for engine replacement. Air India requested Air Canada on 15th June, 1985, for prepairing the failed engine for installation as fifth pod engine on 22nd June. Accordingly, Air Canada's technicians undertook the preparatory work of removing the cowlings, fan blades, panels, locking of compressor, turbine rotors etc. on 17th June, 1985, and completed the work on 21st June, 1985. The fan blades (46 in number) from the failed engine were placed in 12 wooden shipping boxes provided by Air India. These boxes were then loaded in a container. The other components of the failed engine were loaded on 4 pallets.

2.4.3.4 Installation of the fith pod engine was carried out by Air Canada technicians and the individual items on the task card were certified by the individuals who had carried out the work.

2.4.3.5 Some difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fittings from the aft cargo compartment door cut-out. After removal of the fittings, the pallet could be loaded. All the removed fittings were then re-installed. Removal and installation of the fittings was certified by Mr. Rajendra.

2.4.3.6 A question arose whether removal of the door stop fittings could have caused some difficulty in flight. From the video films of the werckage it was found that the complete aft cargo door was intact and in its position except that it had come adrift slightly. The door was found latched at the bottom. The door was found lying along with the wreckage of the aft portion of the aircraft. This indicates that the door remained in position and did not cause any problem in flight. In the front cargo compartment, there were 16 containers out of which four were empty. Five containers had baggage of Delhi bound passengers. Container at Position 13L had baggage of the first class and London passengers and container at position 13R had crew baggage. The entire baggage of passengers ex-Montreal was loaded in containers at positions 12R, 21R, 22R, 23R and 24R in the front cargo compartment. Container at position 24L contained fan blades in wooden boxes and the other components of the pod engine. Valuable container was at position 14R.

2.4.3.7 In the aft cargo compartment, there were four pallets containing parts of the fifth pod engine and two containers at positions 44L and 44R containing baggage of Delhi bound passengers. The bulk cargo compartment contained passenger baggage bound for Delhi and Bombay. All the baggage and engine parts in the aft and bulk cargo compartments were loaded at Toronto.

2.4.3.8 The total weight of the fifth pod engine and its items was about 9000 kgs. As a result of carriage of the fifth pod engine, the payload of the flight was considerably reduced on London-Delhi sector.

2.4.3.9 At the time of take off from Montreal the aircraft had 104,000 kgs of fuel on board which was adequate for 08:40 hours of flying as against sector flying time of 06:15 hours. The flight plan fuel was calculated taking Paris as the alternate airport for London.

2.4.3.10 The load and trim sheet from the sector Montreal London was prepared and was duly counter-signed by the commander. The take off weight of the aircraft was 317,877 kgs which was within the maximum take off weight limit of 334,500 kgs. The estimated landing weight of the aircraft was 237,177 kgs which was also within the maximum landing weight limit of 256,279 kgs. The centre of gravity of the aircraft was at 21.3 percent
of MAC at take off and the estimated C G position at the time of landing at London was 25.8 percent of MAC which was within the limits.

2.4.3.11 The load and trim sheet and the flight plan of the aircraft indicated that there was 301+2 passengers on board the aircraft whereas there were actually 301+6 passengers on board. The error occured because four of the six infants were not taken into account.

2.4.4 Corrosion Control Measures

2.4.4.1 Boeing Company have recommended various measure to control corrosion on Boeing 747 aircraft through different documents such as Maintenance Planning Data Document, Corrosion Prevention Manual and Service Bulletins. Compliance of these measures on Air India fleet is accomplished as follows:

(I) Support structure under galleys and lavatories

Boeing Company have recommended repeat inspections of under galley/toilet structure at intervals of 12000 hours. However, in order to detect corrosion at an early stage, these inspections are carried out by Air India at intervals not exceeding 9000 hours.

(ii) Fuselage Lower Bilge Area:

Boeing Company have recommended modifications to provide improved drainage systems by incorporation of various Service Bulletins. All the relevant modification have been completed by Air India on the affected aircraft. In addition to completion of these modifications, repeat inspection of lower bilge area is being carried out to meet the requirements of Boeing Service Bulletins.

(iii) Canted Pressure Deck:

In order to prevent water accomulation and consequent corrosion in the area, Boeing Company have issued SBs 51-2015, 51-2026 and 51-2032. Air India have incorporated Service Bulletins 51-2015, and 51-2032 on all their affected airplanes SB 51-2026 is being complied progressively.

(iv) Cargo Compartments:

Inspection of all the cargo compartment interior structures for corrosion and cracks is being accomplished periodically by Air India after removal of linings and insulation blankets.

(v) Aft Pressure Bulkhead:

During every equalised Periodic Check routine, the aft surface of aft pressure bulkhead is being visually inspected for corrosion condition and security of attachements. The forward surface of the pressure bulkhead, which is covered by aft toilets, is inspected after removal of toilets at intervals not exceeding 9000 hours although the recommended interval by Boeing Company is 12000 hours.

2.4.4.2 Air India has stated that in addition to the above specific measures, aircraft structure particularly the areas below toilets, galleys, cargo compartments, outflow valve area etc. which are prone to corrosion, are inspected for corrosion, cleaned and protected during every equalised Periodic Check. Air India have further stated that no serious corrosion problem has been experienced by them so far on their fleet.

2.4.5 Supplemental Structural Inspection Programme

2.4.5.1 In the case of airplanes which have completed 10,000 flight cycles as on June 30, 1983, Federal Aviation Administration (FAA) U S A and Boeing Company had recommended additional structural inspections known as Supplemental Structural Inspection Programme. In the Air India fleet, the first three 747 aircraft, namely, VT-EBE, VT-EBN and VT-EBO fell in this category and are known as 'Candidate Airplanes'. The subject aircraft (VT-EFO) had completed only 7525 flight cycles at the time of the accident on 23rd June, 1985, and therefore, the Supplemental Structural Inspection Programme was not applicable to this aircraft.

2.4.6 Special Corrosion Inspection of B-747 Aircraft Fleet of Air India

2.4.6.1 In order to examine whether corrosion to the aircraft structure of Kanishka aircraft could have contributed to the accident, a group was constituted by Mr. H.S. Khola, Inspector of Accidents to carry out special corrosion Inspection of all the Boeing 747 aircraft of Air India.

The group consisted of the following members:

(a) Senior Air Safety Officer of the D.G.C.A.

(b) Senior Airworthiness Officer of the D.G.C.A.

(c) Air India's Representative.

2.4.6.2 The inspection was carried out in the following areas:

(a) Below toilets and galleys

(b) Forward and aft cargo compartments belly areas - internally and externally

(c) The forward and aft pressure bulkheads

(d) Canted pressure web area from inside the passenger cabin.

(e) Area around outflow valves

(f) MEC area inside and outside.

2.4.6.3 The inspection reports submitted by the Group show that no corrosion was noticed on the significant primary structural members of the aircraft. Surface corrosion was, however, noticed on some of the members below the toilets and galleys. The corrosion observed during the inspection was of minor nature which is normally expected on such inspection schedule. The Kanishka aircraft was subjected to Periodic Check on 24th May, 1985 at 23,274.53 hours/7,439 cycles and no significant corrosion was observed. Among the Nine 747 aircraft inspected for corrosion, 5 aircraft had logged hours more than the Kanishka aircraft. Three of the aircraft had actually logged nearly double the flying hours. Taking into consideration that the corrosion prevention measures recommended by the Boeing Company were followed by Air India and that even the high life aircraft (45,000 hours approximately) subjected to corrosion inspection at the time when Periodic Check was due i.e. 1100 hours since previous check, had no significant corrosion, it is considered unlikely that Kanishka aircraft, which had logged only 23,275 hours since new and 360 hours since last

Periodic Check, had corrosion which could have contributed to the accident.

METEOROLOGICAL INFORMATION

2.5.1 A report on the Meteorological conditions prevailing en-route near the location where the aircraft crashed was provided by the Meteorological Service, Department of Communications, Dublin, Ireland. This report covers a period of one to two hours before and after the time of accident (0714 Z).

2.5.2 From the report it is seen that the surface Synoptic Situation in the vicinity of 51°N, 12.50°W at 0715 Z on 23rd June was as given below:

Surface wind : 250/15 knots

Surface visibility : 10 Kms (occasionally 4 kms in drizzle)

Surface temperature : 13°C

Cloud conditions : Cloud cover in the area was estimated to have been layered upto about FL 100 with a base of 600 feet. There is no evidence of cumulonimbus or thunderstorm activity.

Freezing Level : 700 feet.

2.5.3 With regard to Upper Air situation the report indicates that a mainly West or West North West airflow covered the area of FL 310 The Jet stream was centred at about 48°N. The estimated wind and temperature at FL 310 were 270/65 knots and -47°C. As per the report, at FL 310, 51°N 12.50°W and at 0715 Z any significant clear air turbulence was not expected.

2.5.4 Sunlight condition was prevailing at the time of accident. There were no sigmets valid for the area at that time.

AIDS TO NAVIGATION

2.6.1 The aircraft was equipped with Inertial Navigation System (INS) and was cruising normally at its assigned flight level 310 on track X-ray over Atlantic. It was under the control of Shannon Upper Area Control and was being monitored on the Secondary Surveillance Radar (SSR) located at Mount Gabreal. Till the time of accident, the aircraft was beyond the range of Shannon primary radar.

2.6.2 The aircraft entered Shannon airspace at the correct position and level and remained on the assigned track and flight level till it disappeared from the radar screen.

2.6.3. There is no evidence to indicate that AI-182 experienced any navigational problem during the flight.

COMMUNICATIONS

2.7.1 Two-way communication between the ill-fated aircraft and the ATS units of Canada and Ireland was maintained during the flight from Montreal till the time of crash. The communications were recorded on the ATC tapes. Transcripts of the relevant tapes were provided by the Canadian Aviation Safety Board and the Director of Air Traffic Services, Ireland.

2.7.2 From the Transcript of the conversations, it is observed that two-way communication between AI-182 and the various ATS units was normal. The last R/T contact with the aircraft was at 0709:58 Z when AI-182 informed Shannon UAC that it was squawking 2005. The tape transcript also shows that the aircraft did not transmit any information regarding the emergency on frequency 131.15 MHz on which it was last working with Shannon UAC or on distress frequency 121.5 MHz. Indecipheiable noise was, however, found recorded on the Shannon ATC tape just at the time of crash i.e. 0714:01 Z. Thereafter, repeated calls were made by Shannon UAC to AI-182, but there was no response.

SEARCH AND RESCUE

2.8.1 The report of the Search and Rescue Group gives the details of the Search and Rescue operations. From the report it is seen that at 0730 Z, Shannon UAC informed Marine Rescue Co-ordination centre (MRCC) shannon that AI-182, a Boeing 747 aircraft enroute Montreal-London had disappeared from the Secondary Surveillance Radar (SSR) at 0713 Z in position 51N/120W. Shannon UAC requested MRCC Shannon to take emergency section. At 0740 Z MRCC Shannon telephonically explained the situation to Valantia Coast Radio Station (CRS) and requested a PAN Broadcast urgently and to ask any vessels in area to keep sharp lookout and report to Valantia Radio. At 0746 Z Valantia Radio transmitted to all stations PAN message and above advice to ships. The transmission was repeated.

2.8.2 At 0750 Z, an Irish Naval Vessel AISLING reported on R/T to Valantia Radio that it was 54 miles from site of accident and was proceeding to the site. Valantia Radio passed on this information by Telex to MRCC Shannon. Between 0740/ 0750 Z MRCC briefed the Irish Naval Service (INS) Haulbowline, MRCC Swansea, RCC Plymouth and Irish Army Air Corps (IAAC) on the situation. At 0754 Z MRCC relayed a distress message to Shannon Aeradio via the Aeronautical Fixed Telecommunication Network (AFTN)

2.8.3 At 0803 Z Valantia Radio again transmitted the PAN message and the advice to ships. At 0840 Z Cargo vessel M W Laurentian Forest/ HBWP (Registered in PANAMA and owned by Federal Commerce of Montreal, Canada) at position 51.09N/12.18W reported that it was 22 miles away from distress area and was proceeding there. Laurantian enquired if there were other ships in the area and was informed about position of Aisling. At 0813 Z Valantia Radio informed MRCC Shannon by telex about Laurentain Forest.

2.8.4 Between 0815/0820 Z, MRCC Shannon updated RCC plymouth and they advised that a Nimrod Rescue Aircraft would depart shortly for the area and that SEA KING helicopters were already enroute the Cork Airport initially. Edinburgh RCC advised MRCC Shannon that a Nimrod Rescue Aircraft was also being prepared at Kinloss. At 0820 Shannon Aeradio informed Valantia Radio that there was message from Shanwick Oceanic Control that aircraft were picking up ELT signal in position 51N/15W and 51N/08W and the actual position was beleived to be 51W/1250W. At 0833 Z, Valentia Radio sent message giving the above information and requesting ships in the area to report to Valentia Radio.

2.8.5 At 0842 Z, Ali Baba informed Valentia Radio that it was at position 5125.5N/0825.4W and was listening on 121.5 MHz. At 0850 Z Western Arctic informed Valentia Radio its position 5207N/1151W and that it would proceed in about 20 minutes after bringing in cable. At 0857 Z, High Seas Driller informed Valentia Radio that Vessel Kongstain could be released, ETA 51/2 to 6 hours and they would standby. At 0858 Z, Valentia Radio informed MRCC Shannon about reports from Ali Baba Western Arctic and High Seas Driller.

2.8.6 At 0905 Z, Laurentian forest reported to Valdentia Radio that it was 5 miles from SOS position 51N/12.5 W and it had not sighted anything. Between 0905/0908 Z, three more vessels viz. Atlantic Concern, MV Norman Amstel and MV Tasman reported their positions to Valentia Radio. At 0908 Z, Swansea advised MRCC Shannon that four Seaking helicopters and two Nimrod Aircraft were enroute.

2.8.7 At 0913 Z, Laurentin Forest reported to Valentia Radio that they had sighted what looked like 2 rafts about 2 miles away. At 0914 Valentia Radio informed MRCC Shannon about the report from Laurentian Forest.

2.8.8 At 0918 Z, Laurentian Forest reported to Valentia Radio that it had sighted wreckage in water at position 5101.9N/1242.5W and the liferafts were not inflated. Valentia Radio passed the message to MRCC Shannon at 0920 and also sent transmission about wreckage sighting. Lifeboats Valentia and Baltimore reported to Valentia Radio that they were proceeding to the position of wreckage.

2.8.9 At 0937 Z, Laurentian Forest reported that it had sighted 3 bodies in water. Valentia Radio informed the same to MRCC Shannon at 0940 Z. At 0945 Z, MRCC Shannon and MRCC Swansea decided that for security and operational reasons Cork Airport would be the primary operational base and ATC Cork were informed of this decision.

2.8.10 At 0953 Z, S MYROLI informed Valentia Radio that it was 80 miles north of position and had a group of 10 to 20 French vessesls and desired to know if they should proceed to site. After consulting Laurentian Forest, S MYROLI was advised that it was not necessary. Valentia Radio kept on giving Mayday relay frequently.

2.8.11 At 1045 Z, a prohibited flying area was established with a radius of 40 N Miles from the datum point from sea level to 5000 feet. Falmouth Coast Guard reqested Valentia Radio the position of all ships in the distress area and those proceeding so that each vessel could be designated to search a particular area.

2.8.12 At 1126 Z, Laurentian Forest reported Valentia Radio that it had located numerous bodies in water and Seaking helicopter was hovering there. Valantia Radio Transmitted this information to all stations.

2.8.13 At 1133 Z, Valentia Radio informed Coast Guard Falmouth the position and ETA of various ships and also of the Lifeabouts Valentia and Beltimore. At 1150 Z, RRC Plymouth requested MRCC Shannon that "Le Aisling" assume duty as "On Scene Commander Surface Unit". At 1204 Z, information was received by Valentia Radio that 8 Spannish Trawlers were proceeding to distress position of AI-182 and their ETAs were between 1630/2000 Z. At 1246 Z, Star Orion informed Valentia Radio that it would be able to refuel any vessel in medium or small quantities at the accident site. Valentia Radio informed MRCC Shannon and Falmouth about the Spanish Vessels and Star Orion.

2.8.14 Falmouth requested Valentia Radio at 1303 to advise Laurentian Forest to inform Aisling that 8 Spanish trawlers would arrive in search area between 1600 Z and 2000 Z and Aisling should deploy trawlers in conjunction with lifeboats to recover bodies as it would be easier to recover than from large vessels. Valentia Radio sent the above message.

2.8.15 Laurentian Forest informed Valentia Radio at 1307 Z that 10 bodies were on Aisling, 4 on Helo, and they had some alongside and had launched lifeboats to pick them up. Valentia Radio informed the same to MRCC Shannon and Falmouth. At 1338Z, MRCC Shannon requested Valentia Radio to include the following in their broadcast:

"Vessels within 100 N Miles of datum 5101.9N/1242.5W are requested to proceed to search area and contact Aisling/EIYP. Any vessels recovering bodies or wreckage are requested to retain them on board and inform MRCC Falmouth of total number of bodies recovered."

2.8.16 Valentia Radio transmitted the above message at 1340 Z to all stations and also informed MRCC Shannon. At 1503 Z Aisling informed Valentia Radio that they had recovered 56 bodies. MRCC Shannon requested Valentia Radio to advise Aisling that if they could locate "Black Box", they should drop buoy. Valentia Radio advised Aisling accordingly. At 1530 Z, on advice from MRCC Shannon, Valentia Radio asked Baltimore, Courtmaesherry and Ballycotton lifeboats to return to base. At 1633 Aisling requested Valentia Radio to inform Falmouth that they were unable to transfer bodies to Valentia Lifeboat as latter was returning to base owing to fuel shortage. At 1659, Laurentia Forest informed Valentia Radio that 66 bodies had been picked up by then. Aisling advised Valentia Radio that Valentia lifeboat was returning with four bodies.

2.8.17 At 1721 Z Falmouth requested Valentia Radio to relay following to all surface units at scene:

1. One mimrod remaining on scene overnight.
2. All other air units will be recalled at 2200 Z. One Helo remains at 15 minutes notice at Cork
3. Air Search recommences at 240400 Z.
4. All Civil surface units will be released by 2200 and may proceed on passage. Bodies should be landed at Irish Post for transfer to receiving station at Cork Airport.
5. Warship Challenger, Emer and Aisling acknowledge".

2.8.18 At 1723 Z Aisling informed Valentia Radio that they saw 3 Spanish vessels approaching and they were using Ch.16 which Aisling was using for co-ordination with RESCUE 52 and requested that Spanish Vessels be asked to stay outside 5 miles radius. Spanish Agent was told about Aisling request.

2.8.19. Valentia lifeboat informed Valentia Radio that they were heading for home (Valientia) at reduced spead of 11 knots and they had five bodies on board. At 1822 Z, Aisling requested Valentia Radio information on 'Black Box' that might help its location. Aisling was advised of ELT signal on 121.5 MHz. At 1840 Z Cork ATC Advised MRCC Shannon that a total of 64 bodies were in Cork.

2.8.20 At 1920 Z, MRCC Shannon downgraded the 'MAYDAY' Broadcast to 'PAN' (Urgency) Broadcast, Aisling informed Valentia Radio that 79 bodies had been recovered. At 1958 Z Laurentian Forest informed Valentia Radio that they were proceeding to Dublin. Valentia Radio thanked them for assistance.

2.8.21 At 2000 Z, MRCC Swansea advised MRCC Shannon that main air search would cease at 2200 Z and would recommence at 240400 Z. The overnight search would continue with one Nimrod providing air cover for the surface search by three warships. Vessels transiting the area were requested to keep a sharp look out and to report to HMS Challenger.

2.8.22 By 0300 Z on 24th June, four Seaking helicopters had deported from Cork to resume the airborne search. At that time the search area covered a six nautical mile radius of position 5059.2 N/1225.3W and the vessels Le Emer and HMS Challenger were requested to search this area. HMS Challenger was the coordinator of the surface search and Nimrod Rescue 02 was on-Scene-Commander.

2.8.23 At 0450 Z Rescue 02 reported sighting of wreckage in position 5101 M/1245 W. Between 0505 and 0543, three USAF Chinook helicopters departed from Cork Airport to join the search. At 0556, MRCC

Swansea confirmed that there were 329 people on board the aircraft (Earlier reportes had idicated 325 people on board).

2.8.24 A continuous search was maintained throughtout the day (24th June) but only one further body and numerous pieces of wreckage were recovered. An extensive surface search was also maintained throughout the day and instructions were passed by MRCC Shannon to Valentia Radio requestiong all shipping to recover any wreckage or bodies sighted.

2.8.25 At 0900 Z, Capt. G Mc. Stay of Department of Communications advised MRCC Shannon that Aisling was bound for Cork, ETA 1300 Z and he (Capt. Mc Stay) was assuming responsibility for collection of wreckage. MRCC were also advised by Mr. Gregory of Britoil that their two vessels 'Constine' and 'Star Orion' were enroute to Foynes having picked up quantities of wreckage.

2.8.26 At 1740 Z, SRCC Plymouth advised Shannon that the Search will terminate at 242200 Z, at 1800 Z Falmouth MRCC advised MRCC Shannon to direct the Portisheal and Valentia Radios to concel Urgency Broadcast from 242000 and to release HMS Challenger and Le Aisling from the search at 242000 hours. All the aircraft were released at 24000. It was also decided that Le Emer would remain at the area. At 242003 Z, a message was transmitted to all stations on R/T and W/T that air and sea search was being terminated at 242000 Z and all the participant were thanked for their assistance.

INJURIES TO PERSONS

3.1.1 Post mortem examination was carried out by Irish Authorities at Cork. At that time Wing Commandor Dr. LR. Hill was also present. Subsequently Air Vice Marshall Kunzru also reached Cork. Both of them were members of the Medical Group which had been constituted by Mr. H.S. Khola.

3.1.2 By then 131 bodies had been recovered. None of the bodies of the flying crew were revocered. The bodies which were recovered represented 39.8 per cent of the victims. The exact seating position of passengers is not certain, because it is known if the passengers had changed their seats after the take off of the aircraft from Montreal. On the information which is available, the passengers were supposed to have been as follows:-

Passengers: Seats Occupied Bodies Available identified Zone A 16 1 0 Zone B 22 0 0 Upper Deck 18 7 0 Zone D 112 104 + 2 29 Zone D 86 84 + 1 38 Zone E 123 105 + 3 50 Sub-Total 377 301 +(6 infants) 117 Crew: Flight Deck 3 3 0 Cabin 19 19 5 Total 399 329 122

3.1.3 The Post-mortem reports were examined by Wing Commander Dr. Hill. He submitted two reports being Exhibits H-1 and H-2. He was also examined in Court as Witness No. 2. Dr. Hill who had developed a system which would indicate the severity of the accident and the injuries suffered. He used a scale from 0 to 4, with naught being no injury and 4 being a fatal lesion. Though there is some amount of subjectivity involved in the system, nevertheless categorising the injuries according to the sacle does give an overall picture of what had happened to the victims. After adding up all the injury scale for a particular body, Dr. Hill in his Report Exhibit H-1 divided the injuries as under:-

No. of victims Mild injury (0-49) total 34.4% 45% Moderate injury (50-99) 38.9% 51% Severe Injury (100-149) 25.2% 33% Catestrophic Injury (150 +) 1.5% 2 Total 100.1% 131 3.1.4 A further break up showing the overall injury score of the recovered victims is as follows:

	Minor			Moderate			Severe			
Zone	No.	%	%	No.	%	%	No.	%	%	Total
C	8	6.1	17.8	9	6.9	17.7	4	3.1	11.4	21
D	9	6.9	20	15	11.5	29.4	9	6.9	25.7	33
E	15	11.5	33.3	15	11.5	29.4	14	10.7	40	44
Unknown	13	9.9	28.9	12	9.2	23.5	8	6.1	22.9	33
Total	145	34.4	100	51	39.1	100%	35	26.8	100%	131

3.1.5 The reports submitted by Dr.Hill further indicted as follows

(a) There were 30 children recovered and they showed less overall injury. The average severity of injury increases from zone C to E and is significantly less in C than in Zones D and E.

(b) Flail pattern injuries were exhibited by eight bodies, five of these were in Zones E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

(c) There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evently distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

(d) Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 Zone D, 11 inZone E, 2 crew and 1 unknown), and 16 had little or no clothing.

(e) Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

(f) There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

(g) There is a general absence of signs indicating the wearing of lap belts.

(h) Pathological examination failed to reveal any injuries indicative of

a fire or explosion.
3.1.6 In his testimony in Court, Wing Commander Dr. I.R. Hill further stated that the significance of flail injuries being suffered by some of the passengers was that it indicated that the aircraft had broken in mid-air at an altitude and that the victims had come out of the aeroplane at an altitude. He further explained that if an explosion had occurred in the cargo hold, it was possible that the bodies may not show any sign of explosion. It may here be mentioned that the forensic examination of the bodies do not disclose any evidence of an explosion. Furthermore, the seating pattern also shows that none of the bodies from Zone A or B was recovered, in fact as per the seating plan Zone B was supposed to have been unoccupied. This Zone is directly above the forward cargo compartment.
3.1.7 Dr. Hill further stated that the pattern of the accident as suggested by the injuries indicated that it was a complex affair and there were at least two phases of injuries, one in the air and the other at water impact. In answer to a specific question that if there was an explosive device in the cargo hold then could the passengers who were seated have suffered such injuries, the answer of Dr. Hill was that "it is possible". According to him, the pattern of injuries indicated that if there was an explosion in the aircraft it was more likely that the explosion had occurred in the rear cargo compartment than in the front cargo compartment. This conclusion was apparently based on the fact that, according to him, in zone E of the aircraft there were larger vertical load type injuries. Dr. Hill was also asked if he had to make any suggestions which would minimise injuries to passangers in the event of an accident. In answer, the witness made his suggestion in the following words "There are very complicated things one would have to do such as rearward facing seats; having safety belts which incorporated restraint for the upper part of the body; increasing the space between aircraft seats; incorporating shocks absorbing system within the seat and using materials which do not break easily like plastic. We would also need fuel systems which would not immediately set on fire and furnishing which would be resistant to burining, and also passengers should not carry into

the aeroplanes large amount of hand bags which only get in way in the event of evacuation, and I personally feel that the carriage of large amount of alchohol both in the passengers and in the aeroplane is a hazard to flight and safety. Finally the passengers should take heed of the flight safety instructions given to them by the crew of the aeroplane".

3.1.8 Air Vice Marshal Kunzru, witness No. 10 in his report dated 14th November, 1985, Ex.A-48, gave his comments not only on the post-mortem reports but also on the statement of Wing Commander Dr. I.R. Hill. With regard to the post-mortem examination, the comment of AVM Kunzru was as follows:

"All victims have been stated in the PM reports to have died of Multiple injuries. However two of the dead, one infant and one child, are reported to have dies of Asphyxia. There is no doubt about the asphyxial death of the infant. In the case of the other child (Body No. 93) there could be doubt because the findings could also be caused due to the child undergoing tumbling or spinning with the anchor point at the ankles. Three other victims undoubtedly died of drowning. There was no evidence of significant Lap-belt injuries.

Considering rupture of the ear-drum, without injury to skull, as a criterion to indicate rapid decompression, two cases may be considered to fall in this category.

Histological examination has been carried out only in 57 bodies out of 131. Lung examination on almost all of them showed decelerative changes. Six bodies (Nos. 6,22,70,103,121 and 131) showed presence of Bone Marrow Embolism in Lung Sections. Though not of much significance in this accident, this finding does indicate survicval after a bony injury for an undefined period of time No evidence of fire burns or explosive material, other than Kerosene burns on some bodies, which I had myself seen at Cork, could be found. Kerosene burns in such acidents is a fairly common findings and is of no significance".

AVM Kunzru generally agreed with the crash injury analysis on the victims which had been furnished by Wing Commander Dr. Hill. He, however, gave the following comments with regard to hypoxia,

decompression and decelerative changes:
"Hypoxia : The main Post Mortem findings in hypoxia is generalised congestion if the hypoxia is of the type described as "hypoxic hypoxia". In other causes of hypoxia of more severe degree such as "histotoxic hypoxia", "asphyxia" or "drowning" additional histological findings such as petechial haemorrhages and generalised congestion, and lung findings such as haemorrhage and extrusion of alvoolar phagocytos are seen.
Decompression : The term used by Dr. Hill is "Decompression". It is presumed that he means "Rapid/Explosive Decompression" which occurs within one Sec. and not "decompression sickness" which takes a minimum of 5 to 7 mnts to occur even at 31,000 ft. altitude and which in this case can positively be ruled out.
The Post-Mortem and histological signs of rapid Decompressions are :-
(a) Possibility of rupture of Ear drums without any injury to the skull.
*(b) Patchy Lung Haemorrhages
*(c) Emphysomatus changes
*(These occur more commonly in those cases where the individual was in the phase of breathing-in at the time of decompression.
3.1.9 If it is assumed that the aircraft suddenly broke up in Mid-Air at an altitude of 31,000 ft. the bodies will be at once exposed to hypoxia and rapid decompression and as a consequence will suffer body changes as mentioned above. As the aircraft/occupants start descending, they will be exposed to increasing amounts of Oxygen and as soon as ;they come down below 15,000 ft. and then below 10,000 ft. the effect of hypoxia rapidly diminishes. Finally, the aircraft/individuals come down and hit the ground/water with a very heavy impact, thus submitting the individuals to extremely severe G-loads of decelarative type.
Decelerative Changes : Decelerative impact brings about well established changes in the lungs besides many other associated injuries. It is relevant to note the decelerative lung changes which are :-
(a) Patchy haemorrhages in Lung.
(b) Marked Emphysomatus Changes.
(c) Extrusion of alvoolar Phagocytes

(d) Desqummation of bronchcolar epitherium.

"Comparative study of the PM/histological findings of hypoxia, Decompression and Decelerative Lung injuries reveal that they are more or less similar. Decelerative injury being the most severe of the three and last to occur tends to so modify the Post-Mortem and Histological findings that it becomes extremely difficult and some times impossible to isolate one from the other."

3.1.10 AVM Kunzru was, therefore, of the opinion that in this accident evidence of hypoxia/decompression (except in 2 cases) had not been confirmed or established.

3.1.11 The difference of opinion between Wing Commander Dr. hill and AVM Kunzru, with regard to evidence of hypoxia and decompression, is of no significance in the present case. What is important to note, however, is that they have agreed that the injury pattern does indicate break up of the aircraft in mid-air and that the occupants of Zone E had suffered the greatest amount of injuries as compared to the occupants of the other zones.

MAPPING, WRECKAGE DISTRIBUTION AND SALVAGE

3.2.1 Introduction

3.2.1.1 Oceanographic charts indicated that the depth of sea in the crash area was about 6700 feet and the site appeared to be a flat sea bed, without any valleys or hills. The immediate necessity after rescuing/searching crash victims, was to locate and recover the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR). The operation was unique of its kind and had never been undertaken earlier in the world at this depth of the sea. It required an equipment which could home on the transmitted signals from the underwater locater acoustic beacons fitted on DFDR/ CVR, identify the units, clear them from attachments/wreckages, grab them and bring them to the surface.

3.2.1.2 The pressure exerted by the water at 6700 feet below mean sea level is extremely high and the temperature is very low. No light penetrates to that depth and it is pitch dark. Scarab I fitted on French Ship "Leon Thevenin" which had undertaken the challenging job of locating DFDR and CVR, and recovering the same, was not designed to operate at 6700 feet depth. Its maximum design operating depth was only 6000 feet. However, it was decided to exceed the design operating depth for this emergency operation.

3.2.1.3 By using the preliminary information of probable area of location OF CVR and DFDR as indicated by ship 'Gardline Locator', the Scarab I was Lowered in the sea to locate and recover these units which it accomplished on 10.7.85 and 11.7.85 respectively.

3.2.1.4 Prior to recovery of DFDR/CVR by the ship 'Leon Thevenin', sufficient spade work was done by the ship 'Gardline Locator' (A ship provided by Accident Investigation Branch, U.K.) and 'Le Aoife' (an Irish Naval Ship). The survey of the crash area, carried out with the help of side-scan sonars fitted on these ships, had indicated a general distribution of the wreckage and a rough idea about the sizes of the parts. Each part of the wreckage was called a target. The method used for survey was triangulation with multiple passes through the crash site.

3.2.1.5 Next phase was the task of :

(a) Locating hundreds of pieces of wreckage by the combined use of sonar and video monitors.

(b) Video and still photography of the pieces of wreckage.

(c) Plotting the distribution of the wreckage.

All this was to be carried out under the directions of the Court.

3.2.2 Scarab

3.2.2.1 The means (vehicles/equipment) proposed to be used in the locating, mapping and video photography of the wreckage were the CCGS John Cabot and SCARAB II.

3.2.2.2 The John Cabot is an ice breaker of the Canadian Coast Guard. Since utilisation as an ice breaker is seasonal, the John Cabot is also equipped for submarine cable laying. In order to enlarge its capabilities in this regard, the John Cabot is equipped to have on its deck the Scarab and to operate it. Thus the John Cabot can be used for repair of submarine cables. The John Cabot has complete facilities for operation, maintenance and repair of the Scarab. This includes a Control Hut, a Test Room, Workshop, Stores etc. The John Cabot has considerable experience in work on deep sea bed.

3.2.2.3 The SCARAB II is a submersible craft assisting repair and burial of cables. As will be clear from the following details, the Scarab is not ipso facto a submarine. It is a total system for carrying out its complex functions.

3.2.2.4 The SCARAB II is a state-of-the-art system designed and built for tethered unmanned work at ocean depths of upto 6000 feet. Scarab's standard equipment are :

Two rugged manipulators.

A complete optical suite.

Six thrusters of 5 hp each.

CTFM Sonar.

Navigation System.

3.2.2.5 The manipulators have a choice of grippers/claws/cutters etc. of any required description and size. The Scarab has three TV cameras mounted on separate pan/tilt mechanism to allow real time observation and video tape documentation. A 35 mm still camera was also installed and used in the present work. There was a choice of quartz-iodide flood lights to provide illumination.

3.2.2.6 The location and control of the Scarab is accomplished through a phased array navigation system.

3.2.2.7 The Scarab was equipped with a 360° high resolution Sonar with a range of 1000 meters. The Sonar was also capable of interrogating and detecting 37 KHz and 27 KHz pingers. It can function independently of the ship's facilities and is equipped with power generators and semiautomatic handling equipment.

3.2.2.8 The John Cabot can salvage items, but it is not a salvage ship as it does not have the specialised high capacity cranes, derricks etc. required for salvage of large objects. Further, it does not have deck space for keeping large salvaged items like the wings, fuselage or tail surfaces of an aircraft as large as a 747. The John Cabot was, therefore, adequate and fully satisfactory for the work envisaged in this phase of the programme, as salvage of large items was not planned in this phase. The task was, as mentioned earlier, locating, mapping and photography of the hundreds of pieces of wreckage. (The salvage work was part of the next phase of the programme).

3.2.3 Control and Monitoring of Operations

3.2.3.1 It was realised that the operation proposed would pose problems of control, monitoring and logistics.

3.2.3.2 Consider : A ship operating on the high seas in international waters on the task of locating, mapping and video photographing the hundreds of pieces of wreckage. The state of art system for Sonar location and photography (Scarab) used by the ship for handling this task. The group located on shore in charge of the operations. Finally, the Court in Delhi was in overall charge of the operatins.

3.2.3.3 It was realised that a proper line of control and communication was essential if the operations were to be smooth and successful.

3.2.3.4 Therefore it was decided that the following would be the chain of command :

Court Investigating the Accident
(Mr. Justice B.N. Kripal)
Control Centre at Cork
(Court's representative)
CCGS John Cabot
(Commanding Officer)
Scarab
(Project Manager)

3.2.3.5 Because of the multiplicity of agencies involved in the operations, the need was felt for a proper delineation of power at all levels. It was, therefore, decided that :

a. Overall responsibility for the operations would rest with the Indian authority viz. the Court. This would cover the identification and definition of assignment of the overall tasks, laying down of the priorities, overall control of the coverage of the operation and, finally, the time schedule for the operation.

b. Decisions taken at the Control Centre, flowing from the above, were to be taken solely by the Court's representative. The experts from CASB, NTSB and Boeing were free to give their views and recommendations, but the final decisions were to be left to the Court's representative. Examples of such matters are : Track of the survey, areas to be covered by John Cabot, assignment of priorities for specific tasks, amount of time to be devoted to any piece of wreckage, whether any item of wreckage is to be picked up, etc.

c. Operation Control of John Cabot would be in the hands of the Canadian Coast Guard Officer in the Control Centre,

who would co-ordinate with the Commanding Officer of John Cabot. This would cover decision on feasibility or otherwise of operations under adverse weather conditions, manner of covering the area, method of retrieving any wreckage, etc.

d. Decisions relating to the Scarab (i.e. whether the weather was suitable for Scarab operations, whether the size, weight etc. of an item would permit its being picked up by Scarab, etc.) would be left to the Scarab Project Manager on Board John Cabot.

3.2.3.6 It might appear at first sight that in the above system excessive power was delegated at certain levels to the detriment of overall control. Any such impression would not be correct. In actual fact, because of proper delegation of responsibility and power at different levels, the operations were carried out with extraordinary efficiency, smoothness and coordination, In this connection, it is relevant to point out that the operations were not a uni-disciplinary one. The operation (aircraft accident investigation) was totally dependent on experts from other disciplines, like naval (coast guard) operations, deep sea photograph, salvage from sea bed etc. It was therefore, decided that for smooth and efficient operations, adequate power and responsibility should be delegated at all levels, particularly to specialists engaged in the different areas of work as above.

3.2.3.7 It was also considered that adequate communication was a sine qua non for smooth operation. Therefore, the following communication facilities were established :

Control Centre at Cork Airport

Telex

Telephones (2)

3.2.3.8 The ship John Cabot had both telex and telephone facility. These links were through satellite (IN MARSAT). The Control Centre was in continuous communication contact with John Cabot through telex and telephones. In order to establish a reliable and satisfactory line of communication it was decided that instructions or communication from Control Centre to the Indian experts on John Cabot would follow the path as under :

Control Centre

Court's representative --- Canadian Coast Guard Officer

John Cabot

Indian experts --- Commanding Officer

3.2.3.9 It was felt that this would eliminate any possibility of inconsistent or contradictory orders/messages going to John Cabot.

3.2.3.10 With a view to have an ordered system of communications between the control centre and John Cabot (which is essential for proper control and monitoring of the operations), it was decided that John Cabot would sent to the Control Centre daily Situation Reports (SITREPS) at specified times viz. 0800 hrs, 1200 hrs, 1600 hrs and 2000 hrs. This however did not preclude the despatch of telexes by both Control Centre and John Cabot at any other time.

3.2.3.11 In order to inform all agencies of the above system of Control and Communication a number of meetings were held. These were on 12.8.85 and 3.9.85 on board John Cabot and on a number of occasions at the Control Centre. The purpose of these meetings was not only to inform all concerned about the specific task, the programme and the line of control and communication but also to sort out differences and to understand the technical and operational difficulties faced by the personnel on the spot and to find a way out.

3.2.4 Daily Monitoring of Progress

3.2.4.1 It may be relevant to point out here that search, location and video photography work was to be carried out round the clock. Thus a considerable volume of data would be coming into Control Centre. This required regular, almost hourly, monitoring, study and analysis for

(a) proper understanding of the data collected and (b) advising John Cabot of any changes in its programme, such as additional photography on an item etc. For this purpose (i) SITREPS were filed in the Control Centre (ii) all data (description, latitude and longitude) obtained on every target was tabulated and the cumulative list updated daily.

3.2.4.2 The location of the targets was plotted on charts every 4 hours. This was in addition to the plotting of targets carried out on John Cabot.

3.2.4.3 Every day (including holidays and week ends) all the officers posted at Control Centre assembled at about 0900 hrs. They studied the SITREPS received at 0800 hrs and any other telexes received from John Cabot in the night. The lists of targets were updated and the new targets plotted on the charts. John Cabot generally also sent brief remarks such as description, nature of failure/damage, dimensions etc. Discussions were held on the significance of the targets and their implications. Instructions if any to be telexed to John Cabot were also discussed. Similarly SITREPS received at 1200 hrs and 1600 hrs were studied.

3.2.5 Monitoring at Cork

3.2.5.1 The Scarab provided video tapes and still photographs. In the initial stages (upto 9.8.1985) the John Cabot was operating in peripheral areas and therefore few targets were found. Hence the output of videotapes was small. In fact upto 9.8.85, only about 10 targets were found and only 3 video tapes were used up. But later, when John Cabot came close to and into the crucial areas, video tapes were recorded at a fast rate. Further, still photography facility on the Scrab was activated at about this time. Therefore, arrangements were made periodically to obtain the video tapes and films from John Cabot. Video tapes and still photographs (these required to be processed) were transported from John Cabot to Cork Control Centre.

3.2.5.2 About 50 video tapes and nearly 3000 still photographs (positives and transparencies) provided the visual information on the targets.

Arrangements had to be made at Cork for such viewing and study of the video tapes and still photographs. Video equipment (TV monitor plus

VCR) suitable for viewing the video tapes had to be arranged.

3.2.5.3 The still photography used special professional quality colour film (35 mm), each roll having 800 frames. The film was diapositive. These had to be developed and transparencies obtained from them. Thereafter negatives and prints had to be made. Special equipment for viewing the transparencies had to be provided for continuous work. The video tapes, transparencies and prints provided the principal means of monitoring of the results of the operation.

3.2.6 Operations

3.2.6.1 The Charts prepared by 'Gardline Locator' were on a different type of grid system, and had to be translated into LAT-LONG system, for use by John Cabot. For the convenience of search/mapping operation the search area was divided into 4 blocks viz. Block 1, Block 2, Block 3 and Block 4.

3.2.6.2 The navigation system used by John Cabot is PULSE-8 system. This system needs the transponders to be placed on the sea bed. These transponders help in getting the correct fix of a target and in obtaining relative positions of the targets on the sea bed which is highly useful for revisit for the purpose of rephotography or recovery. Initially 4 transponders were placed, and subsequently the number was increased as the search operation was continued. The strategic locations for placing the transponders was decided by considering :

(a) frequencies of relative transponders,

(b) distances required between relative transponders,

(c) wreckage distribution suggested by side scan sonar plots of Eithena and Garline Locator, and

(d) size of search area.

These transponders were calibrated to match the navigation system of the ship.

3.2.6.3 In order to obtain the maximum information from search, it was decided that the Scarab search paths should be as follows :

(a) Normally the search paths should be east to west, or west to east within the individual blocks.

(b) The pattern of search should be a parallel search method.

(c) Distances between the parallel paths to be 1,200 feet (i.e. 2 cable widths), for effective use of sonar fitted on the Scarab.
(d) If Scarab deviates from its planned path for photography or recovery, it should return to its planned path for further search.
(e) In each block, the search was to be made, at least 1/2 mile (North or South) beyond the last target sighted, so as to ensure no target is missed out from the given block.
3.2.6.4 However, when there was a need to modify the search pattern, due to wreckage distribution in particular areas, the following changes were made:
(a) Expanding box type search pattern was used in Block 1.
(b) Some North to South and South to North passes were made in Block 3.
(c) In Block 3 northern end, the distances between the search passes was reduced to 600 feet i.e. 1 cable width.
However, these deviations were made basically to improve the reliability of search in specific areas, as demanded by peculiar distribution of aircraft wreckage.
3.2.6.5 To facilitate identification of the wreckage located by Scarab it was necessary to position aircraft maintenance personnel on board the ship. As the aircraft structure was badly torn, mutilated and distorted, serious difficulty was anticipated in identification of small pieces of structure. It was therefore essential that these maintenance personnel were provided with aircraft photographs, manufacturing drawings, parts catalogue, wiring diagram manuals and maintenance manuals. Since carriage of such voluminous literature was not praticable, 3M micro film reader printer
machines with micro film cassettes of the above literature were produced and installed on the ship. In case of difficulty of locating any particular information, the engineers were advised to contact Cork Search Centre by telex or telephone who, in turn, could seek the desired information from the manufacturers.
3.2.7 Wreckage Distribution
3.2.7.1 The wreckage distribution as determined by the mapping of the

sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling at the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled. Although badly damaged, sections 41, 42 and 44, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been mapped or photographed. Section 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the western most identified aircraft component located at lat 51°02.90'N and long 12°50.1'N. The wreckage extended in a line about 110 degrees to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern. A third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southwest orientation. One of the operating engines was displaced 0.5 nautical mile to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components

and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

3.2.7.2 Details of the various targets which were identified by the Structures Group is contained in Appendix 1 of this Report.

3.2.8 The Break up Pattern

3.2.8.1 The forward fuselage section of the aircraft was found inverted and badly broken into many pieces, the major pieces being :

(I) Section of fuselage right side below cockpit windows containing part of the name 'Kanishka' (in Hindi) and 3 passenger windows (Target No. 192)

(ii) Portion of upper skin between B S 360 and B S 520 below window belt right side, up and over crown. This portion includes the crew door and last letter of the "Air India" (in Hindi) logo (Target No. 192).

(iii) Section of fuselage between B S 510 to B S 700, including the passenger window belt right side, up and over crown to include upper deck windows left side (Target No. 218).

(iv) Section of fuselage between B S 720 to B S 840 including left side passenger window belt, up and over crown to right side passenger window belt. Forward and upper edges of L H No.2 door cutout can be seen (Target No. 193).

(v) Large section of fuselage between B S 1000 to B S 1460 including left side passenger window belt, up and over crown to right side passenger window belt. This section was found lying on its right side (Target No. 137).

(vi) The lower portion of the fuselage skin/frame between the nose and B S 1000 was damaged past recognition except for a small portion with the forwarded cargo door (Target No.204) and another portion containing the aft access door cutout at B S 810 (Target No. 362).

3.2.8.2 The aft fuselage was found in the following major pieces :

(I) Section of RH fuselage skin between B S 1640 and B S 1940 below the window belt up to the crown (Target No. 321).

(ii) The RH fuselage bottom skin between B S 1820 (forward edge of C2 door) and B S 2060 and between two stringers above the door cutout to just below stringer 46 lap joint (Target No. 40).

(iii) The lower fuselage skin with stringers between B S 1480 and B S

1846 about 100 inches wide approximately (Target No. 7).
(iv) The LH fuselage skin panel between B S 1740 and B S 1880 about 110 inches wide (Target No. 11).
(v) The LH fuselage skin between B S 1460 and B S 1800 width 80 inches including No. 4L door and passenger windows (Target No. 28).
(vi) The RH fuselage skin between B S 1660 and B S 1920, from below window belt up to the crown including the 4R door cutout (Target No. 321).
(vii) A fuselage lower skin panel (containing out flow valve) between B S 2120 and B S 2240 and 120 inches wide (Target No. 320).
(viii) A fuselage LH skin panel (containing 5 windows with "T -" part of registration) between B S 1980and B S 2080 between stringers 19L and 24L (Target No. 369 and 26).
(ix) A fuselage LH skin panel between B S 1460 and B S 1800 with 8 stringers below the bottom of the door and 3 stringers above the top of the door (Target No. 28).
3.2.8.3 The tail portion of the fuselage was found in the following pieces:
(I) The lower fuselage skin between B S 2412 and B S 2598 about 20 stringers wide (Target No. 371).
(ii) The vertical fin with rudders attached was lying on the ground by itself with a portion of B S 2517 frame. This includes a small portion of the aft pressure bulkhead (Target No.37).
(iii) The horizontal tail with elevators attached was lying on ocean floor with the jack screw and drive motor attached (Target No. 31).
(iv) The fuselage tail cone aft of B S 2669 was found basically intact and lying separately (Target No. 27).
3.2.9 Extent of Damage
Photographic and Video Interpretation of Wreckage
Photographic Interpretation
3.2.9.1 All wreckage sighted was recorded on video tapes and all major items were recorded on 35 mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when

some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage pattern. For example, the sine wave bending of target 7 appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into acount.

3.2.9.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

3.2.9.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gears were in the 'up' position at the time of impact.

3.2.9.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

3.2.9.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

3.2.9.6 Section 42

Portions of Section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers. All cargo doors were found intact and attached to the fuselage structure, except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different from that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back on to the sea bed. An attempt to relocate the door was unsuccessful.

3.2.9.7 Section 44

Section 44 containing the aircraft structure between B S 1000 and B S 1480 including that area where the fuselage and wings were mated was located and identified. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gears were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

3.2.9.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northern most area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

3.2.9.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of B S 1480 and, for purposes of this report, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

3.2.9.10 The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were positively identified (targets 35, 37, 73 and 296). Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognisable as having come from a specific area of the aircraft.

3.2.9.11 Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from B S 1600 to B S 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive
wheels and cargo roller trays was located. This structure was severely damaged and mangled.

3.2.9.12 The tail cone and the auxillary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

3.2.9.13 A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure.

3.2.9.14 The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

3.2.9.15 The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates° to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabiliser was missing and the auxilliary spar was exposed. There was localized damage to the right-hand root of the loading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

3.2.9.16 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from section 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42 and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat belts were not fastened.

3.2.10 Salvage Operations

3.2.10.1 During recovery operation the video tapes as well as photographs of the wreckage to be recovered, were supplied to the personnel on board the ship for facilitating identification and recovery of correct targets.

3.2.10.2 Whenever any component/part of the aircraft wreckage was salvaged it was essential to immediately subject the same to inspection and to identify the damage sustained during recovery operation. In order to oversee this critical operation, the Court deputed one of its Assessors, Dr. V. Ramachandran, to be on board the ships. Under his supervision, the components/parts were thoroughly washed with fresh water, dried and treated with corrosion inhibiting compounds. A detailed inspection was thereafter carried out, observations recorded and the targets were appropriately labelled and their numbers were painted thereon. A laboratory microscope was taken on board by Dr Ramachandran. With that, fragments of significance were segregated for further investigation. Indeed some of these fragments did give important clues.

3.2.10.3 All the investigating personnel on board the ship were provided with leather gloves, fisherman's shoes, raincoat, life floating suits, writing and labelling material, camera with coloured films, etc. Sufficient number of "body bags" were positioned on each ship to cater for the eventuality of recovery of bodies with the wreckage. This precaution helped when a body did come along with wreckage on 25.10.1985.

3.2.10.4 The ship John Cabot completed the operation of locating, mapping and photography of the wreckage and returned to Cork on 1.10.85 at 2020 hours. The next phase of operation was to recover the significant wreckage parts which would be useful for deciding the cause of the crash.

3.2.10.5 Subsequent to the accident to Japan Airlines Boeing 747 aircraft, suspected to have been caused by failure of the repair to the rear pressure bulkhead, NTSB and FAA decided to fund the U.S. Navy for a two week operation over the seas for recovery of significant pieces of wreckage. For this purpose, U.S. Navy appointed Commander J.R. Buckingham, a deep sea salvage expert, to head the recovery operation. An offshore supply vessel M.V. Kreuzturm, of Canada was hired by U.S. Navy to recover the wreckage with the help of Scarab on John Cabot. One nylon lift line together with winch and ram were installed on the ship prior to its sailing to Cork where it arrived on 4th October,

1985. One crane was installed on the ship Kreuzturm in Cork.

3.2.10.6 One inch dia Kevlar lines coated with black plastic for abrasion resistance and braided with Dacron lining were used by John Cabot as primary lift lines.

3.2.10.7 The structure group after studying the photographic data, had formulated a list of 32 targets for recovery on 3.10.85. A systemwise priority list proposed by the Court of Inquiry was received through Dr V. Ramachandran on 4.10.85. Using these two lists, and taking into account the operating restrictions imposed by two ship operation, a final list of targets was prepared for recovery by the ships, assigning a priority number to each target. However, as the recovery operation progressed, changes in priority list were made to achieve optimum utilisation of the ships.

3.2.10.8 A meeting was held at 1400 hrs. on 4.10.85 on board CCGS John Cabot to establish/clarify the priorities for the wreckage recovery operation and coordination between John Cabot, Kreuzturm and Cork Search Centre. All the personnel involved in the recovery operation were shown the slides and photographs of the targets which were chosen for recovery on priority basis. The method and procedure of the recovery operation was discussed in detail and finalised. Another meeting was convened on 6.10.85

to clarify the doubts and to present the picture albums containing various photographs of targets to be recovered. The mode of attaching grippers/grabbers to the targets at strong points was clarified. A serialised list of priorities was prepared based on the mode of operation indicated by the the crew of John Cabot and Kreuzturm. Dr Ramachandran was given the authority to make on-the-spot decisions during the salvage operations.

3.2.10.9 A detail log of the activities of the ships John Cabot and Kreuzturm which started the recovery operation of 10.10.85, reveals the following :

(a) The Scarab working independently recovered the following

(1) Basket at target 192 containing copilot's chair, 2 suitcases and radar antenna (12.10.85)

(2) Target 8 - Lower fuselage skin of aft cargo compartment. (11.10.85).
(3) Target 245 - Forward belly skin just aft of radome (16.10.85).
(4) Target 350 - Economy class seats and carpet (23.10.85).
(5) Target 296 - Piece of aft pressure bulkhead.

(b) The Scarab after attaching the grippers, bridal cable and lift line to the targets buoyed off the same to Kreuzturm which recovered the following targets :

(1) Target 362/396 - Forward cargo fuselage skin from station 700 to 840 and STR 41L to 43R. (16.10.85).
(2) Target 193 - Fueselage skin from station 720 to 860 and passenger door 2L (17.10.85)
(3) Target 223 - Nose landing gear pressure deck web and stiffeners, container pieces (staion 260-340)(19.10.85).
(4) Target 181 - Wing skin with forward cargo compartment SLIPPED OFF WITH GRIPPERS (21.10.85) AND WAS LOST.
(5) Target 399/358 - Fuselage skin from station 780 to 940 and STR 7R to 35R with 2R door (25.10.85). A body entrapped in target 399/358 was recovered. Another body which came upto surface with the wreckage fell off into sea and was lost while hauling the wreckage on board. The recovered body was identified as of Dr. Mathew Alexander, a Canadian passenger and was brought to Cork by Fisherman's vessel "Orion" at 0130 hrs. on 28.10.85 and was sent for Post Mortem etc.
(6) Target 7 - Aft cargo compartment fuselage skin from station 1480 to 1860 (26.10.85).
(7) Target 47/50 - Aft cargo floor structure with roller tracks, frames, latch etc. from station 1600 to 1760 (27.10.85).
(8) Target 117 - Three rows of coach class seats with passenger cabin floor boards, broken floor beam (28.10.85).
(9) Target 35 - Aft Pressure Bulkhead piece (30.10.85).

3.2.10.10 The Scarab experienced malfunctions with its arms, Sonar equipment, multiplex system, junction box, microprocessor unit, etc. off and on during the above period of operation. Fouling of lift line with umbilical cord was also experienced in the early stages of operation. Since the assigned recovery by Kreuzturm was over by 30.10.85, and as the Scarab became unserviceable due to breakdown of its power suppluy, the OSV MV Kreuzturm was directed to return to Cork to off-load the recovered wreckage and its operation was terminated, (Indian Government had funded the cost of operation of M.V. Kreuzturm from 21.10.85 onwards).

3.2.10.11 Since the Scrab continued to remain unserviceable, the ship John Cabot was called back to Cork. It anchored in Cork at 1100 hrs. on 5.11.85. All the wreckage on board the ship was transported to the boat yard, in the afternoon.

3.2.10.12 After detailed macro photography of the recovered wreckage, the experts group mentioned in section 1.5.16 prepared a detailed factual report after carefully inspecting each of the targets recovered. It was decided to send the wreckage to Bombay for which necessary crates were then prepared and the large pieces of wreckage were cut along the lines indicated by the experts group to facilitate their packing.

3.2.10.13 RCMP investigators carried out a close visual and microscopic examination of the fragments recovered with the wreckage, suitcases, seats and cushions, etc. For further laboratory analysis. Dr A.D. Beveridge collected a few samples.

3.2.10.14 The Scarab appeared to be serviceable on 19.11.85 and the ship John Cabot sailed for completion of recovery of left over targets, on 20.11.85. However, the serviceability of Scarab proved elusive, it became inoperable on 21.11.85 and the ship returned to Cork at 1700 hrs on 25.11.85.

3.2.10.15 Efforts were made to repair Scarab so that the ship John Cabot could sail again in order to salvage as many pieces as possible. It was fortunate that the weather had not deteriorated. Some of the important but small pieces which had to be recovered had been placed in a basket at the bottom of the ocean. The ship sailed out again after Scarab had been repared. The basket was sought to be lifted, but, unfortunately, when it reached near the surface of the sea it overturned and the contents of the basket spilled and were never traced again.

3.2.10.16 At this juncture it was decided that the salvage operations should be terminated. The ship returned and sailed for home in the first week of December 1985.

3.2.11 Examination of Wreckage

3.2.11.1 Floating Wreckage

Soon after the accident, a number of light weight parts of the aircraft were found floating over a wide area at the crash site. These were picked up by the ships engaged in rescue operations and were brought to Cork where they were kept in the boat yard. The floating wreckage recovery continued for four days i.e. upto 26th June.

3.2.11.2 Some of the wreckage items were subsequently washed to the west coast of Ireland. These were picked up by the Irish Police and were brought to Cork. Some wreckage items were taken by a ship to Halifax, Canada. These were flown to Cork by the Canadian Aviation Safety Board. With the assitance of Air India engineers, the wreckage items were identified, labelled, photographed and laid out in the boat yard hangar for examination.

3.2.11.3 The wreckage was initially examined at Cork by the Structures, Power Plant and Systems Group. It was subsequently transported to Bombay for further examination. A few wreckage items which were taken by the Spanish trawlers to Madrid were also transported to Bombay. Some wreckage items had washed to the west coast of England. These were collected by the Accident Investigation Branch of UK and were transported to Cork and then to Bombay.

3.2.11.4 The floating wreckage recovered constituted approximately 3 to 5 per cent of the aircraft structure. The major items of the wreckage recovered were :

Various leading edge skin panels of LH nd RH wing, LH wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canon fairings aft end pieces, landing gear wheel wall doors, pieces of elevator and aileron, toilet doors, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggages, suitcases etc. and three empty oxygen bottles.

3.2.11.5 The Structures Group which had been constituted by the Court examined the floating wreckage and submitted its report. From the report the following significant information about the damage to major items of the floating wreckage is noted :

(I) VT-EFO aircraft was carrying a -7Q engine on 5th pod and a -7Q 5th pod kit in the aft cargo compartment. It had therefore, in all 14 engine fan cowls (eight working engine fan cowls plus two 5th pod engine fan cowls plus two -7T engine kit fan cowls in the aft cargo compartment plus two -7Q engine fan cowls in the aft cargo compartment). Out of these 14 fan cowls, 9 cowls (6 of working engines plus 2 of -7J kit plus one of 7Q kit) and two additional pieces of fan cowls were found. Five of the fan cowls of working engines show folding damage lines at approximately 3 O'Clock and 9 O'Clock positions. The number 3 engine inboard fan cowl has severe impact damage on its leading edge and has small inward to outward puncture holes (not penetrating through outer skin) in the lower centre region. The two fan cowls of -7J 5th pod kit stowed in the aft cargo compartment exhibit severe damage. One of these cowls is broken in two pieces. One of the pieces is cut at one corner in an arc of about 20 inches diameter and its external skin is pealed back. The external surfaces of all the three pieces have considereable scratches, tears and holes from outside to inside. None of the punctures penetrates the inner skin. Some punctures are also present from inside to outside but none of these penetrates the outer skin.

(ii) Out of the 12 spoilers, seven (number 2, 3, 5, 7, 8, 9 and 12) have been retrieved. Of these, six have their actuators attached to them in fully retracted position. Six spoilers have splits in their lower skin with split edges curled into the cores of honeycomb. Number 8 spoiler (located just inboard of number 3 engine) has a concentrated local impact damage on front spar and trailing edge beam from forward to aft and up direction over a span of 2 feet starting from outboard of spoiler actuator.

(iii) The left hand wing tip assembly with a part of H F Antenna was retrieved. No burning/discolouration marks around lightning arrester of H F system were noticed. The rib inboard of the lightning arrester was found intact. There were no burn marks anywhere on the panel.

(iv) The right hand wing leading edge top panel inboard of number 3 engine with a position of kruger flap frame along with bull nose attached was recovered. The bull nose was found crushed from top in the area just below the stay rod and the lower surface of stay rod has scratch marks from front to rear.

(v) The right hand wing root leading edge (inboard of W S 268.81) shows an impact damage at the leading edge. Bottom skin and internal structure are torn away. The leading edge skin is caved in over a span of about 3 feet and shows signs of heavy body impact in air. The impact damage shows signs of downward and backward movement of the impacting body.

(vi) A 3' x 2' piece of right hand inboard trailing edge fore flap with accordian seal was recovered. The inboard 8" portion of leading edge was found damaged by impact of an object going from lower forward to upper aft.

(vii) All the floor panels recovered from upper deck and main cabin indicate that these were detached from their attachments in an upward direction from all sides.

(viii) One main deck blow out door located between B S 2040 and 2140 left hand side was available. Out of its four metal clips, one clip was broken off with 2 nylon rivet heads sheared.

(ix) The cockpit entry door and the side bulkhead panel were found fairly intact but had come out of their attachment.

(x) Twelve toilet doors, out of a total of 16, were available and were found fairly intact, but had come out of their attachments.

(xi) The available cabin interior panels and overhead bins of the main deck and upper deck have only minor damage.

(xii) The woodent boxes which contained the fan blades of 5th pod engine and were loaded in container at position 24L in the forward cargo compartment were found broken apart with no burn marks.

3.2.11.6 Wreckage Salvaged from Sea

The wreckage salvaged from the sea was visually examined at Cork by the Committee of Experts as mentioned in section 1.5.16 and the observations thereon recorded. Subsequently detailed metallurgical examination was carried out at the Bhabha Atomic Research Centre, Bombay by
Dr. M.K. Asundi and Dr. G.E. Prasad of B.A.R.C., Mr. S. Radhakrishnan and Dr. R.V. Krishnan of National Aeronautical Laboratory and Mr. B.K. Athawale of the Explosives Research and Development Laboratory, under the guidance of Dr. V. Ramachandran. During this examination, representatives of CASB, CP Air and Boeing were present in the first week. These represntatives left Bombay while the metallurgical examination was being carried out. The metallurgical examination was continued and the aforesaid group submitted the metallurgical report to the Court in December, 1985.

3.2.11.7 Although all the recovered wreckage was examined, only those items exhibiting characteristics which provide some evidence as to what may have happened to the aircraft during its final moments of flight are discussed herein below :

3.2.11.8 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from B S 1480 to 1850 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear and the torn edge was buckled in waves, like the trace of a sine wave. One the right side, between the one quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at B S 1480. The skin tear located at about B S 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distored and elongated.

3.2.11.9 This panel was examined by the committee of experts at BARC and according to their report the keel beam trunnion fitting beneath the outer chord of the station 1480 bulkhead had fractured at the aft set of bolt holes. The fracture surface of the right side of the trunnion fitting was clean. As per the report, it was typical of overload failure in tension. The fracture surface of the left side of the trunnion fitting was covered with corrosion products, especially, at one corner, due to sea water. After cleaning this area by the recommended techniques, scanning electron microscopy revealed morphology of overload fracture consisting of dimples. Away from this corner also the fracture was similar as being due to overload. There was no evidence of there having been any fatigue failure.

3.2.11.10 At B.A.R.C., a sample was cut from the corroded corner of the failed left side trunnion fitting and metallographic examination was carried out on the same. The said examination showed on a face perpendicular to the corroded fracture surface, pits due to corrosion by sea water. The basic microstructure was however free from intergranular cracking. It was thus concluded by the experts that the material in the region corroded by sea water had not suffered stress corrosion cracking which generally manifests as intergranular cracking.

3.2.11.11 A piece of the trunnion fitting was cut and the hardness and electrical conductivity values were measured by the said experts. As per their report, the electrical conductivity values were within the specified limits.

3.2.11.12 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from B S 1860 to 1960 and from stringer 46L to 46R. The forward end of target 8 matched with the aft end of Target 7. A region of fracture along the rivet holes near stringer 46L was marked for SEM examination. SEM examination after cleaning revealed that the fracture was characterised by dimples along its length, including areas adjacent to the edges of the rivet holes. These features are consistent with an overload mode of failure.

3.2.11.13 According to the metallurgical report, there was no evidence of fatigue failure on this target.

3.2.11.14 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 O'Clock position, the piece from 12 to 1

O'Clock position had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 O'Clock position the outer edge showed sinusoidal buckling, and the edge sector at 9 O'Clock position was partially collapsed and its edge was turned under. Samples taken for optical stereo microscope and SEM examination revealed that the fracture characteristics were consistent with an ovrload mode of failure.

3.2.11.15 According to the metallurgical report, there was no evidence of fatigue or any other mode of failure.

3.2.11.16 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occuped the 7 to 9 O'Clock position. Optical and SEM examination were undertaken on this item.

3.2.11.17 The fracture alont the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

3.2.11.18 Representative fracture samples were cut from the left-hand side and circumferential fracture edges of the fracture surfaces. Optial and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

3.2.11.19 Target 47 - Aft Cargo Floor Structure

This portion of the aft cargo compartment was located between B S 1600 and B S 1760. No significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

3.2.11.20 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between B S 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

3.2.11.21 In the metallurgical report it is stated that on an examination of this target it was also found that on the underside of this floor near the forward end, a number of dents and impact marks were observed. This region appeared to have suffered shrapnel penetration. This area was radiographed but no metallic fragment was detected.

3.2.11.22 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segement was located between B S 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

3.2.11.23 Target 399 - Fuselage around 2R Door

This target is shown in Fig. 399-1. A detailed description is given below :

TARGET 399 Fuselage Station 780 to 940 in the longitudinal direction and stringer 7R down to stringer 35R circumferentially.

This piece contained five window frames, one in the 2R passenger entry door. Three of the window frames, including the door window frame, still contained window panes. Little overall deformation was found in the stringers and skin above the door. The structure did contain a significant amount of damage and fractures in the skin and stringers beneath the window level. In the area beneath the level of the windows, the original convex outward shape of the surface had been deformed into an inward concave shape. Further inward concavity was found in the skin between many of the stringers below stringer 28R. The skin at the forward edge of the piece was folded outward and back between stringers 25R and 30R. Over most of the remaining edges of the piece a relatively small amount of overall deformation was noted in the skin adjacent to the edge separations. Twelve holes or damage areas were numbered and are further described.

No.1 : Hole, 5 inches by 9 inches with two large flaps and one smaller curl, all folded outward. Reversing slant fractures, small area missing.

No.2 : Hole, 2 inches by 3/4 inch, one flap folded outward, reversing slant fractures, one curled sliver, no missing metal.

No.3 : Triangular shaped hole about 2 inches on each side. One flap, folding inward, with one area with a serrated edge. No missing metal, extensive cracking away from corners of the hole, reversing slant fracture.

No.4 : Tear area, 8 inches overall, with deformation inward in the centre of the area. Reversing slant fracture.

No.5 : Fracture area with two legs measuring 14 inches and about 24 inches. Small triangular shaped piece missing from a position slightly above stringer 27R. Inward fold noted near the joint of the legs. An area of 45° scuff marks extend onto this fold.

No.6 : Hole about 2.5 inches by 3 inches with a flap folded outward, reversing slant fracture. Approximately half the metal from the hole is missing.

No.7 : Hole about 3 inches by 1 inch, all metal from the hole is missing. Fracture edges are deformed outward.

No.8 : Forward edge of the skin is deformed into an "S" shaped flap. Three inward curls noted on an edge.

No.9 : Inwardly deformed flap of metal between stringers 11R and 12R at a frame splice separation. No evidence of an impact on the outside surface.

No.10 : Door lower sill fractured and deformed downward at the aft edge of the door.

No.11 : Frame 860 missing above stringer 14R. Upper auxilliary frame of the door has its inner chord and web missing at station 860. A 10 inch piece of stringer 12R is missing aft of station 860.

No.12 : Attached piece of floor panel (beneath door) has one half of a seat track attached. The floor panel is perforated and the lower surface skin is torn.

3.2.11.24 Much of the damage on this target was on the skin and stringers beneath the window level, i.e., on the starboard side of the front cargo hold. The inside and outside surface of the skin in this region are shown in Fig. 399-2 and 399-3 respectively. There were 12 holes or damaged areas on the skin as described above, generally with petals bending outwards. The curl on a flap around hole no.1 shown in Figh 399-4 has one full turn.

This curl is in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.

3.2.11.25 When this target was recovered from the sea, along with it came a large number, a few hundreds, of tiny fragments and medium size pieces, All of the fragmets were recovered from the area below the passenger entry door 2R. One of the medium size pieces recovered with this target was a floor stantion, about 35 inches long, shown in Fig. 399-5. It is a square tube. It had the mark station 880 painted on its inner face, i.e. facing the centre line of the cargo hold. The part number printed on this station is 69B06115 12 and the assembly number is ASSY 65B06115-942 E3664 1/31/78*. It was confirmed that this stantion belongs to the starboard side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the station. Fig. 399-6 is a print from the radiograph of this station. The inward curling can be seen clearly in this figure. Curling of the metal in this manner is a shock wave effect.

3.2.11.26 A piece near the fracture edge of this stantion was cut, and examined metallographically. Fig. 399-7 and 399-8 show the micro-structure of this piece. Twins are seen in the grains close to the fracture edge. The normal microstructure of the stantion material is free from twins as shown in Fig. 399-9.

3.2.11.27 Fig. 399-10 shows a collection of small fragments recovered along with target 399. There were some curved fragments with small radius of curvature (A). Reverse slant fracture (B) was noticed in some of the skin pieces. A piece 3/4" x 1/2" and 3/16" thick was found to have three blunt spikes at the edge (C). This piece was metallographicaly polished on the longitudinal edge. The microstructre of the piece is shown in Fig. 399-11. It may be seen that the grains in this fragment also contain a large number of twins.

3.2.11.28 Target 362/396 Forward Cargo Skin

This piece indluded the station 815 electronic access door, portions of seven longitudinal stringers to the left of bottom centre and five longitudinal stringers to the right of bottom centre. The original shape of the piece (convex in the circumferential direction) had been deformed to a concave inward overall shape. Multiple separations were found in the skin as well as in the underlying stringers. Further inward concavity was found in the skin between most of the stringers.

3.2.11.29 The two sides of this piece are shown in Fig. 362-1 and 362-2. This piece has 25 holes or damaged areas in most of which there are multiple petals curling outwards. These holes are numbered 1 to 3, 4a, 4b, 4c and 5 to 23. These are described below. Unless otherwise noted, holes did not have any material missing :

No.1 : Hole with a large flap of skin, reversing slant fracture.

No.2 : Hole with multiple curls, reverse slant fracture.

No.3 : Hole with multiple flaps and curls, reversing slant fracture, one area of spikes (ragged sawtooth)

No.4A : One large flap, reverse slant fracture, one area of spikes.

No.4B : Hole with two flaps.

No.4C : Hole with two flaps, one area of spikes

No.5 : HOle with two flaps.

No.6 : Braching tear from the left side of the piece, reversing slant fracture.

No.7 : Hole, with one flap, one curl and one area of spikes.

No.8 : Very large tear from the left side of the piece with multiple flaps and curls, reversing slant fracture and at least two areas of spikes.

No.9 : Hole with multiple flaps, one curl.

No. 10 : 2.5 inch tear

No.11 : One flap

No. 12 : Grip hole, plus a curl with spikes on both sides of the curl.

No.13 : "U" shaped notch with gouge marks in the inboard/outboard direction. Three curls are nearby with one are of spikes. Gouges found on a nearby stringer and on a nearby flap.

No. 14 : Nearly circular hole, 0.3 inch to 0.4 inch in diameter. Small metal lipping on outside surface of the skin. Most of the metal from the hole is missing.

No. 15 : Hole in the skin beneath the first stringer to the left of centre bottom. Small piece missing.

No. 16 : Hole in the stringer above hole No. 15. Most of the metal from this hole is missing.

No. 17 : Hole through the second stringer to the left of centre bottom, 0.4 inch in diameter. The hole encompassed a rivet which attached the stringer to the outer skin. Small pieces of metal missing.

No. 18 : Hole at the aft end of the piece between the third and fourth stringers to the left of centre bottom. The hole consisted of a circular portion (0.4 inch diameter), plus a folded lip extending away from the hole. The metal from the circular area was missing.

No. 19 : Hole with metal folded from the outside to the inside, about 0.6 inch by 1.5 inch. Flap adjacent to the hole contained a heavy gouge mark on the outside surface of the skin.

No. 20 : Hole containing a piece of extruded angle.

No. 21 : Hole containing a piece of extruded angle.

No. 22 : Hole with one flap.

No. 23 : Hole about 0.3 inch in diameter, with tears away from the hole. Small piece missing.

3.2.11.30 Fig. 362-3 to 362-7 show a few of these holes. There were also cracks or tears around some of the holes. The curls around some of the holes had nearly one full turn. In the large tear between body stations 700 and 740 and stringers between 41L and 45L, there were many pronounced curls as shown in Fig. 362-8. On the edges of the petals around several holes, reverse slant fracture was seen at a number of places. This slant fracture is at an angle of about 45° to the skin surface, the fracture continuing in the same general direction but with the slope of the slant fracture reversing frequently.

3.2.11.31 Sharp spikes were observed at the edges of the holes or at the edges of the petals around the holes No. 3, 4A, 4C, 7, 8 (at two locations), 12, 13 and 16. Some of the spikes are shown in Fig. 362-9 to 362-12. One of the holes, No. 14, on the skin was nearly elliptical with metal completely missing, as shown in Fig. 362-13. On the inside surface of the skin, paint surrounding this hole was missing. Hole No. 16 was through the hat section stringer, as shown in Fig. 362-14. In this, most of the metal was missing. On the inside of the hat section, the fracture edge of this hole had spikes, as shown in Fig. 362-15. Hole No. 17 was through the stringer and the skin, as shown in 362-16.

3.2.11.32 Through holes No. 20 and 21, extruded angles were found stuck inside, as shown in Fig. 362-17 and 362-18 respectively. In the petal around hole No. 20, there was an impact mark by hit from the angle as seen in Fig. 362-19 photographed after removing the angle. Such a mark was not present in the petals around other holes.

3.2.11.33 On the skin adjacent to hole No. 13 gouge marks were noticed, Fig. 362-20. These marks were on the inside surface of the skin. To check whether these could be due to rubbing by the bridal cable of Scarab during the recovery operations, a sample of bridal cable was obtained from "John Cabot" and gouge marks were produced by pressing this cable against an aluminium sheet. The gouge marks thus produced, as shown in Fig. 362-21, appear to be different from those observed near hole No. 13.

3.2.11.34 A piece surrounding hole No. 14 was cut out and examined in a Jeol 840 scanning electron microscope at the Naval Chemical and Metallurgical Laboratory, Bombay. Fig. 362-22 and 362-23 are the scanning electron micrographs showing the inside surface and outside surface of the skin around this hole. Flow of metal from inside to outside can be seen from these figures. Energy dispersive x-ray analysis was carried out on the edges of this hole. Only the elements present in this alloy and sea water residue were detected.

3.2.11.35 A portion of the skin containing part of hole No. 14 was cut, polished on the thickness side of the skin and examined in a metallurgical microscope. Fig. 362-24 shows the microstructure of this region. The flow of metal along the edge of the hole can be seen from the shape of the deformed grains near the hole. This can be compared with the bulk of the grains shown in Fig. 362-25, away from the hole. In addition, in Fig. 362-24, a series of twin bands can be seen in some of the grains near the hole. Fig. 362-26 shows these bands at a higher magnification. Normal deformation rates at various temperatures do not produce such twinning in aluminium or its alloys. It may be noted that this microstructural feature is absent in the microstructure of the skin, away from hole No. 14, Fig. 362-25.

3.2.11.36 Metallography was also carried out on a petal around hole No.7 and on a curl with spikes around hole No. 12. The microstructures indicate twins, however they could not be recorded due to their poor contrast.

3.2.11.37 Small pieces containing the spikes around holes No. 12 and 16 were cut and energy dispersive x-ray chemical analysis on the region of spikes in both was carried out in the Jeol 840 SEM. Only elements present in the alloys and sea water residue were detected.

3.2.11.38 A number of small fragments were found along with the forward cargo skin in target 362. Amongst them was a piece from the web of a roller tray. This has pronounced curling of the edges towards the drive wheel, Fig. 362-27.

3.2.11.39 Another small fragment was found from the above target. This piece, identified as specimen No. 12 in box No. 1, target 362, has a number of spikes along the edge. A scanning electron micrograph of the spikes is shown in Fig. 362-28. The sides of the spikes on SEM examination revealed elongated dimples as shown in Fig. 362-29, characteristic of shear mode of fracture. Metallography was carried out on the thickness side of this specimen. Fig. 362-30 and 362-31 show the microstructure near the apex of the spike and at the root of the spike respectively. Extensive twinning can be seen in these regions of the spikes.

3.2.11.40 Another fragment recovered with target 362 and identified as specimen No. 8 in box No. 1, also showed extensive twinning. The microstructure is recorded in Fig. 362-32.

3.2.11.41 Reference has also to be made to two other reports concerning wreckage.

3.2.11.42 The floating wreckage recovered was initially examined at Cork. On 25th June, Mr. Eric Newton a retired investigator of AIB, UK, was requested to examine the floating wreckage recovered and other materials with specific reference to the possibility of explosive sabotage having taken place. Mr. Newton examined the floating wreckage, passenger clothings and the other materials recovered from the crash victims The findings of Mr. Newton on the material available at that time are summarised below:

a. Taking the scatter of the wreckage and bodies into consideration and the condition of the limited wreckage recovered indicates that the aircraft had broken up in flight before impact with the sea.

b. Detailed examination of the structural wreckage recovered did not reveal any evidence of collision with another aircraft. Nothing was found suggestive of an external missile attack.

c. There was no evidence of fire internal or external.

d. There was no evidence of lightning strike.

e. Examination of all available structural parts recovered, did not reveal any evidence of significant corrosion, metal fatigue or other material defects. All fractures and failures were consistent with overstressing material and crash impact forces

f. Examination of clothing from the bodies did not show any explosive fractures or any signs of burning. The seat cushions and head cushions also did not show any explosive characteristics.

g. The damage to the suitcases (14 large and 29 small) which were examined was due to impact crash forces. The presence of 14 large suitcases could, however, indicate that one of the baggage containers had been broken to permit these suitcases to escape.

h. A number of lavatory doors and structure also did not show any damage consistent with explosion. The flight deck door showed no explosion damage inside or outside.

i The circumstatnial evidence strongly suggests a sudden and unexpected disaster occurred in flight.

j. There was no significant fire or explosion in the flight deck, first and tourist passenger cabin including several lavatories and the rear bulk

cargo hold.
3.2.11.43 The other report dated 30th November, 1985 is of Mr. V.J. Clancy. Mr. Clancey had examined the wreckage and had also taken part, though only for a few days, in the metallurgical examination which was being conducted at BARC, Bombay.
3.2.11.44 Mr. Clancey examined practically all the items of wreckage which had been brought to BARC and in his report he has dealt with all of them. His report contained a description of the recovered items and also his comments thereon.
3.2.11.45 With regard to the aforesaid target 362, he observed that there were about 20 holes in it clearly resulting from penetrations from inside.
3.2.11.46 He further stated that:
"In addition to the fact that perforation was from inside there are certain features which suggest that they were made by high velocity fragments such as are produced by an explosion. These features are:
(a) Presence of toothed or spiked edges at some parts of the metal which had petalled out from the perforations.
"Tardif and Sterling (Canadian Aeronautics and Space Journal, 1969, 16, 1, 19-27) obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.
(b) Presence of marked curling, in some cases of more than 360°, of some of the petals.
Tradif and Sterling stated that such curling was a feature of explosively produced fragments.
(c) The virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal.
(d) The virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object. This suggested that the production of at least many of the perforations were separate independent events.
(e) One perforation (identified as No. 14) resembles a "bullet hole", that is cleanly punched out - a type of hole usually associated with a

high velocity missile.
"There is evidence that the forward part of this item had been folded back inwards along the line of station 760 and then bent back again along a line slightly forward of this station.
"Such folding, may be violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.
"One hole identified as No. 13, was almost certainly caused by a slipping wire rope used as a sling.
"Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken by me of this area and are being examined by R.A.R.D.E. for evidence of fire or explosives".
3.2.11.47 There were several hundred small fragments which were recovered from the same general area as Target 362. While dealing with these Mr. Clancey observed that the production of a large number of small fragments is generally regarded as indicative of an explosion. One piece out of this was isolated, which was about one inch square of sheet alloy, and it was noted by Mr. Clancey that this piece had characteristic spikes on one edge similar to those described by Tardif and Sterling. (This piece is the same as shown in Fig. 362-28).
3.2.11.48 Mr. Clancey also examined a few suit cases which had been recovered. One particular suit case to which reference was made by him was of red plastic material with blue lining. With regard to this he stated that the damaged lining, severely tattered, resembles that of one found after an explosion in an aircraft in Angola. In that case microscopic examination showed definite evidence of damage by an explosion.
3.2.11.49 The later part of the report of Mr. Clancey contained his opinion. With regard to Target 362 his opinion was as follows:
"The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

"Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

"A more detailed study, metallurgical and fractographic, is required.

"The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance

from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

"The single "bullet hole", No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

"If the forward part of this item was forcefully and rapidly folded back to impact on the other part it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility".

3.2.11.50 The opinion of Mr. Clancey about the small fragments was as follows:

"The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.

"The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

3.2.11.51 It appeared to the Court that the report of Mr. Clancey required certain clarifications. It was suggested to Boeing Commercial Airplane Company by the Court that Mr. Clancey should appear as a witness. The Court received a message to the effect that Mr. Clancey felt that he could not add anything useful to his report.

3.2.11.52 A close examination of the report of Mr. Clancey shows that the opinion expressed by him in the later part of the report is at considerable variance with the observations contained in the earlier part of the report. Particularly with regard to Target 362 and the small fragments, Mr. Clancey has stated in his observations that there was strong evidence of explosion. In his opinion, however, he has stated that more detailed study is required. It is interesting to note that though Mr. Clancey has referred to the opinion of Tardif and Sterling, he has not chosen to contradict the conclusions arrived by them. Mr. Clancey has also not stated as to what could possibly have caused the special features which were noted on Target 362.

3.2.11.53 We find the metallurgical report inspires more confidence. Not only is reference and reliance made in the report to other expert opinions contained in various articles written by experts all over the world, certain explosion experiments were also carried out by the experts which led them to the same conclusion.

3.2.11.54 The particulars of the experiments so carried out and the results obtained therefrom have been stated in their report as follows:

EXPLOSION EXPERIMENTS

"To determine the damage by high velocity fragments or shock waves on a structure similar to the one in aircraft cargo hold, the following experiments were conducted on November 30 and December 1, 1985 at the Explosives Research and Development Laboratory, Pune, using plastic explosive (PEKI) and different mixtures of plastic explosive and TNT. The explosive was kept in a box made of sheet metal of 6" x 6" x 6" of 1/16" thickness. This box was kept inside another box made of sheet metal 2' x 2' x 2' of .04 or .06" thickness. The boxes were made of 2024 aluminium alloy sheets used for aircraft skin. To the inner surface of the outer box, hat section stringers similar to those used in the aircraft were riveted. The quantity of explosive used in the inner box was varied from 60 g to 100 g. The explosive was detonated with an electrical detonator. After the explosions the fragments and the panels were collected and examined.

"Experiments were also conducted to produce explosive damage on skin panels, individual hat section stringers and individual stantion tubes. In the case of stantion tubes experiments were carried out placing the explosive charge both inside and outside. The quantity of explosive used was varied from 5 g to 50 g.

"Various types of damages were recorded on all the targets. These include punched holes, petaling and curling around holes, spikes at fracture edges, curved fragments with small radius of curvature and reverse slant fracture. Fig. EXP-1 shows a collection of fragments. The features mentioned above are shown in Fig. EXP-2 to EXP-7. It may be noticed that the features produced by experimental explosion were similar to the features observed largely in target 362 of the wreckage. The small fragments had features similar to those in the fragments from targets 362 and 399.

"Metallography was carried out in (a) a specimen surrounding a punched hole in the skin (b) a specimen surrounding a hole in the stringer, (c) a curl in the stantion and (d) spikes in a fragment. In all these cases, the grains adjacent to the area of explosive damage are having twins. Two typical microstructures are shown in Fig. EXP-8 and EXP-9. Away from these areas the microstructure is normal. Thus it is confirmed that twinning in the microstructure of these structural members is a unique feature of explosive fracture, not produced by any other measns known so far."

3.2.11.55 The findings in the said metallurgical report are also strengthened by the observations of Eric Newton in the article "Investigating Explosive Sabotage in Aircraft" published in the International Journal of Aviation Safety, March 1985, p. 43. Mr. Newton is an acknowledged authority in the detection of explosive sabotage in aircraft. The conclusions contained in the article are based on his review of incidents of explosion between 1946 and 1984 which were known to him. Some of the conclusions arrived at by him which were relevant in the present case are when he states "Generally speaking, the smaller the fragment, higher the velocity of the detonation. Minute fragmentation is indicative of high explosive having been used, and provides clues to the focal point or region of the explosion. The mode of break up of the aircraft itself and its sequence of failure is usually very complicated and quite without the logic dictated by normal aerodynamic overstressing".

3.2.11.56 Mr. Newton has also observed that curling, cork-screwing, and saw tooth edges may also be indicative of an explosion though such fractures by themselves may not be conclusive evidence that an explosion was involved. Firmer evidence, according to him, was of fusing of metal, scorching, pitting and blast effect. He further states that "Perhaps the most conclusive material evidence to be found on metal specimens is cratering, very often in groups, often minute and numerous".

3.2.11.57 Mr. Newton also refers to the positive explosive signatures which remain on a detonation in an aircraft. These positive singatures, according to him, are as follows:

"(a) The formation of distinctive surface effects such as pitting or very small craters formed in metal surfaces, caused by extremely high velocity impacts from small particles of explosive material. Such craters, when viewed under the microscope, have raised and rolled over edges and often have explosive residue in the bottom of the crater.

"(b) Small fragments of metal, some less than 1 mm in diameter, which, under the scanning electron microscope, reveal features such as rolled edges, hot gas washing (orange peel effect, surface melting and pitting and general evidence of heat; such features have been proved and observed following explosive experiments with known explosives). Supporting strong evidence would be if such fragments (normally found embedded in structures, furnishing or suitcases) were found embedded in a body where evidence of burning of tissue is present at the puncture entry and where the fragment came to rest.

"(c) As well as surface effects on metal fragments produced by explosives there are deformation mechanisms which are peculiar to high rates of strain at normal temperature. At normal rates of strain metals deform by usual mechanism associated with dislocation movement. However, because this process in an explosion is thermally activated at

very high rates of strain, there is insufficient time for the normal process to occur. In some metals such as copper, iron and steel, deformation in the crystals of the metal takes place by 'twinning', that is to say by parallel lines or cracks cutting across the crystal. Such a phenomenon can occur only if the specimen has been subjected to extreme shock wave loading at velocities in the order of 8000 m/sec. Such specimens, usually distorted must be selected with care, prepared in a metallurgical laboratory, polished, mounted
and microscopically examined. Where such twinning of the crystals is found it establishes (a) that the specimen was close to the seat of the explosion and (b) that a military type explosive had been used with a detonating velocity of 8000 m/sec or more. Twinning is rarely produced when shock impact loadings are below 8000 m/sec.

"The above features, singly or combined, are considered to be proof positive evidence of a detonation of a high explosive; they could not be produced in any other way."

3.2.11.58 The metallurgical report indicates that the microscopic examination (conducted by them) discloses such features being present which had been described as positive signatures of the detonation of an explosive device in an aircraft by Mr. Newton. Furthermore, twinning effect has also been noticed at a number of places - around holes and in fragments. These have been categorised by Mr. Newton as positive signature of an explosion.

3.2.11.59 In the primary zone of explosion, metallic structures disintegrate into numerous tiny fragments and usually these fragments contain the above mentioned distinct signatures of explosion. In the present case the explosive damage had occurred at an altitude of 31000 feet when the aircraft was flying over the ocean. The fragments that formed due to explosion must have been scattered over a wide area and it is impossible to locate and recover all of them from the ocean bed. Nevertheless, some of the fragments which were recovered along with the targets 362 and 399 do contain signatures of explosive fracture.

3.2.11.60 From the aforesaid discussion it would, therefore, be safe to conclude that the examination of targets 362 and 399 clearly reveals that there had been a detonation of an explosive device on the Kanishka aircraft and that detonation has taken place not too far away from where these targets had been located.

FIRE

3.3.1 There is no evidence that there was any fire on board the aircraft before it met with the accident.

3.3.2 Amongst the floating wreckage, however, was found, what was later on identified as, a spares equipment box belonging to this aircraft. This box was charred on one side and partially on the bottom. The depth of charring suggested that the burning time was three to four minutes. This box contained some sand and small shellfish. The flesh from the shelfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

FLIGHT RECORDERS

3.4.1 Recovery of Flight Recorders

3.4.1.1 Recovery of the flight recorders was a very difficult and challenging job. At the site of accident, depth of water is about 6700 feet. The job involved fixing the location of recorders and then retrieving them. For this purpose three ships viz. Guardline Locator (a ship provided by Accident Investigation Branch of U.K.), Le Aoife (an Irish Naval Ship) and Leon Thevenin (a French Cable laying ship, charterd by the Government of India) were utilised. Guardline Locator and Le Aoife were solely for fixing the positions of recorders and also had the capability to lift the recorders with the help of its scarab.

3.4.1.2 Both the Cockpit Voice Recorder and the Digital Flight Data Recorder were fitted with Dukane Underwater Acoustic Beacons (Pingers) which enabled establishing the location of flight recorders under water. The Beacons are designed to provide a signal at 37.5 ñ 1 Khz frequency that can be heard for approximately 2 miles in any direction for 30 days after water entry. Its high strength case permits operation in water depth to 20,000 feet. Its pulse repetition rate is not less than 0.9 pulse per second.

3.4.1.3 On 4th July, 1985, Guardline Locator reported strong possibility of two separate sound sources of frequencies between 39 KHz and 42

KHz. On 5th July, Guardline Locator gave coordinates of an area, which it believed contained the pinger. Guardline Locator later reported that using a Dukane Hand Locator, it had located pinger (2) at 5102.6N, 1248.6W. Leon Thevenin then concentrated its search in this area for retrieving the recorders.

3.4.1.4 In response to a query, Messrs Dukane Corporation advised that Pinger transducer is made of ceramic and if cracked during impact, its frequency could be elevated. The pulse rate should, however, be uneffected. Keeping this in mind, the Leon Thevenin increased its Sonar Band one upper frequency limit from 40 KHz to 45 KHz.

3.4.1.5 On 9th July at about 2300 hours the Scarab of Leon Thevenin located the Cockpit Voice Recorder at 5102.67N, 1248.93W and the recorder was brought on the deck at 0747 hrs on 10th July. The CVR was kept in a drum filled with water. The scarab was again lowered on 10th July in the same area and at about 2130 hours faint signals were picked up on Sonar. By about 2200 hours the signals became louder and the pulse rate frequency was calculated to be 72 transmissions per minute. At about 2230 hours the DFDR was also located at 5103.10N, 1249.59W and it was brought on deck at 0245 Z on 11th July.

3.4.1.6 The DFDR was also placed alongside the CVR in the drum filled with water. Leon Thevenin was then advised to return to Cork with the Flight Recorders. Leon Thevenin reached Cork on the morning of 12th July and the flight recorders were placed in two specially fabricated water tight steel containers filled with water. The recorders were then carried to Bombay on the same day by Mr. Satendra Singh, Reginal Controller of Air Safety, Bombay, accompanied by Mr. Vishwanath of Air India for preparing read-outs and transcript of the recorders. Necessary precautions were taken to ensure that the data recorded was not affected during transportation to Bombay.

3.4.1.7 Both the recorders reached Bombay on the morning of 13th July and were kept in the office of the Regional Controller of Air Safety under Armed Police Guard.

3.4.2 Description of Flight Recorders

3.4.2.1 Kanishka was equipped with a Fairchild A-100 Cockpit Voice

Recorder Serial No. 5809 and a Lockheed 209E Digital Flight Data Recorder Serial No. 1282. These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the rear pressure bulkhead.

3.4.2.2 The CVR records all crew communications and sounds in the cockpit on a continuous tape loop which has a tape speed of 1-7/8 inches per second. The Recorder has two heads, one head which erases the previous recording and the second which records the current information and thus the last 30 minutes of recorded signals are retained, the previous being automatically erased. It continuously records convervations/sounds from 4 different sources on the following four separate channels:

Channel 1 : Radio channel of pilot

Channel 2 : Radio channel of flight engineer

Channel 3 : Cockpit Area Mike

Channel 4: Radio channel of co-pilot.

3.4.2.3 The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor. Adjacent to this unit was a Lockheed Model 280 Quick Access Recorder that recorded the same serial digital signals on to a 50 hour cassette.

3.4.2.4 The DFDR records 52 basic parameters on a magnetic tape. The tape preserves records of the last 25 hours. The serial digital signal has a bit rate of 768 bits per second and is recorded at a tape speed of 0.37 inches per second.

3.4.3 Examination of Flight Recorders and Tapes

3.4.3.1 General

The recorders brought to Bombay from Cork were opened on 16th July, 1985 at the Air India's Facilities in Bombay in the presence of the Court and Assessors. A team of foreign experts including one each representatives from both the Recorder Manufacturers, three from National Transportation Safety Board, one from Canadian Aviation Safety Board and one from NRC Flight Recorder Playback Centre, Canada were present when the tapes were taken out of the recorders.

Apart from them, representatives of the Government of India and Air India were also present.

3.4.3.2 Cockpit Voice Recorder

When the unit was removed from its shipping and storage container, some mechanical damage was immediately evident. The top of the cover had been deformed inwards, probably due to initial external strong attachments for the horizontally mounted Underwater Acoustic Beacon. The plate had torn away from the light structure behind it. The cause of the damage was not obvious. The light outer cover was removed by cutting it open with hand shears and pliers.

3.4.3.3 When the armoured and insulated containment was opened, the tape transport was found to be in relatively good condition and the tape physically undamaged. Eighteen inches of the tape was pulled from the centre of the tape stack and the tape cut near the stack well clear of the end of recording. The tape was then removed from the recorder, transferred to standard tape reels, laboriously cleaned several times with distilled water and dried with lint free absorbent material.

3.4.3.4 Digital Flight Data Recorder

When the recorder was removed from its shipping and storage container, it was noted that there was very little external damage. A cover on the rear section was removed and it was observed that, when viewed from the front of the recorder, the right hand edges of the four rearmost printed circuit cards were displaced towards the front of the recorder. The left hand edges were restrained by plug-in connectors to the boards. The rearmost card, that controls track selection on the tape, and the one in front of it, had bowed along the right-hand edges and popped out of their plastic guides in the top and bottom of the recorder. Deflection of the other two cards had occurred following failure of the attachments of the right hand ends of the plastic guides to the chassis. The damage could have been caused by a high lontitudinal decelaration, as would occur if the front face of the recorder impacted the water.

3.4.3.5 When the tape deck was opened, it was found that the tape was intact but had become dislodged from the last tape guide when the tape was moving in the direction of the odd-numbered tracks and had also jumped out of the adjacent end-of-tape sensor. One edge of the tape had been streteched in this area. The drive belt to the tape transport was still in its correct position. The tape was stuck to the third tape guide in the odd-numbered track direction and suffered some damage when it was finally detached from it. This was repeaired with a splicing tape.

3.4.3.6 The location of the record heads was marked on the back of the tape with a waterproof felt pen. It was noted that there was slightly more tape on the supply reel for the odd tracks than on the other reel. The tape reels and tape were removed from the recorder, keeping the tape wet with distilled water, and the tape transferred to the standard reels for meticulous cleaning. During the cleaning process, it was found that the edge of the tape had also been stretched locally 336 inches down- stream from the splice repair in the odd track direction. The tape was dried by patting it with absorbent lint-free material before loading it into a serviceable recorder as this was the only means by which it could be replayed at the Air India base.

3.4.3.7 The circuit card controlling track selection was removed from the accident recorder and the status of the latching relays checked to determine the last track on which recording was being made. It was found that the relay states indicated Track 1, but since this requires all relays to be set in the same condition, it was considered possible that they had been mechanically set on water impact. The card was subsequently inserted to another recorder and the Track 1 setting confirmed on a test bench.

3.4.3.8 When a change in track selection was attempted, it was found that the relays would not switch, probably due to the effects of salt water corrosion or high water pressure. It was decided that Track 1 would be considered as the most likely one to contain the accident data with the possibility that it could have occurred on any of the other tracks. When the data was recored, the accident information was found some distance past the mid-point of Track 1.

3.4.4. Recovery of Information

3.4.4.1 Cockpit Voice Recorder Tape

The spool was removed from the CVR and was washed with distilled water, dried and loaded on to another spool. The cleaned and dried tape was taken to the Bhabha Atomic Research Centre (BARC), and a copy of the tape was prepared which was used for preparing transcript and carrying out further analysis. The transcript of the CVR conversation is given in Appendix 2.

3.4.4.2 Shannon Air Traffic Control Tape

A copy of this tape that contains all radio communications between the aircraft and Shannon was provided to the Indian Authorities by the Air Traffic Control Authorities, Shannon. The recording also included the short series of unusual sounds that occurred about the time of the accident.

3.4.4.3 When the CVR and the ATC tapes were played it was found that some adjustment in speed was necessary so as to synchronize the two. This adjustment was independently carried out by different experts who analysed the CVR tapes.

3.4.4.4 Digitial Flight Data Recorder Tape

The Lockheed representative had brought a Lockheed Model 235 Copy Recorder from his plant. This unit copies all the 25 hours of data from the recorder by running it at high speed for only two passes of the tape, an operation lasting only 16 minutes. A copy tape was made by this procedure before embarking on the standard Air India recovery procedure to serve as a back-up tape in the event of physical damage to the original tape in subsequent playback.

3.4.4.5 Air India playback equipment for the DFDR required that the tape be re-installed in another DFDR in which it was driven at high speed. In the standard playback procedure, the tape was first run to the beginning of Track 1 through 6 sequentially on to a computer tape followed by a repeat of Track 1. The computer tape was then taken to Air India's main computing facility where selected information was printed out in engineering units.

3.4.4.6 The first printouts showed that the accident was recorded on Track 1, as indicated by the latching relays, and suggested a rather abrupt end to the recording. There was a loss in bit synchronization in word 26 of the last Subframe 3 of data that was followed by a normal Subframe 4. Prior to the loss in bit synchronization, all measurements appeared normal. Plans were made to borrow the high speed oscillograph recorder previously used to studythe final CVR signals from BARC to examine the end of the recorded serial digital signal in detail.

3.4.4.7 Meanwhile, the critical section of the tape and the heads of the playback recorder were re-cleaned and a second transfer of data on to the computer tape was made. Printouts from this computer tape showed no significant difference from the first one.

3.4.4.8 The recorder was then opened and the tape positioned about 1.5 inches before the final resting place of the tape that was clearly indicated by head imprints on the magnetic oxide coating side. A high speed oscillograph record of a few seconds of data was made and visually decoded. It was found that the recorded GMT was 21 hr 16 min. This time corresponded to 15 min or about 333 inches of the tape after start of the oldest recording downstream of the accident.

3.4.4.9 The tape was then re-positioned using a Lockheed analogue playback unit, that had a display of the recorded time and a stopwatch was used to locate the accident timing. Two oscillograph copies of the end of the serial digital data were made, the second one having more data preceding the end. Visual reading of the traces confirmed that recording became erratic and irrecoverable at the end of Word 26 in Subframe 3 at the recorded time of 07 h : 14m : 35s. The erratic signal continued for about 0.27 inches of the tape before switching back to the data recorded 25 hours earlier.

3.4.4.10 Examination of the printouts confirmed a suspicion that the complete Subframe 4 of data following the partial Subframe 3, was data from 32 seconds earlier that had not been cleared from the data buffer in the computer and that Word 26 of the Subframe 3 was the last normal measurement provided by the recorder.

3.4.4.11 The end of recording occurred at the point on the tape at which some damage had been observed during the cleaning process. It was apparent that, after the end of the recording, the tape had run on for 336 inches before finally coming to rest.

3.4.4.12 A copy tape of the DFDR tape was made at Bombay and taken to Ottawa. Data from the accident flight, the preceeding Toronto-to-Montreal flight and part of the cruise conditions of the earlier flight to Toronto were transcribed on to the computer tape. The tape was edited to minimize errors and converted to engineering units using standards calibration. Time histories of all parameters for periods of interest were plotted. In addition, chart records were made of all parameters in raw data form for the total duration of the last lap of the flight.

3.4.4.13 The DFDR read out shows that the aircraft was cruising at an altitude of 31,000 ft. and a computed air speed of 296 knots till it suddently stopped recording at 07:14:35 GMT recorded time.

3.4.5 Reports received by the Court

3.4.5.1 The CVR was taken to B.A.R.C. This tape was played by the CVR group a number of times and hard copies of the time information were also prepared using an ultra violet (UV) Recorder. The group consisted of Mr. Satendra Singh, Regional Controller of Air Safety of D.G.C.A., Mr. S.N. Seshadri of BARC, Mr. Paul C. Turner of NTSB, USA, Mr. John G. Young of NTSB, USA and Mr. P. dE Niverville of CASB, Canada. On 18th July, 1985 this group made the following observations after playing the aforesaid tape (UV recording of CVR is at Fig. 1) :-

"The first visible rising signal volume was observed on channel number three the CAM channel It reaches a maximum in about 50 milliseconds. At this time noticeable disturbances are observable on the other three channels. A smaller disturbance is observable on channels 2 and 4 earlier than observable on channel 1. A major disturbance is observed to begin approx. ninety milliseconds following the initial observation on channel number 3 (CAM), on channels 1,2 and 4. Following this point

at 75 milliseconds the CAM signal subsides to a lower level but much higher than observed ambient (prior to disturbance) where it remains for approximately 375 milliseconds from initiation when it ceases. Channel four goes off at the same time. Channel 1 goes off twenty five milliseconds earlier. Channel two is inconclusive and had a different pattern. All four channels exhibit a disturbance at approx. 450 milliseconds. The cockpit voice recorder power then shuts off at 650 milliseconds.

The Shannon area control centre tape made the night of the accident was examined and printed. It shows a signal was received at approximately the time the aircraft disappeared from radar. It isn't conclusive at this time that the signal originated from the accident aircraft. The signal was received in pulses for approximately five seconds."

3.4.5.2 The tape was again played on 19th July, 1985 and a further report was prepared which was signed by the aforesaid persons and Mr. B. Caiger of NRC, Canada. In this report it was stated as follows:-

"The Shannon area control centre tape was again printed at .05"/second per inch speed from approximately 22 sec. before the first broadcast from the accident aircraft at 0709.58 until Radio carrier with indecipherable modulation can be heard at 0714:01. The print contains a time encoded signal.

A similar print was made from the CVR channel 4 (Co-Pilot's) of the same audio as received on the ATC tape. Although the tape speed is different, the events when corrected for tape speed errors occur at the same time. It appears that the ATC recording contains the beginning of the aircraft breaking until power is lost to the transmitter since channel one and channel four (Capt + Co-pilot's radio) appear to contain a transmitted signal on the CVR. It is probable that the ATC signal at 0714:01 coincides with the final quarter second of CVR radio channels".

3.4.5.3 On the date i.e. 19th July, 1985, Mr. Paul Turner of NTSB also gave an additional report which is to the following effect :-

"During my observations of numerous cockpit voice recorders I have heard and observed a number of aircraft breakages due to various causes. In this case the explosive sound on the CAM channels occurs prior to any electrical disturbance observable on the selector panel signals. Electrical disturbances can generally be seen prior to audio signal when explosive sounds originate at any significant measureable distance from the microphone (15 feet) and in the area where there is significant electrical systems. It is my opinion that an explosive event

occurred close to the cockpit. The CAM signal which follows the explosive event shows a very much higher noice level than cockpit ambient 85 db, indicating to me the cockpit area was penetrated and opened to the atmosphere. The selector panel signals show signatures similar to those of an aircraft breaking up and are apparantly caused by electrical systems disturbance (circuit breaker blowing, fuse switching etc.). The lack of Mayday call and apparent inadvertant signal from the cockpit crew incapacitation. The transmitter coming on due to breakup is phenomena observed previously.
This contains only my personal opinion and in no way should be considered a final determination of cause without corroborating evidence".

3.4.5.4 Copies of the tapes were also sent to some of the participants who wanted to carry out independent analysis.

3.4.5.5 With regard to DFDR the Court received reports from Dr. Caroll Roberts of NTSB and report dated 11th November of Mr. B. Caiger.

3.4.5.6 With regard to CVR the Court received reports from Mr. B. Caiger dated 11th November, 1985, report dated November, 1985 of Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K., report dated 31st August, 1985 of Mr. S.N. Seshadri of BARC, Bombay.

3.4.6 Court Observations

3.4.6.1 Digital Flight Data Recorder

The reports of Dr. Caroll Roberts and Mr. Caiger which also coincide with the report submitted by Mr. Satendra Singh disclose that the DFDR showed no evidence of abnormal values of any of the many parameters being monitored upto a point at which the recorded data signal became irregular for a fraction of a second and recording ceased. Both the DFDR and the CVR stopped at the same time.

3.4.6.2 The short period of irregular digital data that occupied only 0.27 inches of tape, most probably indicates that the recorder was subjected to a sharp angular acceleration in the left wing down sense about the aircraft longitudinal axis.

3.4.6.3 According to Mr. Caiger's report the possibility that the digital recorder was subjected to a sharp disturbance more rapid than violent motion of the aircraft lends some credence to the possibility of a detonatiaon of an explosive device in the aircraft. The other alternative, according to Mr. Caiger, which could have led to this was that the Flight Data Acquisition Unit in the main electronics bay .or its power supply were suddenly disturbed. As the Lockheed Quick Access Recorder was not recovered from the wreckage, this possibility could not be investigated further. A perusal of the DFDR print out, however, shows that whereas there was a speed limit of 290 knots (.81 Mach) of the aircraft due to carriage of the 5th pod engine, in actual fact the aircraft's speed during cruise varied from 287 to 296 knots. Mr. H.S. Khola asked the Boeing Airplane Company to examine the effect of aircraft cruising at a speed of 296 knots with a 5th pod engine installed on it. The Boeing company sent a reply, inter alia, stating as follows:

"The operating speed limit of Air India 747-237B, JT9D-7J with fifth engine pod was 290 knots indicated airspeed, with an altitude limit of 35,200 feet. Flight testing of this model airplane configuration was successfully accomplished to a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, with no adverse effects.

In the event that the operating speed placard was exceeded an increase in perceptible vibration levels would be felt. As the dive Mach number (0.92) is approached the buffet vibration would increase to level that could become objectional to the flight crew, but would not he bazardous".

3.4.6.4 It would thus be clear that if no adverse effects could have been noticed with a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, there was little likelihbood of the aircraft having been subjected to any adverse effect by reason of the speed varying from 287 to 296 knots while it was cruising at a height of about 31,000 feet.

3.4.6.5 Cockpit Voice Recorder

The Court received four reports of the CVR tape analysis. These reports were of Mr. B. Caiger, Mr. R.A. Davis, Mr. S.N. Seshadri and Mr. Paul C. Turner. Whereas the first three experts appeared and deposed in

Court, Mr. Paul Turner did not come.

3.4.6.6. There were certain aspects of the report of Mr. Turner which required clarification. After the Court had failed to secure his presence, it sent a questionnaire to Mr. Turner for his answers thereto. It is indeed unfortunate that till now no reply has been received. It is in this background that the report dated 13th November, 1985 of Mr. Turner and the reports of other experts have to be judged and analysed.

3.4.6.7 Mr. B. Caiger's Report and Deposition

Mr. Caiger has said in his report that the Cockpit Area Microphone signal was studied in detail. According to him, in an aircraft, sound can be transmitted by multiplicity of paths. If an explosive device was located close to the microphone then the short wave from the disturbance would cause a sharp rise in pressure which was not noticed. From more remote location, however, structurally transmitted sounds could reach the microphone first and induce more complex signals. According to Mr. Caiger, at this time he did not have any evidence from occurrences of this nature that would permit any meaningful comparisons or conclusions.

3.4.6.8 Mr. Caiger obtained from the manufacturers details of Automatic Gain Control (AGC) on the cockpit area microphone. According to the information so provided it was indicated that the decrease in amplitude of the recorded noise over about 33 msec after the peak level was reached 40 msec from the start of the disturbance is most probably due to the AGC and that the actual envelope of the pressure levels at the microphone continued to increase until 90 msec from the start before establishing at about four times the recorded level until the 160 msec point when the recorded amplitude started to decrease rapidly. Mr. Caiger could not find any explanation for this marked reduction. Mr. Caiger further recorded that the large amplitude lower frequency signature, that immdediately followed this reduction, is similar to signatures observed by the manufacturer when there was an abrupt break in the line from the cockpit area microphone pre-amplifier output to the voice recorder. No similar signature was observed in tests on the crew audio channels when the appropriate lines to the recorder were similarly

interrupted.
3.4.6.9 The observation of Mr. Caiger with regard to ATC tape was as follows :-
"The ATC recording that followed the cockpit area microphone sounds appears at first to contain a series of short intermittant sounds. Closer study reveals that the background noise only returns to its steady level for about 160 msec immediately after the first low level noise and again for about 85 msec just over halfway through the 5.4 sec duration of the recordings. At the end of all routine radio transmissions, a damped sine wave transmitter keying signature is observed with a frequency in the region of 450 Hz. In the accident recordings, only two of these are observed".
"Listening to the sounds, it also appears that a human cry occurs near the end of the recordings. Spectral analysis of these sounds and comparison with voice limitations reveals that the accident sounds do not contain all the pitch harmonic frequencies normally associated with such voice sounds. The origin of all the sounds has not been identified."
3.4.6.10 From the aforesaid investigation Mr. Caiger concluded that :-
"From the voice and data recorders, Air India Flight 182 was proceeding normally enroute from Montreal to London, England at an altitude of 31,000 feet and a computed airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound the cause of which has not yet been identified. The sound continued for about 0.35 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder".
"The initial waveform of the cockpit area microphone signal is not consistant with the sharp pressure rise expected with detonation of an explosive device close to the flight deck but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, we cannot at this time exclude the possibility that it originated from such a device elsewhere in the aircraft".
"Within 1 to 2 seconds of the first detection of the loud sound on the

cockpit area microphone, a series of unidentified noises were recorded on the Shannon ATC tape. These extended over a period of 5.4 seconds and are assumed to have origniated from VT-EFO. They gave the impression of abnormal conditions on the flight deck".

3.4.6.11 In his evidence in court, Mr. Caiger explained about Automatic Gain Control. He stated that the CAM channel of the CVR had an Automatic Gain Gontrol in a pre-amplifier that is installed close to the microphone. This AGC is designed to prevent excessively loud signals from saturating the microphone and the associated electronics. He further stated that from the tests conducted by the manufacturers it could be concluded that most likely at 45 msec. point the AGC came into effect which gradually reduced the signal over the next 33 msec. before letting it stabilise at a roughly constant value. This figure of 33 msec. was taken by Mr. Caiger not by carrying out any experiment himself but it was provided to him by the manufacturers. He also stated that there was no positive indication of structural failure being evident from the flight recorders. Mr. Caiger was asked to explain as to what was the reason for loud sound to which reference had been made in his report. In answer to the said question from the Court he said that there could be a number of reasons. The detonation of an explosive device not close to the microphone was one possibility, the occurrence of some type of structural failure was another possibility. He was further of the opinion that at the present stage of development in structural acoustics, he did not think it was possible to come up with any reasonable estimate of the location of either explosive device or some type of possible structural failure. When asked for his opinion about the sequence of events which he could determine by looking at the sound spectrum, he said as follows:

"From the study that we have made which have of course been augmented by studies done by several other groups it would appear that there was a very sharp bang that was detected by the CAM. Approximately one-third of a second after this happened the line from the CAM to the CVR was disconnected but intermitant power supply was still being sent to the voice recorder for approximately one and a half seconds. During this 1-1/2 seconds period sounds were being transmitted from the 'Kanishka' aircraft that tend to suggest that the aircraft was in some distress. Though it is difficult to be specific about the basis on which we assesss the state of the aircraft, this signal ceased after a period of 5.4 seconds and we have no more audio information concerning the aircraft from that point onwards."

3.4.6.12 Mr. R.A. Davis's Report and Deposition

Mr. R.A. Davis in his report on the analysis of CVR has stated that he did not have with him a faithful copy of the original CVR tape. The tape supplied to his contained signals which warranted investigation but any measurement could be hampered by a decreased signal to noise ratio due to the copying process. Mr. Davis however analysed the tape which admittedly according to him was not of good quality. Mr. Davis in his report states that he carried out a spectrum analysis of the different channels of the CVR. The spectra did contain the sound of a bang. He however, could not find any significant low frequency content in the spectrum which according to him, would have been expected if the sound was of a high explosive detonation.

3.4.6.13 While carrying out detailed study of the tape he also looked out for any evidence of various audio warning signals which may have been buried in the noise. One such audio warning which could have been detected was that of pressurisation warning. Mr. Davis stated that this warning possessed a very defined frequency spectrum which was not present in the signal of the CVR of Kanishka. With regard to this he, however, stated that absence of this signal was not surprising as any decompression would take a finite time before reaching the warning level. Mr. Davis further observed that the presence of warnings due to attititude display disagreement, excessive speed and fire were investigated but with negative results.

3.4.6.14 During the course of investigations, Mr. Davis had compared Kanishka CVR recording with the recordings of an explosive decompression on a DC-10, a bomb in the freight hold of a B-737 and a gun shot on the flight deck of a B-737. According to Mr. Davis the spectrum of VCR tape of B-737 showed a much low frequency content with very little content at upper frequencies. This bomb, in the forward baggage hold of B-737, had exploded while the aircraft was at a low level and therefore the CVR did not have the sound accompanied with that of depressurization. That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a high explosive device, then the spectra should have shown large low frequency content, but this was absent. He further opined that, even if there was a possibility of a bomb remote from the flight deck and of a low power, even then the characteristics of a bomb would still be apparent in the time record. He also analysed the spectrum of the sound of the hand gun shot on a B-737 flight deck and according to him the said signal was sharp edged and did not compare with that of Kanishka's signal.

3.4.6.15 Mr. Davis also analysed the sounds recorded on the ATC tape. He concluded that the sounds emanated from Air India's Kanishka aircraft. According to him the transmission from the ATC is "chopped" until at approximately 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound was similar to that heard in other accidents where there had been a rapid increase in airspeed.

In the noise which continues until the end of the transmission is heard a crying sound. This was originally thought to be a human cry. He, however, noted that a human cry would contain more harmonics than was noticed in this case. It was also reported by Mr. Davis that knocking sounds which were heard during the transmission were initially thought to be due to hand-held microphone vibration. This was discounted because of the frequency of the sounds. He noticed that almost identical sounds were heard on the DC-10 CVR after the decompression had occured and the source of that sound had not been identified. On the DC-10 the pressurization audio warning commenced 2.2 seconds after the decompression. Analysing the ATC tape Mr. Davis observed that no such warning was identified during the open microphone transmission.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-

"It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182.

"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.

"Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. Such a situation would be most unusual, if not unique, in that we have never failed to detect sounds of structural failure, decompression, explosives etc., on any accident CVR, even though the event occurred at the rear of the aircraft. If such a device was used on AI 182 it is considered that it would have to be a very small device in order not to be detected (unlikely in itself). Such a device would be unlikely to cause the sudden total destruction which occurred in this instance. It is considered that a device of sufficient power to produce this effect could not fail to be detected on the CVR. The B-747 explosions referred to earlier, blew holes several feet wide in the structure but the crew were still able to control and operate the aircraft.

"It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

3.4.6.17 In reply to a question it was stated by Mr. Davis, when he was examined in Court, that it was true that there was no evidence that rapid decompression was caused by any structural failure. In an answer to another question, as to whether in his opinion there is a low frequency content present in every situation whereever there has been a high explosive device detonated, Mr. Davis answered in the affirmative, he however added that "But we do not have sufficient numbers to indicate that that would always be the case". Mr. Davis, however, agreed that DC-10 aircraft was quite dissimilar to Boeing 747, and the sound of an explosive decompression in the aft cargo hold of a DC-10 would not be identical to an explosive decompression in the aft cargo hold of a Boeing 747.

3.4.6.18 Mr. Davis further agreed that he was looking for low frequencies in Kanishka tape, but he did not know what type of low frequencies should be looked out for because there was no available data anywhere in the world for the sound of a bomb explosion in a Boeing 747. Mr. Davis was however emphatic in saying that he could not measure the distance of the origin of the sound from the cockpit area mike. In his report, and also in the earlier part of the examination, Mr. Davis had referred to the absence of low frequency component in the spectrum and had sought to conclude that such absence showed that there was no detonation of a high explosive device. In an answer to the question put by the Court however, Mr. Davis appeared to have altered his stand. This is evident from the following deposition of Mr. Davis :-

"Court Ques Am I to understand that there must necessarily be a low frequency whenever an explosion occurs?

Ans. No. What we thought was there would be. There was only one sample of explosion in B-737. But we would need more accidents of that nature to able to say that yes we must have a low frequency component.

Court Ques: Am I to understand that the absence of a low frequency component would not therefore necessarily mean that the sound was not that of an explosion?

Ans. Because of the absence of a low frequency component we would not be able to say positively that there was an explosion or it was not explosion."

Court Ques : Would the frequency of a particular type of sound change depending upon the environment in which that sound occurs?

Ans Yes.

Court Ques If an event results in low frequency sounds in one type of environment, can it mean that the same event can result in a high frequency sound in a different environment?

Ans. That must be possible".

3.4.6.19 Mr. S.N. Seshadri's Report and Deposition

A detailed analysis of the CVR and the ATC tapes was also carried out by Mr. S.N. Seshadri at BARC. For the purposes of comparison, CVR tapes of Iranian Air Force Boeing 747 accident as well as that of Indian Airlines Boeing 737 accident were also analysed at BARC.

3.4.6.20 The original CVR tape of Kanishka was played on a 4 channel tape recorder modified to run at 1-7/8" per second. The output of this tape recorder was copied faithfully on an eight channel HP 3968A instrumentation tape recorder. Channels 1 to 4 were used for recording the CVR data and channels 5 for recording a time marker. For further processing and signal analysis this copy of the original tape was used.

3.4.6.21 The observations of the data so recorded, as contained in the said report inter-alia are as follows :

"Repeated and careful listening to all the four channels revealed the presence of explosive sounds on all these channels occuring nearly at the end at the same time. Speech information is present on channels 3 and 4 during the last few minutes. Channel 1 does not contain any speech data during this period. Channel 2 contains indecipherable speech data about 20 to 25 seconds before the explosive sound".

"It was decided to analyse in detail the tape data during the final few seconds within which significant audio and electrical changes were observed to be present. Data from all the four channels were displayed on a Tektronix 2-channel storage oscilloscope Model 466 for initial observations. Based on this study the relevant portion of the tape was selected for more intensive snalysis. Simultanious ultraviolet recording of all the four channels on this portion of the tape was next carried out".

The following observations are relevant.

1. Channel 3, which corresponds to the area mike shows the first indication of a rising audio signal. This instant is termed, for conveniece, as zero time reference. The signal level rises from the ambient level in the cockpit by about 18.5 db in approximately 45 milliseconds. The signal then starts falling and stablises at a level about 10 db higher than the ambient level before zero time. The signal continues to remain at this level for about 275 milliseconds. The total duration of the signal from zero reference is thus about 360 milliseconds.

2. Channels 1 and 2, which are the radio channels of the pilot and the flight engineer respectively, show start of electrical disturbance signals 45 milliseconds from zero time at which the audio signal on channel 3 is at its maximum. These signals, which have do minant frequencies in the range of 70 to 210 Hz, persist for about 100 milliseconds on both channels. Subsequent to this, channel 1, shows an audio burst lasting about 200 milliseconds. Channel 2 shows a delayed audio burst lasting 25 milliseconds, 220 milliseconds from zero time, or in other words, 175 milliseconds after the peak signal from channel 3. A low amplitude tail appears after this burst and lasts around 40 milliseconds. Channel 4 which is the co-pilot's radio channel shows an electrical disturbance commencing at 85 milliseconds from zero time and lasting around 60 milliseconds. The frequency distribution during this period is similar to those on channels 1 and 2. This is followed
by an audio burst of 230 milliseconds duration. The frequency spectra of the audio portions of channels 1,2 and 4 are reasonably similar."

3.4.6.22 "Correlation of Events of ATC Shannon Tape and Channel 4 of CVR tape :

"It was observed that during the last few minutes before the stoppage of the CVR, information recorded on the ATC tape and channel 4 of the CVR tape are identical. However, the ATC tape contains a series of audio bursts approximately corresponding to the instant at which a single explosive sound is recorded on channel 4. Thus a doubt arose whether the series of audio bursts recorded on the ATC tape had originated from channel 4 of Kanishka CVR since these are not recorded on the CVR tape. In order to obtain an answer to this it was necessary to check with very good accuracy the simultaneity of the explosive sound on channel 4 and the series of audio bursts on the ATC. The procedure followed for the same is given below.

"The ATC Shannon tape and the CVR tape were run on two independent tape recorders. It was found that the speeds of the two tapes were mismatched. In order to match speeds the earliest speech signal on both the tapes.

"Seven seventy that checks maintain three five zero" was used as the

reference point. The speech signals which mostly contain the conversation between the co-pilot and ATC Shannon lasts for about 146 seconds. Channel four was kept ready for starting exactly at the reference point. The ATC was next played starting well before the reference point. The tape recorder playing channel 4 was started manually exactly at the time when the reference point on the ATC was audible. By noting the time of ending of the conversation on both the tapes which corresponds to
"Right Sir squaking two zero zero five one eight two" the speed of the recorder playing the ATC tape was corrected by pitch control to approach the speed of CVR tape. The process was repeated a number of times till audibly the speeds were matched. The two tapes were next synchronously played and both the channels were simultaneously recorded on a third recorder to a point well after the explosive sound on channel 4. This tape was used for all further analysis.

"The first significant observation was that the explosive sound on channel 4 coincided with the beginning of the series of audio bursts on the ATC tape as heard by the ear. It was thus clear that both the recordings correspond to those generated by Kanishka during its last moments.

"To confirm this preliminary conclusion which was judged solely by the ear, accurate instrumented tests were carried out. The two channels were simultaneously recorded on an ultraviolet recorder at the four speeds, 0.1"/sec, 1"/sec, 10"/sec and 160"/sec for study of synchronism as well as frequency details. It was noticed that the two waveforms were not exactly suynchronised though by the ear they appeared to be so. In order to find out exactly the difference in synchronisation the following tests were done:

UV recordings at 16" per second were taken at three representative points relating to the communication of ATC with Kanishka. These points correspond to speech portions at 070838 "Five eh Squawking and eh Air India", at 070958 "Right Sir Squawking" and near the blast on channel 4. It was found that the ATC was running slightly faster. At the first point the ATC was leading by 90 milliseconds, and at the second point by 130 milliseconds. The time interval between these points is about 80 sec. By extrapolating this lead to the time of the blast which occurs about 243 sec. from the second point, it is clear that the lead of the ATC with respect to channel 4 at this point will be given by 130 + (130-90) (243/80) which is approximately 250 milliseconds. This error is very small."

"Thus one can conclude that the sounds recorded on the ATC Shannon tape are those which emanated from Kanishka during its last seconds."

3.4.6.23 "Frequency Analysis:

Mr. Seshadri also carried out frequency analysis of the CVR and the ATC tapes. His opinion with regard to the same was the follows:

"Significant audio and electrical disturbances were observed in the final few seconds of the CVR tape. It was therefore decided to analyse all the four channels for their frequency contents at the various places in this pertinent region. For Fourier analysis of each signal, digitized time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

3.4.6.24 "The frequency analysis of electrical disturbances in channels 1,2 and 4 indicate presence of low frequencies in the region of 20 Hz to 600 Hz. The dominant frequencies are in the range of 70 Hz to 210 Hz.

3.4.6.25 "The frequency spectrum of the background noise in channel 3 just before the explosive sound has a broad band spectrum with some dominant frequencies in the region of 650 Hz to 1550 Hz. At the bang, many additional frequencies appear. The frequency spectrum of bang on channel 3 indicates an increase in the bandwidth.

3.4.6.26 "The frequency spectrum of channel 1 at the bang position indicates a fairly broad spectrum with dominant frequencies in the range of 150 Hz to 1 KHz. Channel 2 displays a frequency spectrum at the bang position in which low frequencies are dominant. It has a significant frequency range between 20 Hz to about 1 KHz. The frequency spectrum of channel 4 at the bang is wide-band with a broad peak in the range of 150 Hz to 800 Hz.

3.4.6.27 "At the beginning of the crackling sound, the frequency spectrum shows narrow band peaks around 1.6 KHz. About 90 and 300 milliseconds later, the spectrum changes with additional peaks appearing around 400 Hz, 600 Hz and 1150 Hz. Frequency analysis was also carried out at 600, 800 and 1000 milliseconds before the start of the crackling sound."

3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

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3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal peaks to its maximum of 18.5 db above ambient level in about 45 milliseconds. A loud audible blast is heard when this channel is played at this point. An analysis of the frequency spectra before this loud blast and during the blast shows a definite change in the frequency composition. From all the above results it can be concluded that an explosion occurred in the aircraft. The exact position in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the Cockpit judging from the rise time of 45 milliseconds.

3.4.6.29 "Explosive sounds on all the four radio channels preceded by electrical disturbance reinforce the evidence provided by channel 3.

3.4.6.30 The synchronised recording and detailed analysis of the ATC and channel 4 confirm that the sounds recorded in the ATC Shannon tape are undoubtedly attributable to the transmissions from AI 182 Kanishka during its last moments. The sounds indicate possible breaking up of the aircraft in mid air and the air blast which follows a decompression. A very detailed UV recording does not indicate the presence of a second explosion."

3.4.6.31 "Copies of CVR tapes of well understood air crashes pertaining to an Indian Airlines Boeing 737 in 1979 and Iranian Air Force Boeing 747 in 1976 were analysed for possible reference in connection with the analysis of the CVR tape of Kanishka.

3.4.6.32 "A definite explosion near the Cockpit was the cause of the crash of the Indian Airlines Boeing 737. An explosive sound recorded on the Cockpit Area Mike shows a rise time of about 8 milliseconds which corresponds to a distance of about 8 feet. This indicates that the rise time is a measure of the distance from the Cockpit Area Mike at which an explosion has occurred.

3.4.6.33 "The Iranian Air Force Boeing 747 broke up in mid air. Analysis of the CVR tape clearly indicates that the frequency spectra of the electrical disturbances are similar to those obtained for Kanishka. Thus the series of audio bursts recorded on the ATC Shannon tape have been most probably generated by the break-up of kanishka in midair.

3.4.6.34 Mr. Seshadri was also examined in Court on 27th January, 1986. In his deposition he very succintly explained some aspects of the work which was done by him. He also dealt with the aspect of AGC to which reference has been made by Mr. R.A. Davis and Mr. Paul Turner in their reports. The relevant part of the testimony in this connection is as follows :-

"We wanted to make sure that the CVR recording and the ATC corresponded to the same aircraft Kanishka. When we played the tapes for the first time we found that there was a difference of about 1 second. Though this figure may be tolerable because of the accuracy of the tape speeds, we wanted to investigate further to make really sure that the ATC corresponded to Kanishka. For this purpose we had simultaneously "recorded channel 4 of the CVR and the ATC on a single tape on 2 channels after synchronising the common speech signals to the best of our ability by the ear. We started with the first speech which was available on both the tapes, namely, "770 that checks maintain 350". This was a conversation with the TWA aircraft which is available on both channel 4 and the ATC. The last sound which is recorded common to CVR and ATC is the speech of the co-pilot who says "right Sir, squaking 2005 182". After this recording though by the ear the explosive sounds on the ATC. as well as the CVR seemed to match, we wanted to check it in more detail. For this purpose we had detailed UV recordings of different portions of the synchronised tapes pertaining to the conversation between ATC and Kanishka. This was done and we noticed that the ATC was running slightly fast. We had about 80 seconds reference time of conservation from Air India Boeing Kanishka and the ATC for reference and we had to extrapolate the information in this section for another 243 seconds at which time the explosive sound occurs. During the beginning of this 80 seconds reference period, we find that the ATC was leading by 90 milli-seconds and at the end of 80 seconds the lead of ATC was 130 milli-seconds. Thus, in 80 seconds, the ATC had gained 40 milliseconds.

"This extrapolated to 243 seconds and gives a figure of 250milliseconds. This is how we arrived at the conclusion that both are synchronised within 250 milliseconds. I would like to bring to the notice of the Court that we have taken great pains to confirm this information by reapeating the tests a number of times. We did not take the 400 cycle signal available on the tape as the time reference. We took for reference the bunching of signals produced by the conversation and the gaps in between the convervation which are very clear on both tapes. Hence we are sure that our results are right. The UV recording which was made has been filed along with my report.

"The main channel which was examined was the CAM channel. This was agreed to by all the experts who were present during the first analysis of the tape at the BARC between 16th and 20th July, 1985. One of the most noticeable things is that channel 3 which corresponds to cockpit area shows the first sign of disturbance. Let us say for reference that the disturbance starts at 0 time. In about 45 milliseconds the signal rises to a peak value which is approximately 18.5 db above the ambient level before the commencement of the signal. After this point the signal decays roughly exponentially in about 40 milliseconds to be almost a steady level which is 10 db above the ambient level before the explosive sound. From this we could draw conclusions. Assuming that an explosion occurred on the aircraft. The explosion produces a shock wave with a steep wave front which travels in air as well as through the aluminium body and the speed of travel will depend upon the distance of the explosive from the point of observation. It will depend on the cube root of the explosive and it will also depend on the ratio of the distance to the cube root of the weight of the explosive. The shock wave is very fast. It can travel at about 10 times the speed of sound. Also when the shock wave hits the aluminium body of the aircraft the vibrating panels which are defined by the stringers and longerons transmit the sound to the CAM location. Because the speed of sound in aluminium is about 19,200 feet per second which is 16 to 18 times that of the speed of sound in air and the shock velocity is also about 10 to 12 times. This signal will be received

"first by the CAM. Nevertheless the shock wave gets attenuated diffracted and refracted during its travels to the cockpit. Hence the signal received at the cockpit will be an attenuated signal and this small signal we have taken as instantaneous with the time of explosion. As the time passes the sound waves travel from the explosion site reinforcing the sound in the cockpit area thereby there is a rise time. Then when all the complete sound information is transmitted we get the peak of the signal and thus the rise time corresponds to the delay between the first rise in signal to the peak as compared to the speed of sound. One may ask the question what is the speed of sound because the aircraft has an explosion and is exposed to the outside environment but since the de-pressurization of the aircraft through the explosive fracture will take a minimum of a few seconds, we can reasonably assume that the pressure of the air in the aircraft corresponds to about 5000 to 6000 feet of altitude. At this presure and temperature, the sound velocity is roughly 1000 feet per second and from the 45 milliseconds delay we concluded that the explosion should have occurred about 40 to 50 feet from the cockpit. A question may be asked that the decay of the signal might be due to the AGC of the CVR coming into action. Mr. Turner, who is an acknowledged expert in the field of CVR has reported that Messrs Fairchild tested the cockpit voice recorders with a 10 db rise and fall of signals at the threshold of AGC and they got a result indicating a decay time of 33 milliseconds. The fall in the waveform of Channel 3 is about 40 milliseconds and is well near 33 milliseconds, so an argument may be advanced that the sound continued to remain steady and the fall in the signal level was effected by the AGC. In order to confirm this we tested the Cockpit Voice Recorder which was identical to the one which was on Kanishka by applying 1 KHz waveform of rectuangular modulation. To our surprise, we found that the decay time roughly was 130 milliseconds as compared to 33 milliseconds given by Mr. Turner. We repeated the tests with an initial background and without any background at all. We further tested with ramp waveforms, in other words, "slowly rising and falling waveforms of triangular shape with modulations of 1000 cycle carrier. This also confirms our finding. In order to clarify how the tests were performed so that others can judge whether it was a realistic test, I will explain the procedure. The modulated waveform was produced by a signal generator. This was fed to an amplifier. The amplifier output was fed to a loudspeaker. The output of the amplifier was checked to ensure that there was no distortion. Thus the signal going into the loudspeaker is the same modulated signal which has been applied at the input of the amplifier. This sound coming from the loudspeaker was recorded on the CVR through the CAM in the laboratory. This is how the test was performed. We were given a CVR tape by the Department of Civil Aviation purported to be that of an explosion which occurred on a Boeing 737 aircraft which crash- landed at Madras. We did the CVR analysis of this aircraft. We first recorded the output of the CVR of Indian Airlines CAM channel on a UV recorder. We found the rise time to be very small. This was of the order of a few milliseconds, about 8 milliseconds or so. We have been told that the explosion occurred just by the side of the front toilet i.e. just behind the cockpit. This to some extent confirms that the rise time is related to the distance of the explosion from the detecting CAM. The next thing that we did was the frequency analysis of this waveform. Mr. Davis has indicated in his report that if an explosion occurs on board the aircraft there should be low frequencies present. When we analysed the frequencies of the Kaniskha aircraft Channel 3, we did not find very low frequencies in case of an explosion abroad the aircraft. When we analysed the Boeing 737 tape we did not find any low frequencies in the signals. The report of Mr. Davis also provides the frequency analysis of a pistol shot which has been fired in the cockpit of the aeroplane. This also shows no low frequency components. So our conclusion, that it is not essential for low frequencies to be present in case of an explosion abroad an aircraft, was confirmed. I will go a step further to say that the frequency received by an area mike which responds to an explosive action abroad the aircraft will contain frequencies of the structure of the defracted " and dragging shock wave, the resonant frequencies of the aluminium panels defined by the longerons and the stiffening channel members and also some frequencies which may be of objects that the shock wave encounters in its path. It is, therefore, impossible to calculate the frequency spectrum that one would expect in the cockpit due to an explosion taking place in the aircraft".

3.4.6.35 In answer to a question Mr. Seshadri categorically stated that the word "explosion" in his report meant "a bomb, a very fast device".

3.4.6.36 Mr. Paul C. Turner's Report

Lastly, a reference may be made to the report dated 13th November, 1985 of Mr. Paul C. Turner. The evaluation of Mr. Turner of the analysis done by him of the CVR and the ATC tapes, as contained in the said report, was as follows:-

"With the foregoing as background, we can make several observations. The CVR record on the CAM channel, captain's channel and flight engineer's channel show that they were all affected at about the same time; the copilot's perhaps 20 milliseconds later. Major disturbances which are recognized as electrical system disturbances can be seen to begin about 60 milliseconds after the initial disturbance. This approximates the time it would take for the electrical system protective circuitry to become active.

3.4.6.37 "A steep wave front which would be indicative of a shock wave cannot be seen on the CAM channel sound spectrum; however, the spectrum analaysis shows that impulse type sounds occurred at the beginning of the event recorded on the CAM channel of the CVR. Since audio signals propagate through aluminium approximately 16 times the speed of sound in air, the CAM channel would probably have been affected by structurally transmitted noise before being affected by airborne noise. The geometry of the aircraft was such that structure borne disturbances could be recorded before the airborne transmitted information appeared at the cockpit microphone and an air transmitted shock wave or steep wave front may not be evident on the CVR.

3.4.6.38 The captain's and copilot's selector box channels recorded signals which appeared to be electrically inducted and similar to those seen on the Huete Boeing 747 breakups. These are then followed by a signal resembling audio frequency noises similar to an open microphone in a noisy environment or the opening of a receiver squelch. Both effects have been seen during aircraft breakups. The audio noise on the captain's and copilot's channels appears to have come from a different source. The flight engineer's channel does not contain audio noise. A spectral diagram of the copilot's and captain's channel noises just show broad band noise across the spectrum. The signal frequncies extend beyond the frequency range of a microphone both on the high and the low end. It does not fit the normal microphone envelope. Spectral diagrams of the event on the CAM channel show the normal microphone preamplifier envelope summed with wide band signal of unspecified origin. Since the signal quits abruptly with a doublet, it indicates that the interference was added upstream of the CVR and was not just reflected in the CVR power supply.

3.4.6.39 "The CVR record shows a signal stayed on for about 200 milliseconds when it appears that the power may have been interrupted to both the radio channel and the CAM channel of the CVR at the same time. It further appears that the signals to the CVR were probably interrupted at 360 milliseconds from the initial disturbance possibly by severance of the signal wires. It further appears from the action of the erase head and record that the main electrical system began to fail at this point and the CVR bus voltage value dropped to a value below 70 volts but not below 20 volts. This fluctuating voltage continued intermittently for a minimum of 1-1/4 seconds at which time the voltage evidently dropped to some value below 20 volts and the recorder ceased to operate. The power for operation of the No. 1 VHF transmitter can be explained by the operation of the standby bus and battery and connection of the No. 1 VHF radio to this standby bus.

3.4.6.40 "The necking down of the signal to a low value shows that no signal was coming to the CVR from the CAM preamplifier. The lack of a signal on the radio channels, which do not need to be erased before being recorded, further suggest that the wires were severed or "that the transmission to Cork began after what appeared to be the loss of the primary electrical system approximately 1-1/2 seconds following the event. Standby power would have become available upon loss of the primary power, the number one VHF would have become available, and CVR would have ceased to operate.

3.4.6.41 "The action of the erase circuitry in the CVR suggests that the fluctuating voltage seen was coming from the main electrical system bus. Anything else causing this fluctuating voltage down stream of the CVR circuit breaker would probably blow it.

3.4.6.42 "The signal received in Ireland indicated that a radio, most probably this aircraft's No. 1 VHF transmitter, stayed operational for about 5.4 seconds following the event at which time the entire aircraft electrical system ceased to function. This assumes that the No. 1 transmitter ceased to operate due to standby bus failure.

3.4.6.43 "In the conclusion, it appears that a catastrophic event occurred on Kanishka. It was reflected in all channels of the CVR and the CVR power supply at the same time. The main electrical bus began to fail within 0.35 second and the standby bus survived for only 6 seconds more at which time the aircraft's electrical system ceased to function. It appears that the event occurred in a manner to affect the cockpit area microphone operation severely and to force operation of the automatic gain control on the CVR. This loud noise continued for the life of the aircraft's main electrical system as reflected in the CVR.

3.4.6.44 "The mechanism of how the ATC transmission was made from Kanishka to Cork is unclear. The sound was not recorded on the CVR, indepentent studies by Canadian and British investigators have the Cork ATC call originating approximately 1-1/2 seconds following the event on the CVR. This is about the time that standby power would have become available to the No. 1 VHF.

3.4.6.45 "This report should be viewed as an accident investigation tool only and used in conjunction with other evidence gathered during the investigation.

3.4.6.46 "The United States Noard/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

3.4.6.47 It is pertinent to note that according to Mr. Turner there was "catastrophic event" which had occurrred on Kanishka. He has, however, not elucidated as to what this event was.

3.4.6.48 After the receipt of the report, the Court requested the NTSB that Mr. Turner should come and depose. It is unfortunate that permission was not granted to him. Faced with this situation and as it was thought necessary that some clarification was called for, the Court sent a telex to Mr. Turner whereby he was asked to give replies to the queries contained therein. He was requested that the reply be sent by 27th January 1986. A copy of the telex was also forwarded to the American Embassy at New Delhi for sending the same to NTSB by way of confirmation. Previously all communications addressed to NTSB were being routed through American Embassy. No reply has been received by the Court till this day either from NTSB or from Mr. Paul Turner. According to paragraph 5.14 of Annex 13 the State is required, on request from the State conducting the investigation of an accident, to provide to that State with all the relevant information available to it. It was, therefore, obligatory on the NTSB to have seen that the information sought for by the Court by way of answers to the queries was supplied.

3.4.6.49 Court Evaluation

From the reports of all the experts and the testimonies of M/s Caiger, Davis and Seshadri it is clear, and it is agreed to by all of them, that there was a breakup of the aircraft in mid-air. The experts also agreed that the sounds recorded on the ATC Shannon tape at 0714:01 Z emanated from the Kanishka aircraft.

3.4.6.50 Mr. Caiger has not said either in the report or in his statement as to what was the cause of the bang. Mr. Davis, on the other hand, is categorical in stating in his report that there was explosive decompression (meaning rapid decompression) on the aircraft. He has, however,
stated in the report that there is no evidence of an explosive device. The

main reason for his coming to this conclusion is that he had not been able to find low frequencies in the spectra of the CVR of Kanishka. Mr. Seshadri, on the other hand is equally vehement in concluding that an explosive device had detonated in the front cargo hold of Kanishka.

3.4.6.51 It may be that the frequency spectrum of Kanishka CVR did not contain low frequencies but, as has been admitted by Mr. Davis himself in answer to a Court question, it is not necessary that in the case of every detonation there must necessarily be low frequencies in the spectrum. Frequency spectra of 'Kanishka CVR before 'bang' and at the 'bang' position are shown in Figs. 2 & 3, indicating presence of additional high frequncies at the bang. Indeed in the case of Indian Airlines Boeing 737, which admittedly was a case where there was an explosion of a device within about 8 feet of the CAM, the frequency analysis showed absence of low frequencies. Frequency spectrum of Indian Airlines Boeing 737 CVR is shown at Fig. 4. Merely, because therefore, there were no low frequencies present would not mean that there was no detonating device on board the Kanishka. The CVR of Indian Airlines Boeing 737 has not been analysed either by Mr. Caiger or Mr. Davis. The analysis was, however, conducted by Mr. Seshadri and as is evident from his report, there were marked similarities between the spectra of Indian Airlines 737 and Air India's Kanishka CVR. One of the important reasons for coming to this conclusion, which has been indicated by Mr. Seshadri, is the rise time of the bang signal. From the analysis of the Indian Airlines Boeing 737 tape it was observed that it had taken 8 milliseconds for the peak to be reached. It was also seen that the explosive device was approximately 8 feet away from the cockpit area mike. Keeping this in view Mr. Seshadri observed that in the case of Kanishka the peak of the bang signal was reached in about 40 milliseconds. He, therefore, concluded that the origin of the bang sound was about 40 feet away from the cockpit area mike.

3.4.6.52 It would be pertinent to note that even according to the report of Mr. Davis the rise time in the case of Kanishka, which has been given for the peak is about 40 milliseconds. He, however, does not attach much importance to this because according to him after about 40 ms automatic gain control would become effective.

3.4.6.53 Mr. Davis has no personal experience of the time which it would take for the Automatic Gain Control to take effect. He has got the figures from the manufacturer. Mr. Davis admitted that the time which it will take for the AGC to be effective is not indicated in any published document of the manufacturer.

3.4.6.54 Mr. Seshadri, however, personally carried out the experiments on a Boeing 747 by using an instrument similar to what was on board Kanishka. From the testimony of Mr. Seshadri it is apparent that the results which he got were different. As per his testimony, for the AGC to be effective it will take 130 ms. If this be so then it may be possible to conclude that in the case of Kanishka the peak was reached in 40 ms. and thereafter the signal decayed and the signal was in no way effected by the AGC.

3.4.6.55 A reference may also be made, at this stage, the frequency spectrum of the sound of the hand gun which was fired on a boeing 737 flight deck. Frequency spectrum prepared by Mr. R.A. Davis is shown at Fig. 5. He has stated that the rise time for reaching the peak is almost instantaneous. Same is the case with regard to the frequency spectrum prepared by him of a bomb in a B-737 aircraft where the bomb had been placed in the freight hold which is shown in Fig. 6. A perusal of that spectrum also shows that the peak was reached in approximately 5 ms. The forward freight hold compartment of Boeing 737 is much more than five feet away from the cockpit area mike. If the theory of Mr. Seshadri was to be applied then as per the frequency analysis of this Boeing 737 bomb, the distance from the area mike could not have been more than 5 ft. It is, however, known, as per the report of Davis, that the bomb was actually in the freight hold which would mean not nearer than about 25 feet.

3.4.6.56 From what has been stated in the various reports, as well as in the testimony of the 3 experts who apperared in the Court, the only safe conclusion which can be drawn is that possibly enough study has not been done, due to lack of adequate data, which can lead one to the conclusion as to the exact nature of the sound and the distance from which it originated.

3.4.6.57 The fact that a bang was heard is evident to the ear when the CVR as well as the ATC tapes are played. The bang could have been caused by a rapid decompression but it could also have been caused by an explsoive device. One fact which has, however, to be noticed is that the sound from the explosion must necessarily emanate a few milliseconds or seconds earlier than the sound of rapid decompression because the explosion must necessarily occur before a hole is made, which results in decompression. In the event of there being an explosive detonation then the sound from there must reach the area mike first before the sound of decompression is received by it. The sound may travel either through the air or through the structure of the aircraft, but if there is no explosion of a device, but there is nevertheless an explosive decompression for some other reason, then it is that sound which will reach the area mike. To my mind it will be difficult to say, merely by looking at the spectra of the sound, that the bang recorded on the CVR tape was from an explosive device.

3.4.6.58 There are various hypothesis and theories which the experts have to investigate before any acceptable conclusions are arrived at. It so happens that in the present case we have the opinions of four experts, but they do not agree with one another on some material aspects. Two of the experts, namely, Mr. Caiger and Mr. Davis are categorical in saying that it is not possible to measure the distance of the origin of the sound on the cockpit area mike, whereas Mr. Seshadri has come to a different conclusion. Mr. Paul Turner in his report dated 13th November, 1985 in silent on this aspect, though in his earlier report dated 19th July, 1985 he had categorically said that there was an explosive device close to the cockpit.

3.4.6.59 With regard to the nature of the sound also we have 3 different opinions. Mr. Caiger is unable to give the nature of the sound, Mr. Davis says it is rapid decompression while Mr. Seshadri says it is a sound of an explosive device followed by decompression.

3.4.6.60 In the absence of any other technical literature on the subject, it is not possible for this Court to come to the conclusion as to which of the Experts is right. The only conclusion which can, however, be arrived at is that the aircraft had broken in midair and that there has been a rapid decompression in the aircraft. Just as it is not possible to say that the spectrum discloses that the bang is due to an explosive device similarly, and as has also been admitted by Mr. Caiger and Mr. Davis, it is not possible to say that the bang is due to break up of a structure.

3.4.6.61 The bang could have been due to either of the aforesaid two causes i.e. a bomb explosion or the sound emanating due to rapid decompression. The advantage of carrying out the said analysis is that a number of possible causes of the accident are eliminated. On the other hand, if the analysis is viewed in conjunction with other evidence on the record it is further possible to determine the exact nature or cause of the bang. In the present case the bang, as already noticed, could have been due to the sound originating from the detonation of a device or by reason of rapid decompression. Other evidence on the record, however, clearly indicates that the accident occurred due to a bomb having exploded in the forward cargo hold of Kanishka. The spectra analysis and the conclusions of Mr. S.N. Seshadri are corroborated by other evidence.

TESTS AND RESEARCH

3.5.1 During the course of investigation a number of groups were formed to study and analyse evidence and data which was available. Materials like CVR, ATC and DFDR tapes were also given to the various participants.

3.5.2 The groups as well as other experts studied and analysed the material with them and submitted their reports which have been referred to earlier.

3.5.3 The experts examining the CVR tapes did carry out a number of tests. Different graphs and traces were prepared and the sound was analysed by them. The result of their analysis has been referred to in Chapter 3.4 on Flight Recorders.

3.5.4. The metallurgical examination of some of the recovered pieces was carried out at BARC. The examination of some of the pieces showed different types of damages having been recorded on the targets such as petalling and curling round the holes, spikes etc. The said team carried out certain explosion experiments. Their report on the experiments so carried out has already been set-out in paragraph 3.2 above.

3.5.5 The Indian Air Force has set up an Institute of Aviation Medicine at Bangalore. The Court visited the said Institute on 9th December 1985. During that visit an experiment was conducted in the explosive decompression and high altitude chamber to demonstrate what actually happens during explosive decompression and subsequently on exposure to hypoxia.

3.5.6 Subjects were taken to 8,000 feet in the explosive decompression chamber with oxygen. They were exposed to an altitude of 25,000 feet within one second. During the course of this explosion a loud bang was heard and inside the chamber there was misting and drop in temperature. After this the chamber was allowed to run at 22,000 feet for roughly two minutes and an experiment to show the adverse affects of hypoxia on the subjects was done. In this experiment, subjects were asked to write a given sentence while their oxygen supply was cut off. It was observed that initially the subjects kept on writing the sentence correctly and then

after about 120 seconds they started making errors while writing the sentence and finally they stopped writing. At this stage oxygen was re-started and within a few seconds, the subjects started writing their sentence once again. The experiment was completed at this stage and the altitude chamber was brought down to ground level.

3.5.7 The subjects were taken out and were asked questions as to what did they feel. They explained that at the time of explosive decompression, they heard a loud bang, felt cold and saw misting inside the chamber. They also found air escaping from their lungs. On further enquiry about the experiment pertaining to hypoxia, they said that they felt light headed and after that they did not know what happened till they once again noticed that they were writing on a piece of paper.

SECURITY

3.6.1 The evidence and the statements filed on record show that Canadian Security arrangements in place prior to 23rd June, 1985 met the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand baggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

3.6.2 Air India, as required by Canadian regulation, had a security programme. Because of the threat level assessed against the Airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and had received and arranged for extra security for the month of June, 1985. For Air India flight 181/182, Air India provided a security officer from its New York Office to oversee the security at Toronto and Montreal.

3.6.3 As it became apparent during the course of investigation that security would be an important aspect whilch would require the attention of the Court, Mr. Rodney Wallis, Director, Facilitation and Security, International Air Transport Association was good enough to appear in Court on 24th January, 1986. His testimony on certain aspects of security was recorded in camera by the Court on that date. The expert evidence has been taken into consideration while formulating some of the recommendations.

INTERNATIONAL COOPERATION

3.7.1 The manner in which persons and organisations from five different countries combined their resources and efforts in connection with this accident is an object lesson in international cooperation.

3.7.2 From the time the accident occurred, till the conclusion of the investigation proceedings by the Court in Delhi, there has been a consistent interplay amongst different persons and organisations. When all the persons got together, for the first time, at Cork the group was very heterogeneous. Each one had his own point of view, which did not necessarily coincide with that of another. At times, the atmosphere was

charged with a bit of tension which continued even when the Court was constituted to investigate into the accident.
3.7.3 It was noticed that not only were the participants a bit apprehensive and suspicious but, during the course of investigation, there were also occasions when there appeared some acrimony between a few of them.
3.7.4 In such a sensitive situation, careful handling was called for. The participants' honesty of purpose could not be doubted. All that was wanted was that there should be an effort to try and understand the point of view of all the persons. This is precisely what the Court tried to do.
3.7.5 It is indeed fortunate that the efforts of the Court, in this regard, succeeded. After the Court had decided that it was not the purpose or the function of the investigation to affix responsibility for any lapse which may have been committed, one could see the general relieving of tension. With the passage of time there was a gradual building up of the confidence of the participants in the conduct of the investigation. The participants' interest for air safety transcended all barriers and any apprehension or suspicion, which was present in the minds of some, was soon dispelled. In its place there grew a deep sense of urgency, anxiety and cooperation in an effort to see that all the participants rendered utmost assistance for the satisfactory completion of the task in hand.
3.7.6 The main beneficiary of this international cooperation was not only the Court investigating the accident but it was the cause of air safety which benefited the most. Countries and Organisations went out of the way to help each other, financially and otherwise, even when they were not obliged to do so. Money and services were readily and voluntarily offered and usually the requirements of the Court were always fulfilled.
3.7.7 As the accident had occurred only about 100 miles off the coast of Ireland, the centre of activity, initially, was centred at Cork. The Government of Ireland, and the Irish people in particular, acted as though they regarded this as a national disaster. Not only did they render every assistance with regard to the search and rescue operation, hospital

facilities, police etc. but the people acted as if one of their own kith and kin had died. In the situation which existed they were pillars of strength to the relatives of the deceased. Not only did complete strangers comfort such relatives but, more often than not, they even joined in their grief. The residents of Cork did everything possible to try and mitigate the sorrow of the victims' relatives. Everyone did their small bit, even the children of Cork queued up to place flowers at the coffins of the victims.

3.7.8 The Representatives of the Government of Canada also came to the scene, at the initial stages itself, and rendered full help and cooperation till the last. The major brunt of the mapping and the salvage operations was borne by Canada. Willingly and without any demur it incurred huge expenses, which must have been to the tune of a few million dollars, in carrying out these operations. It rendered full help and assitance to the Court whenever called upon to do so. For example, it offorded full facilities and help to the team which had been sent to Canada by the Court in August, 1985. It was only with the help of the Canadian Government, and the CASB and RCMP in particular, that the Court was able to obtain evidence and information relating to the accident. Without Canadian help the conduct of the investigation would have only been speculative in nature.

3.7.9 On their own, and without any request from the Court or from the Government of India, the Government of United States decided to lend a helping hand in the salvage operations. This was done at a very critical juncture when financial help and expertise were required so as to salvage the important critical pieces of the wreckage. It arranged for the services of a salvage expert and it also made necessary arrangements for the deployment of a second ship, duly fitted with necessary equipment to enable it to salvage some of the heavier pieces of the wreckage. The Court understands that the amount which was contributed in meeting the expenses by the United States was to the tune of U.S. $ 700,000.

3.7.10 The Government of United Kingdom also provided ship and helicopters in connection with the search and rescue operations. Even during the time when salvage operations were being carried out it was the British Helicopters which assisted in transporting personnel to and from the ship which were engaged in the salvage operations. The A.I.B. at Farnborough, on being asked by the Court to do so, carried out a very detailed analysis of the CVR and the ATC tapes.

3.7.11 Being the state of Registry of the aircraft and also the state holding the investigation, the major brunt of the work fell on the shoulders of officers of the Government of India and BARC. They acted as coordinators who had to oversee the work being carried out by persons belonging to diverse organisations and coming from different countries. Young engineers of Air India took turns in going aboard the ships and manning the Control Centre at Cork. They worked in conjunction with the engineers of Boeing and CASB and the crew members of the ships during the salvage operations. Without their enthusiastic participation the progress of the salvage operations would have been severely hampered.

3.7.12 The Scientists from BARC and National Aeronautical Laboratory, Bangalore were ever ready and willing to work together with the experts from abroad. Whenever called upon to do so, they rendered whatever assistance which was desired by the Court and the other participants.

3.7.13 It was seen that when the persons, coming from different countries and backgrounds, worked together with sincerety and honesty of purpose then they functioned smoothly and harmoniously, and usually arrived at an agreed solution or finding. These days it is indeed rare to see such a degree of international cooperation between different persons, organisations and countries.

ANALYSIS AND CONCLUSIONS

4.1 From the evidence which is available what has now to be determined is as to what caused the accident.

4.2 Finding the cause of the accident is usually a deduction from known set of facts. In the present case known facts are not very many, but there are a number of possible events which might have happened which could have led to the crash.

4.3 The first task is to try and marshal the facts which may have a bearing as to the cause of the accident.

4.4 It is undisputed, and there is ample evidence on the record to prove it, that Air India's Kanishka had a normal and uneventful flight out of Montreal. The aircraft had been in air for about five hours and was cruising smoothly at an altitude of 31,000 feet. The readout from the CVR shows that there was no emergency on board till the catastrophic event had occurred. This is corroborated by the printout available from the DFDR. The event occurred at approximately 0714 Z and that brought the aircraft down, and it probably hit the surface of the sea within a distance of 5 miles. The time within which the plane came down at such a steep angle could not have been more than very few minutes. There was a sudden snapping of the communication between the aircraft and the ground. The aircraft had also suddenly disappeared from the radar.

4.5 It is evident that an event had occurred at 31,000 feet which had brought down 'Kanishka'. What could have possibly happened to it? The aircraft was apparently incapacitated and this was due either to it having been hit from outside; or due to some structural failure; or due to the detonation of an explosive device within the aircraft.

4.6 Evidence indicates that after the event had occurred, though the pilots did not or were not in a position to communicate with the ground, they nevertheless appeared to have taken some action. According to Mr. Laflamme, witness No. 12, the examination of the wreckage showed that spoilers had been deployed and this must have been done with a view to enter into emergency descent. He has further speculated that such an emergency descent would support or perhaps cause a rupture in the forward area or a partial damage to the hydraulic system or damage to the control system which created such a condition that the pilots were not able to control the flight. The wreckage fruther showed that the jack screw for the stabilizer trim was found in the nose-up position and it was hard to explain how this got there merely as a result of impact with the water. The trim being in that position could only have been due to the pilot selecting it or as a result of a situation created by an explosion. In that position, and at a high aircraft speed, there would have been an extremely high g-loading on the aircraft.

4.7 It can further be speculated that if an explosion takes place in the forward cargo compartment, the oxygen stream might have been damaged so that when the pilots donned their masks as part of the emergency drill for explosive decompression, they were not breathing enriched oxygen and the time of useful consciousness at about 31,000 feet would be significantly less than 30 seconds under high stress and if the pilots became unconscious as a result of this, then the aircraft would have got out of control which would explain the subsequent events.

4.8 None of the participants have produced any evidence which could lead one to the conclusion, that there was any external hit to the aircraft. In fact in the report dated 13th November, 1985, Mr. Paul Turner has stated as follows:

"The United States Norad/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.

4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.

4.11 The circumstantial and direct evidence which leads to the aforesaid conclusion is as follows :

A. Connection with an explosion at Narita Airport :

On 23rd June, 1985 there was an explosion at the Narita Airport. The explosion occurred when a bomb exploded in a suit case which was to be interlined to Air India's Flight No. 301 from Tokyo to Bangkok. The following events, which had occurred prior to this explosion, clearly establish the connection between the two incidents :

(i) On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight Indian accent. He identified himself as Mr.

Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vacouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

(ii) On the same date at approxmimately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

(iii) On 20 June, 1985 at about 1210 PDT (1910 GMT), a male appearing to be of Indian origin purchased the tickets with cash from a CP Air Ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to 'M. Singh'. The telephone contact number was also changed. The final itinerary was as follows :

(a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22nd June, 1985
- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22nd June, 1985

(b) L. Singh - CP 003 Vacouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June, 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 time in Tokyo, local 23 June, 1985

(iv) On 22 June, 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that the was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

(v) On Saturday morning, 22 June, 1985, a CP Air passenger agent worked check-in position number 26 at the CP AIR ticket counter, Vancouver International Airport, and recalls dealing with a passenger of Indian origin booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto his baggage could not be interlined. The passenger insisted and, as the line-up were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that 'M. Singh' checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage.

(vi) The flight manifest for CP 003 shows that on the same day the person using the name of 'L. Singh' with an interline ticket to Bangkok also checked through the same counter, was assigned seat 38H, and checked one piece of baggage.

(vii) A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as 'M. Singh' and 'L. Singh' did not board these respective flights.

(viii) In a statement of William Long, annexed to the affidavit of I.G. Pole, Police Officer, City of Toronto, he has stated that on 22nd June, 1985 he was employed as a driver whose responsibility was to deliver interlined baggage between terminal 2 to Terminal 1 and vice versa at Toronto. He has further stated that he had picked up 4 bags from Terminal 1 which were destined for terminal 2 Air India. Three of these bags were from U.S. Air originating from New York city. Regarding the last bag he stated as follows :

"The fourth bag destined for Air India was, I distinctly remember looking at the baggage tag and it was pink with the CP logo in blue and letters saying CP on it there were also numbers but I can't remember the number, from CP Air and I remember it was from Vancouver. On the bottom of the tag it said vancouver using the initials YVR and the flight number which I can't remember. The bag was destined for India. When I arrived at the CP Air belt there were a number of bags from other airlines on the belt included in these were the three U.S. Air bags destined for Air India. As I was finishing loading the carts, a CP Air station attendant who had been unloading bags from containers, I noticed as I checked once more for anymore bags, drop another bag on the conveyer belt. This was the bag destined for Air India. It was dark brown Samsonite Hard sided Type 01A on the Baggage Identification Chart. After they were loaded onto the cart I took them over to Air Canada domestic belt at Gate 89-91".

To further questions posed to him, Long stated that this bag from CP Air weighed approximately 70 lbs and there was something which rattled inside the bag. He could not say what it was but he said that "it sounded small". When specifically asked whether he thought there was something big inside the bag, he answered in the affirmative, and added that he did not know what was in it but it was heavy. There was discrepancy in the time when he is alleged to have picked up the bags which he had indicated in his schedule when compared with CP Air Vancouver flight which had arrived at 1622 hours. When this was pointed out to Long, he answered "I could have may be got the time wrong, it was during the busy period. It could have been an estimate time. But I do remember the bag came off CP air. It could have been 16:34 Hrs. I don't know."

(ix) The aircraft departed from Toronto for Mirable and London with the suitcase unaccompained by the passenger who had checked it in at Vancouver. Similarly, CP Air 003 departed Toronto for Tokyo with the baggage of one passenger 'L. Singh' to be interlined to Air India flight AI 301 to Bangkok even though 'L Singh' had not boarded that flight.

(x) The linking of the two occurrences namely the blast at Narita Airport and the Air India accident becomes startingly evident if we look at the following chronology of events:

CPA 003 (VANCOUVER-TOKYO) CPA 060 (VANCOUVER-TORONTO) Connection to Connecting to Air India 301 Air India 182 WESTBOUND EASTBOUND All Times GMT Thurs 20 June, 1985 0057 A male called C.P. Air Reservations in Vancouver and after discussing a number of routings, booked a one-way ticket and CPA 060 to Toronto with connections to Air India 182 under the name of Jaswand SINGH. A return ticket was also booked on CPA 003 to Tokyo connecting with Air India 301 to Bangkok in the name of Mohinderbel SINGH.

1912 A male attended the CP Air Ticket Office in Vancouver. He paid $ 3005.00 in cash for the above tickets after changing the ticket of Mohinderbel SINGH to L. SINGH and changing
from a return to a one-way ticket. He changed the Jaswand SINGH ticket to M. SINGH.

Saturday 22 June A Mr. SINGH called Reservations and got 1330 confirmation on his one-way ticket to Toronto with luggage to be sent through to India. M. SINGH checked in with seat 10B confirmed to 1550 Toronto. Wanted suitcase interlined to AI 182. Agent relents. 1618 CPA 060 departed Vancouver 18 minutes late. M. SINGH not in assigned seat. L. SINGH checked in for CPA 003 and one suitcase interlined to Air India 301. Assigned seat 38H. CPA 060 arrived Toronto 2022 12 minutes late. Some passengers and baggage interlined to AI 181.
CPA 003 departed 17 min. late for Tokyo. L. SINGH not in 2037 assigned seat. Sunday 23 June Air India 181 departed 0015 Toronto for Mirabel 1 hour 40 minutes late. 0100 Air India arrived Mirabel. 0218 Air India 182 departed Mirabel 1 hour 38 minutes late. CPA 003 arrived Narita Airport, Tokyo. Arrived 14 minutes early 0541 Baggage cart explodes in transit area. 2 killed, 4 injured, 0619 0714 Air India 182 disappeared from

Radar

Air India 301 departed Narita. 0805 0815 Air India 182 Scheduled arrival Heathrow (fuel stop).

(xi) It would indeed to too much of a coincidence that two persons, whose tickets were bought at the same time and who had checked in under the names of 'L. Singh' and 'M. Singh' missed their respective flights, more so when 'M. Singh' had insisted at the check in counter at Vancouver that he should be interlined, even though his seat from Toronto on AI 181/182 was not confirmed, and his baggage (one suitcase) accepted and be routed through to Delhi. If there had been some reason for 'gate no-show' by both of them, one would ordinarily have expected both, or at least one of them, to have made efforts, at that time or thereafter, either to ask for refund of money or they should have contacted the airline staff at the Airport and asked that they should be put on another flight.

(xii) A large amount of money had been spent on the purchase of the two tickets and a question which comes to mind is as to why was this money spent if both the tickets were to be wasted and no one was to travel on them, after having checked in and obtained boarding cards. Furthermore, no effort has been made by any of these two persons to try and lodge a claim for the baggage which they had checked in.

(xiii) The aforesaid facts clearly indicate the connection between the travel plans of so called 'L. Singh' and 'M. Singh'. In fact the manner in which the reservations were changed to the names of 'M. Singh' and 'L. Singh' shows the anxiety of some one to hide behind the identity of persons who bore notorious names.

(xiv) The interlined baggage exploded at Narita Airport and there is strong probability that the suticase from Vancouver, which was interlined to AI 182, contained a device similar to the one which had exploded at Narita Airport on 23 June, 1985.

B. CVR and DFDR both stopped simultaneously:

There was simultaneous interruption of electrical power to the flight recorders. The electrical supply could have been interrupted either because of the cables being cut or because of total electric failure. Power supply wires to the CVR and the DFDR run under the passenger cabin ceiling on the left and the right hand side. The supply of electricity through these cables originates from the MEC compartment, which is in front of the forward cargo hold. If the CVR and the DFDR had stopped due to the breakage of electrical supply wires as a result of possible explosion in the aft cargo hold there would have had to be an instantaneous break of almost the entire section of fuselage, because both these recorders had stoped simultaneously. In such a catastrophic event it is not possible that the bottom skin panels of the aft cargo compartment would remain undistorted, or would have no rupture or holes in them. Furthermore, in such an event the tail portion of the aircraft would have been found in the beginning of the wreckage trail, but this was not so. On the other hand, and explosion in the forward cargo compartment would have resulted in damage to the electrical buses located in the MEC and that would, in turn, result in cutting off the electrical power supply causing simultaneous stoppage of the recorders.

C. The ATC Transponder Stopped Transmitting :

The transponder is located at the bottom of the one of the forward rakes immediately forward of the front cargo compartment. Signals from this also stopped being received by the secondary radar at Shannon. Keeping in view that the CVR and the DFDR had stopped simultaneously at about the same time, when the signals from ATC transponder had also ceased, it is reasonable to presume that there must have been a complete breackdown of electrical supply which had affected all the three units. The only event which could have caused such a damage to paralyse the entire MEC compartment could only have been an explosion in the forward cargo hold. It was not possible that any rapid decompression caused by a structural failure could have disrupted the entire electricl power supply from the MEC compartment. In known cases of aircraft being subjected to rapid decompression there has never been such an instantaneous and total stoppage of electrical power and in fact aircrafts have been known to have continued to fly and communicate with the ground even after decompression.

D. Non-supply of Oxygen :

Oxygen supply cylinders are located in the ceiling of the forward cargo compartment. Any rupture of the only pipeline which supplies oxygen to the passengers would result in there being no surge of oxygen flow, which alone drops the oxygen masks. The inspection of the wreckage shows that there is no indication of the oxygen masks ever having dropped. A rupture of this pipeline, simultaneously with power rupture, could only have been caused if there had been a detonation of the explosive device in the front cargo hold.

E. Damage in air :

The examination of the floating and the other wreckage shows that the right hand wing leading edge, the No. 3 engine fan cowl, right hand inboard mid flap leading edge and the leading edge of the right hand stabilizer were damaged in flight. This damage could have occurred only if objects had been ejected from the front portion of the aircraft when it was still in the air. The cargo door of the front cargo compartment was also found ruptured from above. This also indicates that the explosion perhaps occurred in the forward cargo compartment causing the objects to come out and thereby damaging the components on the right hand side.

F. Evidence of Overpressurization :

The examination of the structural panels and the other parts of the forward cargo compartment and the aft cargo compartment, recovered from the sea bed, indicates that overpressure condition had occurred in both the cargo compartments. The failure of the passenger cabin floor panels in upward direction also indicates that overpressure was created in both the compartments. It cannot be disputed that whenever an explosive detonates very high pressure shockwaves are formed which travel in all directions and high speed fragments of the container, or the loose material, also move away from the source of explosion. It is, therefore, clear that there was overpressurization in the cargo compartments which resulted in such rupture of the cabin floor panels.

G. Holes in the front cargo hold panels

While the skin panels of the aft cargo compartment are fairly straight and undamaged, the panels of the front cargo compartment are ruptured and have a large number of holes. This shows that there was occurrence of an event in the front cargo compartment and not in the aft cargo compartment.

H. Buckling of Seats :

The seats towards the rear of the aircraft had only the aft legs buckled, whereas the seats towards the front had both the front and the aft legs buckled. This indicated that the whole floor was subjected to a vertical force and was more severe towards the front. Moreover, the upper deck storage cabin was found among floating wreckage. The bottom of this cabin was pushed up in the shape of a dome with no evidence of impact damage. This deformation was indicative of having been caused, possibly, as a result of a shockwave.

I. Metallurgical Examination Results :

A metallurgical examination, especially of Targets 362 and 399, clearly confirms that there was an explosion in the forward cargo compartment. Microscopy around some of the holes discloses that they have such characteristics like twinning which can be present only if the holes had been puntured due to the detonation of an explosive device.

J. CVR Tape Analysis :

The report of CVR tape analysis by Mr. S.N. Seshadri also corroborates the aforesaid evidence i.e. that there was a bomb in the forward cargo hold of the aircraft.

RECOMMENDATIONS

5.1 ICAO, IATA and the States should :-

(a) undertake an ongoing review of established aviation security standards to prevent the placement of explosive substances on board commercial aircraft;

(b) establish a programme of monitoring the implimentation of security measures in airports around the world, in cooperation with the Governments concerned. For each airport studied, it should report its findings and recomend any improvements that may be required;

(c) consider establishing a group of civil aviation experts to investigate serious breaches of security. The purpose of these investigations would be to determine the facts of an incident so that necessary measures could be developed and implemented world wide to prevent similar breaches in the future.

Note : As it may take some time for ICAO and IATA to implement these recommendations, at least those countries which have international air traffic should take up effective measures without delay.

5.2 ICAO should :-

(a) develop a model clause on security that could be used in the bilateral air agreements that govern the exchange of air traffic rights between countries;

(b) consider establishing standards for the training of security personnel.

5.3 IATA should develop practical procedures for reconciliation of interlined passengers and their baggage at intermediate airports.

5.4 Interlining of checked-in baggage should not be done if a passenger does not have a confirmed reservation on the onward carrier flight.

5.5 The baggage of interlined passengers should be matched with passengers by the onward carriers before loading the baggage on the aircraft.

5.6 Whenever a Government becomes aware of particular high risk security threat it should notify not only the airline at risk, but also all connecting airlines in order that extra precaution can be taken at potential points of introduction of interline baggage into the system.

5.7 When an Airline is aware of a high security threat it should communicate the same to the host state as well as, if possible and prudent, to the other airlines operating there.

5.8 Passenger count should be done at boarding gate and in case of 'no gate show' of a passenger, his baggage must be off-loaded.

5.9 All checked-in baggage, whether it has been screened by X-ray machine or not, should be personally matched and identified with the passengers boarding an aircraft. Any baggage which is not so identified should be off-loaded. This is advisable as examination of the baggage with the help of an X-ray machine has its own limitations and is not fool proof. Some explosives hidden in Radios, Cameras etc. may not be readily detected by such a machine. In fact an explosive not placed in a metallic container will not be detectable by an X-ray machine. Similarly, a plastic explosive can be given an innocuous shape or form so as to avoid detection by an X-Ray. Reliance on an X-Ray machine alone may in fact provide a false sense of security.

5.10 Effectiveness of the instrument known as PD-4 is highly questionable. It is not advisable to rely on it.

5.11 All unaccompanied baggage should be placed on the aircraft after their contents have been physically checked. In the alternative, it should be loaded only after it has been placed in a decompression chamber and the host state is satisfied that the baggage is clean and the shipper has been identified.

5.12 Airlines should have effective backup security equipment or procedures available in case of machanical break down of security equipment.

5.13 All hand baggage, including that of the crew, should be opened and the contents physically checked even if the said baggage has been x-rayed. This will no doubt be a bit time consuming and laborius but if security is to be meaningful, then slight inconvenience has to be endured in order to ensure a safer flight.

5.14 The manufacturers of aircraft should take effective steps for protecting sensitive parts of the aircraft from explosive damage.

5.15 Studies should be undertaken to determine the feasibility of physically separating the avionics bay and emergency oxygen systems from the cargo area in aircraft so that these sensitive and essential areas of the aircraft cannot be damaged or destroyed by a relatively small explosive deivce concealed in luggage.

5.16 The seats should have safety belts which can act as restraint for the upper part of the body e.g. like a shoulder harness with inertial restraint.

5.17 The seats in the aircraft should be so designed so as to incorporate shock absorbing systems within the seat and they should be manufactured by using material which does not break easily.

5.18 In addition to the cockpit voice recorder, there should be in the cockpit a video/scanning camera which would record the movements and the audio sounds in the cockpit. This will not only assist in ascertaining as to how the pilots act during as emergency but, in the case of hijacking, would also assist in the identification of the hijackers.

5.19 The CVR should record all the conservation and sounds in the cockpit for the entire duration of the flight, and not merely for the last 30 minutes.

5.20 The CVR and the DFDR should be powered from two alternative sources of energy.

5.21 The oxygen for the flight crew should be supplied from two different sources i.e. in the event of an emergency the pilot and the co-pilot must don the oxygen mask and the oxygen must be supplied from different source.

5.22 Suitable provisions should be incorporated in Annex 13 which would give power to an Investigator to record evidence outside the country of investigation and also to summon witness from abroad. It should also be mandatory on the contracting States to give information sought for by an Investigator.

(B. N. KIRPAL)

February 26, 1986 COURT

We agree with the conclusions and recommendations stated above.

ASSESSORS

(V. Ramachandran) (J.S. Gharia)

(J.S. Dhillon) (J.K. Mehra)

(B.K. Bhasin)

ACKNOWLEDGEMENTS

When I was appointed as the Court to investigate into the accident, the magnitude of the task involved was known. With the help, assistance and cooperation of a team of dedicated workers, the work was, however, completed in not too long time. The assistance received from those who helped me cannot be too highly praised.

From amongst my Assessors, Captian B.K. Bhasin was the only one who was permanently stationed in Delhi. We met for the first time on

15th July, 1985 and little did I realise then that, by the time our work would be over, how much I would be depending upon him. Not only was his advice on the technical aspects of flying and air safety invaluable but, whenever any difficulty or a problem arose, I invariably turned to him for assistance and advice which I readily got. I found him having a very practical and positive approach to all the problems but, at the same time, he very rightly was not prepared to compromise on any principal issues.

The only interest Dr. V. Ramachandran appeared to have was to do his work to perfection. No praise can be too high for the manner in which this Metallurgist from landlocked Bangalore volunteered and boarded the salvage ships which were carrying out operations in the cold and choppy waters of Atlantic Ocean. He sarificed all comforts and went to sea with a view to be present on board the ships at the time when salvaged pieces of wreckage were brought on board. His deep knowledge of metallurgy greatly assisted the examination of the salvaged pieces of wreckage. In this connection the entire metallurgical examination was planned and organised by him.

Whenever any information was required concerning explosives, Mr. J.S. Gharia was ever eager and in a position to provide the information.

Mr. J.K. Mehra looked into the engineering aspect of the accident and he spent a lot of time in going through various Air-India Maintenance Manuals. He always made discussions very lively and interesting.

Captain J.S. Dhillon came out of his retirement and provided useful information to the Court on some aspects of flying.

This work would never have been satisfactorily completed without the help and assistance received by the Court from late Mr. S.N. Seshadri of Bhabha Atomic Research Centre. From the time when the CVR was first played by him at BARC on 16 July, 1985 till the very end, he most willingly and pleasantly undertook any assignment which was given to him by the Court. It was a great national loss when he suddenly passed away on 2nd February, 1986, only a few days after he had deomonstrated his brilliance when his testimony, regarding the analysis of the CVR tape, was recorded by me in the Court.

I am also grateful to the other Scientists and staff of B.A.R.C. who rendered considerable assistance to the Court. The facilities made available by Dr. P.K. Iyengar, Director, B.A.R.C. with regard to the finalisation and completion of the report cannot be easily forgotten. In the absence of late Mr. S.N. Seshadri, with whom I had developled a personal rapport, Dr. Ashok Mohan and Mr. V.K. Chadda met with all our requirements in the finalisation and preparation of the Report. Dr. Asundi of BARC and the other Metallurgists of that Organisation and of the National Aeronautical Laboratory also spent a considerable amount of their time and energy in successfully carrying out metallurgical tests and examination of the salvaged pieces.

During the investigation I had to visit Ireland on two occasions. I immediately realised the extent of help, assistance and guidance which was being rendered to all of us by Mr. Kiran Doshi, the Indian Ambassador to Ireland. There was no problem to which he did not have a solution. On my visit to Dublin not only did I enjoy the hospitality of Kiran and his wife Razia but it also gave an opportunity to personally meet Mr. Mitchel, the Minister of Communications, and senior officials of his Ministry, and to express my gratitude to them for all the help and assistance which the Government and people of Ireland had, most willingly, rendered.

At Tokyo the Indian Ambassador and members of his staff looked after all our needs and arranged meetings with the Japanese officials whom we wanted to meet.

As representatives of the Court in Cork, Mr. P.R. Chandrasekhar and Mr. C.D. Kolhe did a commendable job. They kept me informed of the progress which was taking place at Cork and, whenever required to do so, they took vital decisions while coordinating the mapping and salvage operations.

Mr. H.S. Khola, Director of Air Safety, New Delhi willingly carried out all the directions of the Court. Special mention must also be made of Mr. Satendra Singh, Regional Controller of Air Safety, Bombay, who worked day and night when the flight recorders were first opened and the copies of the tapes made and the data analysed.

I have also to express my gratitude to the Counsel who assisted the Court in the Investigation. Without their help and cooperation, it would not have been possible to complete the work in 7-1/2 months.

On my trip to Bombay, the Staff and Management of Centaur Hotel made my stay very comfortable. It was like a home away from home.

The work done during the salvage operarations by four young engineers of Air-India was highly commendable and valuable. All of them namely, Mr. Balasubramanium, Mr. L.S. Carvalho, Mr. G.D. Nayar and Mr. A.K. Sheode, worked round the clock even during adverse climatic conditions.

The Registrar of the Delhi High Court, Ms. Usha Mehra spared no efforts in rendering every assistance whenever the same was required. She ably marshalled all the resources available in the High Court in order to ensure the smooth and efficient functioning of my office. My own personal staff in particular, headed by Mr. V.P. Ahuja, Court Master and Mr. Balram Chopra, Private Secretary, as usual, rose to the occasion. While Mr. Ahuja kept complete control of hundreds of documents and affidavits which had been filed, Mr. Chopra besides bearing the brunt of the typing work, very ably supervised the work of other Stenographers.

It was most fortunate that I was able to persuade Mr. S.N. Sharma to accept the trying job of being the Secretary to the Court. His vast experience in such Investigations, he had been a Secretary in three such Investigations earlier, made my task much lighter. Moreover, as an Aircraft Engineer, he was always ready to explain technical intricacies involved in the case. Without his help I could not have completed my work within the stipulated time.

(B. N. KIRPAL)

26th February, 1986 COURT

POSITIVELY IDENTIFIED DEBRIS AIR INDIA 747 VT-EFO KANISHKA AIRCRAFT

SECTION TARGET LAT LONG DESCEIPTION 41 DOOR 192 51 03.28 12 47.74 FIRST CLASS AND COCKPIT AREA (+ UPPER DECK DOOR) 41 131 51 03.21 12 47.93 LEFT HAND

UPPER DECK SLIDE MECHANISM 41 134 51 03.28 12 47.81 NOSE LANDING GEAR 41 265 51 02.37 12 44.51 LANDING GEAR DOOR (NOSE GEAR) 41 244 51 03.56 12 48.19 UPPER DECK WINDOW TRIM (REVEAL) 41 63 51 02.51 12 47.37 2 FIRST CLASS SEATS 41 77 51 02.59 12 47.83 2 FIRST CLASS SEATS 42 DOOR 193 51 03.30 12 47.85 PIECE OF FUSELAGE, WING PLUS LANDING GEAR (#2 LEFT DOOR) 42 138 51 03.37 12 47.77 SMALL PIECE OF WRECKAGE (BS 800) 42 200 51 03.347 12 47.831 Dual Heat Exchanger 42 DOOR 204 51 03.33 12 47.87 FORWARD CARGO DOOR + FLOOR 42 255 51 03.72 12 48.01 GALLEY COMPLEX (UPPER DECK) 42 232 51 03.49 12 47.92 'P93' RACK MARKED 'DANGER HIGH VOLTAGE' (BS 670) 42 327 51 01.62 12 43.03 NACA SCOOP 42 DOOR 358 51 03.39 12 47.86 MASS OF DEBRIS (#2 RIGHT DOOR) 42 361 51 03.384 12 47.848 BOX MARKED "FAN BLADES" 42 362 51 03.372 12 47.840 MASS OF DEBRIS FUSELAGE SKIN 42 383 51 03.32 12 47.81 MASS OF DEBRIS WITH UPPER DECK FLOOR 44 DOOR 137 51 03.30 12 47.80 CENTER FUSELAGE SECTION WITH #3 LEFT DOOR 6 WINDOWS AFT OF DOOR AND 13 WINDOWS FORWARD. LEFT UPPER WING SKIN AND ONE MAIL LANDING GEAR ATTACHED. 44 103 51 02.86 12 46.37 LANDING GEAR DOOR 44 105 51 02.81 12 46.04 LEFT WHEEL WELL LANDING GEAR DOOR 44 186 51 03.32 12 47.825 KEEL BEAM 44 195 51 03.32 12 47.78 WING STRUCTURE 44 224 51 03.46 12 48.49 TWO WHEELS FROM MAIN LANDING GEAR 44 239 51 03.62 12 47.38 MAIN BRAKE UNIT WITHOUT AXEL, PLUS EQUALIZING ROD 44 240 51 03.62 12 47.44 MAIN TIRE AND RIM 44 241 51 03.62 12 47.40 MAIN TIRE AND RIM PLUS AXEL 44 242 51 03.61 12 47.40 MAIN BRAKE UNIT 44 267 51 03.35 12 44.45 PART OF LANDING GEAR DOOR 44 275 51 02.13 12 44.10 BODY LANDING GEAR DOOR 44 279 51 02.30 12 44.64 MAIN LANDING GEAR DOOR 44 280 51 02.26 12 44.61 SECTION OF MAIN LANDING GEAR DOOR 44 343 51 03.285 12 47.809 MAIN LANDING GEAR DOOR 59 51 02.57 12 45.73 SECTION OF LANDING GEAR 44 218 51 03.41 12

47.86 STEP WELL AREA (STA 1250-1480)
46 6 51 02.79 12 49.44 SMALL MOTOR 10" x 8" (FAN) 46 7 51 02.90 12 49.92 LOWER SKIN OF CARGO AREA 4' x8' (BS 1480)) 46 #11 51 02.04 12 45.44 PIECE OF OUTER SKIN BODY STATION #1760 PART NO. 65B04325-403 46 25 51 02.21 12 46.27 BODY FRAME (BS 1660-1680) 46 26 51 02.20 12 46.72 CABIN SECTION WITH 4 WINDOWS (ABOVE 'T' IN REG No.) 46 28 51 02.31 12 47.02 SKIN PANEL 1460-1800 46 33 51 02.49 12 48.28 AFT FUSELAGE SKIN PANEL 'YOUR PALACE IN THE SKY' (AFT OF #5 DOOR) 46 34 51 02.49 12 48.29 RIGHT HAND FUSELAGE SKIN PANEL AT DOOR #5 46 DOOR 40 51 02.47 12 47.41 CARGO DOORS C2, C3 46 47 51 02.39 12 46.61 REAR CARGO FLOOR 46 50 51 02.38 12 46.60 CARGO FLOOR (STA 1500) 46 DOOR 74 51 02.49 12 47.71 FIVE FRAMES AND DOOR-PORT SIDE AFT (#5 LEFT DOOR) 46 78 51 02.52 12 47.95 FRAME SECTION (SHEAR WEB STA 2000-2020) 46 87 51 02.58 12 48.43 BUILT UP STRUCTURE (STA 2412) 46 DOOR 97 51 02.52 12 47.38 FUSELAGE SKIN SECTION WINDOW BELT AREA WITH DOOR FOLDED UNDER FRAME 46 DOOR 101 51 02.84 12 47.14 5 WINDOWS AND DOOR (#4 RIGHT DOOR) 46 292 51 01.81 12 44.24 FRAME (STA 2240) 46 321 51 02.39 12 46.61 '4R' DOOR ENTRANCE WITH NO DOOR AND 10 WINDOWS (BS 1700) 320 51 01.84 12 44.59 FUSELAGE BOTTOM SKIN NEAR OUTFLOW VALUE 46 336 51 01.34 12 42.03 BULK CARGO COMPARTMENT FLOOR AND STRUCTURE 46 369 51 02.17 12 46.20 FUSELAGE PANEL SECTION, 4 WINDOWS 48 31 51 02.37 12 48.43 HORIZONTAL STAB 48 37 51 02.47 12 47.99 VERTICAL TAIL FIN (+ PRESSURE BULKHEAD SECTION) 48 35 51 02.50 12 48.08 AFT PRESSURE BULKHEAD (25%) 48 22 51 02.19 12 45.68 ELECTRICAL PANEL (RUDDER RATIO JUNCTION BOX) 48 27 51 02.20 12 46.83 APU HOUSING 48 66 51 02.59 12 47.54 BODY FRAME (BS 25XX) 48 67 51 02.55 12 47.50 FUSELAGE SKIN (3 FRAMES FORWARD OF APU BS 2638) 48 68 51 02.57 12 47.55 FUSELAGE SECTION (BS 2598) 48 73 51 02.51 12 47.70 PART OF PRESSURE BULKHEAD 48 75 51 02.47 12 47.63 FRAME FOR

OVERHEAD LUGGAGE COMPARTMENT (ROW 46 F-G) 48 88 51 02.90 12 48.84 CONTROL LINKAGE FROM TAIL OF AIRCRAFT (ELEVATOR CONTROL QUADRANT) 48 99 51 02.71 12 47.92 FUSELAGE SKIN SECTION (BS 2598) 48 296 51 02.03 12 43.17 PART OF PRESSURE BULKHEAD 48 314 51 01.84 12 44.19 APU AIR DUCT 48 371 51 02.51 12 48.28 AFT FUSELAGE SKIN 10'x15' (HORIZ. STAB CUTOUT)

SECTION TARGET LAT LONG ENGINES 7.13 108 51 02.97 12 47.12 AIRCRAFT ENGINE (WITH STRUT) 149 51 03.26 12 47.38 ENGINE AND STRUT 154 51 03.32 12 47.75 ENGINE SECTION (5th ENGINE) 171 51 03.16 12 47.16 TURBINE SECTION OF ENGINE (POSSIBLY COMPLETE ENGINE) 235 51 03.63 12 47.07 AIRCRAFT ENGINE ENGINE PARTS 106 51 02.98 12 46.41 ENGINE COWLING (INLET) MARKED 'A124' (5th ENGINE) 109 51 02.97 12 47.11 STARTER FOR AIRCRAFT ENGINE 111 51 03.02 12 47.20 ENGINE COWL 116 51 02.99 12 47.80 ENGINE DEVICE 124 51 02.85 12 48.47 FIFTH ENG CENTER DOME 150 51 03.25 12 47.36 PART OF ENGINE 151 51 03.29 12 47.42 SMALL PART OF ENGINE 152 51 03.31 12 47.44 LOWER PORTION OF ENGINE 153 51 03.31 12 47.44 LOWER ENGINE COWLING 155 51 03.32 12 47.44 FAN INNER EXIT AREA 156 51 03.32 12 47.43 PART OF ENGINE 158 51 03.23 12 47.35 PART OF ENGINE COWLING 159 51 03.25 12 47.29 ENGINE COWLING 161 51 03.26 12 47.29 PORTION OF ENGINE COWL 165 51 03.20 12 47.21 THRUST REVERSER SLEEVE 166 51 03.20 12 47.21 UNIDENTIFIED ENGINE PARTS 167 51 03.21 12 47.24 UNIDENTIFIED ENGINE PARTS 168 51 03.20 12 47.22 UNIDENTIFIED ENGINE PART 169 51 03.18 12 47.20 UNIDENTIFIED ENGINE PARTS 170 51 03.19 12 47.19 PART OF DIAPHRAM (OIL COOLER) 172 51 03.25 12 47.21 ENGINE EXHAUST CONE 173 51 03.27 12 47.38 ENGINE EXHAUST CONE AND EXHAUST 237 51 03.690 12 47.10 ENGINE PARTS CASE 238 51 03.72 12 47.10 ENGINE INLET COWL 206 51 03.34 12 47.50 SECTION OF ENGINE EXHAUST STAGE #7 207 51

03.35 12 47.49 ENGINE HOT SECTION AREA 208 51 03.37 12 47.51 ENGINE TAIL CONE 214 51 03.19 12 47.36 CASCADE VANE

STRUTS 7.12 4 51 02.87 12 49.05 #3 ENGINE NACELLE STRUT 157 51 03.23 12 47.36 STRUT (SIMILAR TO 149) 110 51 03.15 12 47.16 NACELLE STRUT WING PARTS 17 120 51 03.01 12 47.98 OUTBOARD AILERON (50%) 16 135 51 03.28 12 47.81 TRAILING EDGE FLAP AND DRAG JACK 16 136 51 03.31 12 47.81 TRAILING EDGE FLAP JACK SKREW 12 140 51 03.35 12 47.83 LEADING EDGE SECTION OF WING 14 145 51 03.34 12 47.85 WING LEADING EDGE VARIABLE CAMBER FLAP 16 177 51 03.34 12 47.91 TRAILING EDGE FLAP 12 181 51 03.38 12 47.87 LOWER CARGO COMPARTMENT AND WING LOWER SKIN 16 183 51 03.38 12 47.87 SECTION OF FLAP SKIN 16 188 51 03.33 12 47.81 TRAILING EDGE FLAP WITH JACK SKREW 16 189 51 03.32 12 47.80 TRAILING EDGE FLAP WITH SKREW JACK 16 191 51 03.32 12 47.78 FLAP ACTUATOR AND FLAP TRACK 16 194 51 03.32 12 47.77 TRAILING EDGE OF FORE FLAP 16 253 51 03.32 12 47.86 PIECE OF TRAILING EDGE FLAP 16 254 51 03.40 12 47.86 PIECE OF TRAILING EDGE FLAP 16 264 51 02.47 12 44.74 TRAILING EDGE FLAP FAIRING 16 277 51 02.18 12 44.40 WING FLAP 16 344 51 03.294 12 47.802 TRAILING EDGE FLAP AND FLAP TRACK 16 384 51 03.33 12 47.80 T/E FLAP TAPER AND DRIVE SHAFT 16 398 51 03.325 12 47.85 PIECE OF TE MID FLAP 15 190 51 03.32 12 47.79 SPOILER ACTUATOR 14 187 51 03.34 12 47.81 LEADING EDGE FLAP SECTION 14 387 51 03.33 12 47.853 PIECE OF L/E FLAP MECHANISM

12 54 51 02.38 12 45.86 LE FROM WING 12 202 51 03.33 12 47.86 WING LOWER SKIN 12 221 51 03.39 12 47.89 UPPER EDGE LEFT WING 12 225 51 03.38 12 48.78 SMALL PIECE OF WING LEADING EDGE PANEL 12 222 51 03.38 12 47.94 WING FILLER & WING PARTS 12 243 51 03.59 12 47.85 PIECE OF LEADING EDGE FLAP 12 252 51 03.38 12 47.84 LOWER WING SECTION 12 262 51 03.85 12 46.92 MID LOWER WING SKIN, ONE AFT FLAP TRACK

WITH JACK SKREW 12 266 51 02.36 12 44.46 LANDING GEAR DOOR 12 297 51 01.91 12 43.18 PART OF WING TIP 12 345 51 03.28 12 47.842 'REAR WING SPAR' 12 365 51 03.338 12 47.842 REAR SPAR RIB WITH SPOILER ACTUATOR 12 379 51 03.315 12 47.785 WING REAR SPAR AND SPOILER STA 1150 12 381 51 03.40 12 47.88 LE OF WING SECTION 12 182 51 03.38 12 47.87 POSSIBLE REAR SPAR, (WING STA 802 I.D. ON PART)   17 274 51 02.19 12 43.57 LEFT INBOARD AILERON

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:49 PM PDT
To: Sterns@trial-law.com
Subject: **PA 103 AAR**

http://www.open.gov.uk/aaib/n739pa.htm

Air Accidents Investigation Branch
Aircraft Accident Report No 2/90 (EW/C1094)

Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21December 1988

Contents

Operator: Pan American World Airways
Aircraft Type: Boeing 747-121
Nationality: United States of America
Registration: N 739 PA
Place of Accident Lockerbie, Dumfries, Scotland
Latitude 55¡ 07' N
Longitude 003¡ 21' W
Date and Time (UTC): 21 December 1988 at 19.02:50 hrs
All times in this report are UTC

SYNOPSIS

The accident was notified to the Air Accidents Investigation Branch at 19.40 hrs on the 21 December 1988 and the investigation commenced that day. The members of the AAIB team are listed at Appendix A.

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind. Major portions of the wreckage of the aircraft fell on the town of Lockerbie with other large parts landing in the countryside to the east of the town. Lighter debris from the aircraft was strewn along two trails, the longest of which extended some 130 kilometres to the east coast of England. Within a few days items of wreckage were retrieved upon which forensic scientists found conclusive evidence of a detonating high explosive. The airport security and criminal aspects of the accident are the subject of a separate investigation and are not covered in this report which concentrates on the technical aspects of the disintegration of the aircraft.

The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie. Five recommendations are made of which four concern flight recorders, including the funding of a

study to devise methods of recording violent positive and negative pressure pulses associated with explosions. The final recommendation is that Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft's structure and systems to explosive damage.

1. FACTUAL INFORMATION

1.1 History of the Flight

Boeing 747, N739PA, arrived at London Heathrow Airport from San Francisco and parked on stand Kilo 14, to the south-east of Terminal 3. Many of the passengers for this aircraft had arrived at Heathrow from Frankfurt, West Germany on a Boeing 727, which was positioned on stand Kilo 16, next to N739PA. These passengers were transferred with their baggage to N739PA which was to operate the scheduled Flight PA103 to New York Kennedy. Passengers from other flights also joined Flight PA103 at Heathrow. After a 6 hour turnround, Flight PA103 was pushed back from the stand at 18.04 hrs and was cleared to taxy on the inner taxiway to runway 27R. The only relevant Notam warned of work in progress on the outer taxiway. The departure was unremarkable.

Flight PA103 took-off at 18.25 hrs. As it was approaching the Burnham VOR it took up a radar heading of 350¡ and flew below the Bovingdon holding point at 6000 feet. It was then cleared to climb initially to flight level (FL) 120 and subsequently to FL 310. The aircraft levelled off at FL 310 north west of Pole Hill VOR at 18.56 hrs. Approximately 7 minutes later, Shanwick Oceanic Control transmitted the aircraft's oceanic clearance but this transmission was not acknowledged. The secondary radar return from Flight PA103 disappeared from the radar screen during this transmission. Multiple primary radar returns were then seen fanning out downwind for a considerable distance. Debris from the aircraft was strewn along two trails, one of which extended some 130 km to the east coast of England. The upper winds were between 250¡ and 260¡ and decreased in strength from 115 kt at FL 320 to 60 kt at FL 100 and 15 to 20 kt at the surface.

Two major portions of the wreckage of the aircraft fell on the town of Lockerbie; other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Residents of Lockerbie reported that, shortly after 19.00 hrs, there was a rumbling noise like thunder which rapidly increased to deafening proportions like the roar of a jet engine under power. The noise appeared to come from a meteor-like object which was trailing flame and came down in the north-eastern part of the town. A larger, dark, delta shaped object, resembling an aircraft wing, landed at about the same time in the Sherwood area of the town. The delta shaped object was not on fire while in the air, however, a very large fireball ensued which was of short duration and carried large amounts of debris into the air, the lighter particles being deposited several miles downwind. Other less well defined objects were seen to land in the area.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	16	243	11
Serious	-	-	2
Minor/None	-	-	3

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1.3 Damage to aircraft

The aircraft was destroyed

1.4 Other damage

The wings impacted at the southern edge of Lockerbie, producing a crater whose volume, calculated from a photogrammetric survey, was approximately 560 cubic metres. The weight of material displaced by the wing impact was estimated to be well in excess of 1500 tonnes. The wing impact created a fireball, setting fire to neighbouring houses and carrying aloft debris which was then blown downwind for several miles. It was subsequently established that domestic properties had been so seriously damaged as a result of fire and/or impact that 21 had to be demolished and an even greater number of homes required substantial repairs. Major portions of the aircraft, including the engines, also landed on the town of Lockerbie and other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Lighter debris from the aircraft was strewn as far as the east coast of England over a distance of 130 kilometres.

1.5 Personnel information

1.5.1 Commander: Male, aged 55 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 720, Lockheed L1011 and

Douglas DC3
Medical Certificate: Class 1,valid to April 1989, with the limitation that the holder shall wear lenses that correct for distant vision and possess glasses that correct for near vision

Flying experience:
Total all types: 10,910 hours
Total on type: 4,107 hours
Total last 28 days 82 hours
Duty time: Commensurate with company requirements
Last base check: 11 November 1988
Last route check: 30 June 1988
Last emergencies check: 8 November 1988

1.5.2 Co-pilot: Male, aged 52 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 727
Medical Certificate: Class 1, valid to April 1989, with the limitation that the holder shall possess correcting glasses for near vision
Flying experience:
Total all types: 11,855 hours
Total on type: 5,517 hours
Total last 28 days: 51 hours
Duty time: Commensurate with company requirements
Last base check: 30 November 1988
Last route check: Not required
Last emergencies check: 27 November 1988

1.5.3 Flight Engineer: Male, aged 46 years
Licence: USA Flight Engineer's Licence
Aircraft ratings: Turbojet
Medical certificate: Class 2, valid to June 1989, with the limitation that the holder shall wear correcting glasses for near vision
Flying experience:
Total all types: 8,068 hours
Total on type: 487 hours

Total last 28 days: 53 hours
Duty time: Commensurate with company requirements
Last base check: 30 October 1988
Last route check: Not required
Last emergencies check: 27 October 1988

1.5.4 Flight Attendants: There were 13 Flight Attendants on the aircraft, all of whom met company proficiency and medical requirements

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1.6 Aircraft information

1.6.1 Leading particulars

Aircraft type: Boeing 747-121
Constructor's serial number: 19646
Engines: 4 Pratt and Whitney JT9D-7A turbofan

1.6.2 General description

The Boeing 747 aircraft, registration N739PA, was a conventionally designed long range transport aeroplane. A diagram showing the general arrangement is shown at Appendix B, Figure B-1 together with the principal dimensions of the aircraft.

The fuselage of the aircraft type was of approximately circular section over most of its length, with the forward fuselage having a diameter of 21† feet where the cross-section was constant. The pressurised section of the fuselage (which included the forward and aft cargo holds) had an overall length of 190 feet, extending from the nose to a point just forward of the tailplane. In normal cruising flight the service pressure differential was at the maximum value of 8.9 pounds per square inch. The fuselage was of conventional skin, stringer and frame construction, riveted throughout, generally using countersunk flush riveting for the skin panels. The fuselage frames were spaced at 20 inch intervals and given the same numbers as their stations, defined in terms of the distance in inches from the datum point close to the nose of the aircraft [Appendix B, Figure B-2]. The skin panels were joined using vertical butt joints and horizontal lap joints. The horizontal lap joints used three rows of rivets together with a cold bonded adhesive.

Accommodation within the aircraft was predominately on the main deck, which extended throughout the whole length of the pressurised compartment. A separate upper deck was incorporated in the forward part of the aircraft. This upper deck was reached by means of a spiral staircase from the main deck and incorporated the flight crew compartment together with additional passenger accommodation. The cross-section of the forward fuselage differed considerably from the near circular section of the remainder of the aircraft, incorporating an additional smaller radius arc above the upper deck section joined to the main circular arc of the lower cabin portion by elements of straight fuselage frames and flat skin.

In order to preserve the correct shape of the aircraft under pressurisation loading, the straight portions of the fuselage frames in the region of the upper deck floor and above it were required to be much stiffer than the frame portions lower down in the aircraft. These straight sections were therefore of very much more substantial construction than most of the curved sections of frames lower down and further back in the fuselage. There was considerable variation in the gauge of the fuselage skin at various locations in the forward fuselage of the aircraft.

The fuselage structure of N739PA differed from that of the majority of Boeing 747 aircraft in that it had been modified to carry special purpose freight containers on the main deck, in place of seats. This was known as the Civil Reserve Air Fleet (CRAF) modification and enabled the aircraft to be quickly converted for carriage of military freight containers on the main deck during times of national emergency. The effect of this modification on the structure of the fuselage was mainly to replace the existing main deck floor beams with beams of more substantial cross-section than those generally found in passenger carrying Boeing 747 aircraft. A large side loading door, generally known as the CRAF door, was also incorporated on the left side of the main deck aft of the wing.

Below the main deck, in common with other Boeing 747 aircraft, were a number of additional compartments, the largest of which were the forward and aft freight holds used for the storage of cargo and baggage in standard air-transportable containers. These containers were placed within the aircraft hold by means of a freight handling system and were carried on a system of rails approximately 2 feet above the outer skin at the bottom of the aircraft, there being no continuous floor, as such, below these baggage containers. The forward freight compartment had a length of approximately 40 feet and a depth of approximately 6 feet. The containers were loaded into the forward hold through a large cargo door on the right side of the aircraft.

1.6.3 Internal fuselage cavities

Because of the conventional skin, frame and stringer type of construction, common to all large public transport aircraft, the fuselage was effectively divided into a series of 'bays'. Each bay, comprising two adjacent fuselage frames and the structure between them, provided, in effect, a series of interlinking cavities bounded by the frames, floor beams, fuselage skins and cabin floor panels etc. The principal cavities thus formed were:

(i) A semi-circular cavity formed in between the fuselage frames in the lower lobe of the hull, i.e. from the crease beam (at cabin floor level) on one side down to the belly beneath the containers and up to the opposite crease beam, bounded by the fuselage skin on the outside and the containers/cargo liner on the inside [Appendix B, Figure B-3, detail A].
(ii) A horizontal cavity between the main cabin floor beams, the cabin floor panels and the cargo bay liner. This extended the full width of the fuselage and linked the upper ends of the lower lobe cavity [Appendix B, Figure B-3, detail B].
(iii) A narrow vertical cavity between the two containers [Appendix B, Figure B-3, detail C].
(iv) A further narrow cavity around the outside of the two containers, between the container skins and the cargo bay liner, communicating with the lower lobe cavity [Appendix B, Figure B-3, detail D].
(v) A continuation of the semi-circular cavity into the space behind the cabin wall liner [Appendix B, Figure B-3, detail E]. This space was restricted somewhat by the presence of the window assembly, but nevertheless provided a continuous cavity extending upwards to the level of the upper deck floor. Forward of station 740, this cavity was effectively terminated at its upper end by the presence of diaphragms which formed extensions of the upper deck floor panels; aft of station 740, the cavity communicated with the ceiling space and the cavity in the fuselage crown aft of the upper deck.

All of these cavities were repeated at each fuselage bay (formed between pairs of fuselage frames), and all of the cavities in a given bay were linked together, principally at the crease beam area [Appendix B, Figure B-3, region F]. Furthermore, each of the set of bay cavities was linked with the next by the longitudinal cavities formed between the cargo hold liner and the outer hull, just below the crease beam [Appendix B, Figure B-3, detail F]; i.e. this cavity formed a manifold linking together each of the bays within the cargo hold.

The main passenger cabin formed a large chamber which communicated directly with each of the sub floor bays, and also with the longitudinal manifold cavity, via the air conditioning and cabin/cargo bay de-pressurisation vent passages in the crease beam area. (It should be noted that a similar communication did not exist between the upper and lower cabins because there were no air conditioning/depressurisation passages to bypass the upper deck floor.)

1.6.4 Aircraft weight and centre of gravity

The aircraft was loaded within its permitted centre of gravity limits as follows:

Loading:	lb	kg
Operating empty weight	366,228	166,120
Additional crew	130	59
243 passengers (1)	40,324	18,291
Load in compartments:		
1	11,616	5,269
2	20,039	9,090
3	15,057	6,830
4	17,196	7,800
5	2,544	1,154
Total in compartments (2)	66,452	30,143
Total traffic load	106,776	48,434
Zero fuel weight	472,156	214,554
Fuel (Take-off)	239,997	108,862
Actual take-off weight(4)	713,002	323,416
Maximum take-off weight	733,992	332,937

Note 1:
Calculated at standard weights and including cabin baggage.

Note 2:
Despatch information stated that the cargo did not include dangerous goods, perishable cargo, live animals or known security exceptions.

1.6.5 Maintenance details

N739PA first flew in 1970 and spent its whole service life in the hands of Pan American World Airways Incorporated. Its Certificate of Airworthiness was issued on 12 February 1970 and remained in force until the time of the accident, at which time the aircraft had completed a total of 72,464 hours flying and 16,497 flight cycles. Details of the last 4 maintenance checks carried out during the aircraft's life are shown below:

DATE	SERVICE	HOURS	CYCLES
27 Sept 88	C Check (Interior upgrade)	71,502	16,347
2 Nov 88	B Service Check	71,919	16,406
27 Nov 88	Base 1	72,210	16,454
13 Dec 88	Base 2	72,374	16,481

The CRAF modification programme was undertaken in September 1987. At the same time a series of modifications to the forward fuselage from the nose back to station 520 (Section 41) were carried out to enable the aircraft to continue in service without a continuing requirement for structural inspections in certain areas.

All Airworthiness Directives relating to the Boeing 747 fuselage structure between stations 500 and 1000 have been reviewed and their applicability to this aircraft checked. In addition, Service Bulletins relating to the structure in this area were also reviewed. The applicable Service Bulletins, some of which implement the Airworthiness Directives are listed below together with their subjects. The dates, total aircraft times and total aircraft cycles at which each relevant inspection was last carried out have been reviewed and their status on aircraft N739PA at the time of the accident has been established.

N739PA Service Bulletin compliance:

SB 53-2064 Front Spar Pressure Bulkhead Chord Reinforcement and Drag Splice Fitting Rework.
Modification accomplished on 6 July 1974.
Post-modification repetitive inspection IAW (in accordance with) AD 84-18-06 last accomplished on 19 November 1985 at 62,030 TAT hours (Total Aircraft Time) and 14,768 TAC (Total Aircraft Cycles).
SB 53-2088 Frame to Tension Tie Joint Modification - BS760 to 780.
Repetitive inspection IAW AD 84-19-01 last accomplished on 19 June 1985 at 60,153 hours TAT and 14,436 TAC.
SB 53-2200 Lower Cargo Doorway Lower Sill Truss and Latch Support Fitting Inspection Repair and Replacement.
Repetitive inspection IAW AD 79-17-02 R2 last accomplished 2 November

1988 at 71,919 hours TAT and 16,406 TAC.
SB 53-2234 Fuselage - Auxiliary Structure - Main Deck Floor - BS 480 Floor Beam Upper Chord Modification.
Repetitive inspection per SB 53A2263 IAW AD 86-23-06 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
SB 53-2237 Fuselage - Main Frame - BS 540 thru 760 and 1820 thru 1900 Frame Inspection and Reinforcement.
Repetitive inspection IAW AD 86-18-01 last accomplished on 27 February 1987 at 67,088 hours TAT and 15,627 TAC.
SB 53-2267 Fuselage - Skin - Lower Body Longitudinal Skin Lap Joint and Adjacent Body Frame Inspection and Repair.
Terminating modification accomplished 100% under wing-to-body fairings and approximately 80% in forward and aft fuselage sections on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
Repetitive inspection of unmodified lap joints IAW AD 86-09-07 R1 last accomplished on 18 August 1988 at 71,043 hours TAT and 16,273 TAC.
SB 53A2303 Fuselage - Nose Section - station 400 to 520 Stringer 6 Skin Lap Splice Inspection, Repair and Modification.
Repetitive inspection IAW AD 89-05-03 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.

This documentation, when viewed together with the detailed content of the above service bulletins, shows the aircraft to have been in compliance with the requirements laid down in each of those bulletins. Some maintenance items were outstanding at the time the aircraft was despatched on the last flight, however, none of these items relate to the structure of the aircraft and none had any relevance to the accident.

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1.7 Meteorological Information

1.7.1 General weather conditions

An aftercast of the general weather conditions in the area of Lockerbie at about 19.00 hrs was obtained from the Meteorological Office, Bracknell. The synoptic situation included a warm sector covering northern England and most of Scotland with a cold front some 200 nautical miles to the west of the area moving eastwards at about 35 knots. The weather consisted of intermittent rain or showers. The cloud consisted of 4 to 6 oktas of stratocumulus based at 2,200 feet with 2 oktas of altocumulus between 15,000 and 18,000 feet. Visibility was over 15 kilometers and the freezing level was at

8,500 feet with a sub-zero layer between 4,000 and 5,200 feet.

1.7.2 Winds

There was a weakening jet stream of around 115 knots above Flight Level 310. From examination of the wind profile (see below), there appeared to be insufficient shear both vertically and horizontally to produce any clear air turbulence but there may have been some light turbulence.

Flight Level	Wind
320	260¡/115 knots
300	260¡/ 90 knots
240	250¡/ 80 knots
180	260¡/ 60 knots
100	250¡/ 60 knots
050	260¡/ 40 knots
Surface	240¡/ 15 to 20 gusting 25 to 30 knots

1.8 Aids to navigation

Not relevant.

1.9 Communications

The aircraft communicated normally on London Heathrow aerodrome, London control and Scottish control frequencies. Tape recordings and transcripts of all radio telephone (RTF) communications on these frequencies were available.

At 18.58 hrs the aircraft established two-way radio contact with Shanwick Oceanic Area Control on frequency 123.95 MHz. At 19.02:44 hrs the clearance delivery officer at Shanwick transmitted to the aircraft its oceanic route clearance. The aircraft did not acknowledge this message and made no subsequent transmission.

1.9.1 ATC recording replay

Scottish Air Traffic Control provided copy tapes with time injection for both Shanwick and Scottish ATC frequencies. The source of the time injection on the tapes was derived from the British Telecom "TIM" signal.

The tapes were replayed and the time signals corrected for errors at the time of the tape mounting.

1.9.2 Analysis of ATC tape recordings

From the cockpit voice recorder (CVR) tape it was known that Shanwick was transmitting Flight PA103's transatlantic clearance when the CVR stopped. By synchronising the Shanwick tape and the CVR it was possible to establish that a loud sound was heard on the CVR cockpit area microphone (CAM) channel at 19.02:50 hrs ±1 second.

As the Shanwick controller continued to transmit Flight PA103's clearance instructions through the initial destruction of the aircraft it would not have been possible for a distress call to be received from N739PA on the Shanwick frequency. The Scottish frequency tape recording was listened to from 19.02 hrs until 19.05 hrs for any unexplained sounds indicating an attempt at a distress call but none was heard.

A detailed examination and analysis of the ATC recording together with the flight recorder, radar, and seismic recordings is contained in Appendix C.

1.10 Aerodrome information

Not relevant

1.11 Flight recorders

The Digital Flight Data Recorder (DFDR) and the Cockpit Voice Recorder (CVR) were found close together at UK Ordnance Survey (OS) Grid Reference 146819, just to the east of Lockerbie, and recovered approximately 15 hours after the accident. Both recorders were taken directly to AAIB Farnborough for replay. Details of the examination and analysis of the flight recorders together with the radar, ATC and seismic recordings are contained in Appendix C.

1.11.1 Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded and that the recorder had simply stopped at 19.02:50 hrs ±1 second.

1.11.2 Cockpit voice recorder

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1 Flight Engineer's RTF.
Channel 2 Co-Pilot's RTF.
Channel 3 Pilot's RTF.
Channel 4 Cockpit Area Microphone.

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings were audible on the RTF channels. The CAM channel was particularly noisy, probably due to the combination of the inherently noisy flight deck of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high flight deck noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified and could have been of either acoustic or electrical origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19.02:50 hrs ±1 second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC.

1.12 Wreckage and impact information

1.12.1 General distribution of wreckage in the field

The complete wing primary structure, incorporating the centre section, impacted at the southern edge of Lockerbie. Major portions of the aircraft, including the engines, also landed in the town. Large portions of the aircraft fell in the countryside to the east of the town and lighter debris was strewn to the east as far as the North Sea. The wreckage was distributed in two trails which became known as the northern and southern trails respectively and these are shown in Appendix B, Figure B-4. A computer database of approximately 1200 significant items of wreckage was compiled and included a brief description of each item and the location where it was found

Appendix B, Figures B-5 to B-8 shows photographs of a model of the aircraft on which the fracture lines forming the boundaries of the separate items of structure have been marked. The model is colour coded to illustrate the way in which the wreckage was distributed between the town of Lockerbie and the northern and southern trails.

1.12.1.1 The crater

The aircraft wing impacted in the Sherwood Crescent area of the town leaving a crater approximately 47 metres (155 feet) long with a volume calculated to be 560 cubic metres.

The projected distance, measured parallel from one leading edge to the other wing tip, of the Boeing 747-100 was approximately 143 feet, whereas the span is known to be 196 feet. This suggests that impact took place with the wing structure yawed. Although the depth of the crater varied from one end to the other, its widest part was clearly towards the western end suggesting that the wing structure impacted whilst orientated with its root and centre section to the west.

The work carried out at the main crater was limited to assessing the general nature of its contents. The total absence of debris from the wing primary structure found remote from the crater confirmed the initial impression that the complete wing box structure had been present at the main impact.

The items of wreckage recovered from or near the crater are coloured grey on the model at Appendix B, Figures B-5 to B-8.

1.12.1.2 The Rosebank Crescent site

A 60 feet long section of fuselage between frame 1241 (the rear spar attachment) and frame 1960 (level with the rear edge of the CRAF cargo door) fell into a housing estate at Rosebank Crescent, just over 600 metres from the crater. This section of the fuselage was that situated immediately aft of the wing, and adjoined the wing and fuselage remains which produced the crater. It is colour coded yellow on the model at Appendix B, Figures B-5 to B-8. All fuselage skin structure above floor level was missing except for the following items:

Section containing 3 windows between door 4L and CRAF door;
The CRAF door itself (latched) apart from the top area containing the hinge;
Window belt containing 8 windows aft of 4R door aperture
Window belt containing 3 windows forward of 4R door aperture;
Door 4R.

Other items found in the wreckage included both body landing gears, the right wing landing gear, the left and right landing gear support beams and the cargo door (frames 1800-1920) which was latched. A number of pallets, luggage containers and their contents were also recovered from this site.

1.12.1.3 Forward fuselage and flight deck section.

The complete fuselage forward of approximately station 480 (left side) to station 380 (right side) and incorporating the flight deck and nose landing gear was found as a single piece [Appendix B, Figure B-9] in a field approximately 4 km miles east of Lockerbie at OS Grid Reference 174808. It was evident from the nature of the impact damage and the ground marks that it had fallen almost flat on its left side but with a slight nose-down attitude and with no discernible horizontal velocity. The impact had caused almost complete crushing of the structure on the left side. The radome and right nose landing gear door had detached in the air and were recovered in the southern trail.

Examination of the torn edges of the fuselage skin did not indicate the presence of any pre-existing structural or material defects which could have accounted for the separation of this section of the fuselage. Equally so, there were no signs of explosive blast damage or sooting evident on any part of the structure or the interior fittings. It was noted however that a heavy, semi-eliptical scuff mark was present on the lower right side of the fuselage at approximately station 360. This was later matched to the intake profile of the No 3 engine.

The status of the controls and switches on the flight deck was consistent with normal operation in cruising flight. There were no indications that the crew had attempted to react to rapid decompression or loss of control or that any emergency preparations had been actioned prior to the catastrophic disintegration.

1.12.1.4 Northern trail

The northern trail was seen to be narrow and clearly defined, to emanate from a point very close to the main impact crater and to be orientated in a direction which agreed closely with the mean wind aftercast for the height band from sea level to 20,000 ft. Also at the western end of the northern trail were the lower rear fuselage at Rosebank Crescent, and the group of Nos. 1, 2 and 4 engines which fell in Lockerbie.

The trail contained items of structure distributed throughout its length, from the area slightly east of the crater, to a point approximately 16 km east, beyond which only items of low weight / high drag such as insulation, interior trim, paper etc, were found. For all practical purposes this trail ended at a range of 25 km.

The northern trail contained mainly wreckage from the rear fuselage, fin and the inner regions of both tailplanes together with structure and skin from the upper half of the fuselage forward to approximately the wing mid-chord position. A number of items from the wing were also found in the northern trail, including all 3 starboard Kreuger flaps, most of the remains of the port Kreuger flaps together with sections of their leading edge attachment structures, one portion of outboard aileron approximately 10 feet long, the aft ends of the flap-track fairings (one with a slide raft wrapped around it), and fragments of glass reinforced plastic honeycombe structure believed to be from the flap system, i.e. fore-flaps, aft-flaps, mid-flaps or adjacent fairings. In addition, a number of pieces of the engine cowlings and both HF antennae (situated projecting aft from the wing-tips) were found in this trail.

All items recovered from the northern trail, with the exception of the wing, engines, and lower rear fuselage in Rosebank Crescent, are coloured red on the model of the aircraft in Appendix B, Figures B-5 to B-8.

1.12.1.5 Southern trail

The southern trail was easily defined, except within 12 km of Lockerbie where it tended to merge with the northern trail. Further east, it extended across southern Scotland and northern England, essentially in a straight band as far as the North Sea. Most of the significant items of wreckage were found in this trail within a range of 30 km from the main impact crater. Items recovered from the southern trail are coloured green on the model of the aircraft at Appendix B, Figures B-5 to B-8.

The trail contained numerous large items from the forward fuselage. The flight deck and nose of the aircraft fell in the curved part of this trail close to Lockerbie. Fragments of the whole of the left tailplane and the outboard portion of the right tailplane were distributed almost entirely throughout the southern trail. Between 21 and 27 km east of the main impact point (either side of Langholm) substantial sections of tailplane skin were found, some bearing distinctive signs of contact with debris moving outwards and backwards relative to the fuselage. Also found in this area were numerous isolated sections of fuselage frame, clearly originating from the crown region above the forward upper deck.

1.12.1.6 Datum line

All grid references relating to items bearing actual explosive evidence, together with those attached to heavily distorted items found to originate immediately adjacent to them on the structure, were plotted on an Ordnance Survey (OS) chart. These references, 11 in total, were all found to be distributed evenly about a mean line orientated 079¡(Grid) within the southern trail and were spread over a distance of 12 km. The distance of each reference from the line was measured in a direction parallel to the aircraft's track and all were found to be within 500 metres of the line, with 50% of them being within 250 metres of the line. This line is referred to as the datum line and is shown in Appendix B, Figure B-4.

1.12.1.7 Distribution of wreckage within the southern trail

North of the datum line and parallel to it were drawn a series of lines at distances of 250, 300, 600 and 900 metres respectively from the line, again measured in a direction parallel to the aircraft's track. The positions on the aircraft structure of specific items of wreckage, for which grid references were known with a high degree of confidence, within the bands formed between these lines, are shown in Appendix B, Figures B-10 to 13. In addition, a separate assessment of the grid references of tailplane and elevator wreckage established that these items were distributed evenly about the 600 metre line.

1.12.1.8 Area between trails

Immediately east of the crater, the southern trail converged with the northern trail such that, to an easterly distance of approximately 5 km, considerable wreckage existed which could have formed part of either trail. Further east, between 6 and 11 km from the crater, a small number of sections and fragments of the fin had fallen outside the southern boundary of the northern trail. Beyond this a large area existed between the trails in which there was no wreckage.

1.12.2 Examination of wreckage at CAD Longtown

The debris from all areas was recovered by the Royal Air Force to the Army Central Ammunition Depot Longtown, about 20 miles from Lockerbie. Approximately 90% of the hull wreckage was successfully recovered, identified, and laid out on the floor in a two-dimensional reconstruction [Appendix B, Figure B-14]. Baggage container material was incorporated into a full three-dimensional reconstruction. Items of wreckage added to the reconstructions was given a reference number and recorded on a computer database together with a brief description of the item and the location where it was found.

1.12.2.1 Fuselage

The reconstruction revealed the presence of damage consistent with an explosion on the lower fuselage left side in the forward cargo bay area. A small region of structure bounded approximately by frames 700 & 720 and stringers 38L & 40L, had clearly been shattered and blasted through by material exhausting directly from an explosion centred immediately inboard of this location. The material from this area, hereafter referred to as the 'shatter zone', was mostly reduced to very small fragments, only a few of which were recovered, including a strip of two skins [Appendix B, Figure B-15] forming part of the lap joint at the stringer 39L position.

Surrounding the shatter zone were a series of much larger panels of torn fuselage skin which formed a 'star-burst' fracture pattern around the shatter zone. Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range. In contrast, the star-burst fractures, outside the boundary of the shatter zone, displayed evidence of more typical overload tearing, though some tears appeared to be rapid and, in the area below the missing panels, were multi-branched. These surrounding skin panels were moderately sooted in the regions adjacent to the shatter zone, but otherwise were lightly sooted or free of soot altogether. (Forensic analysis of the soot deposits on frame and skin material from this area confirmed the presence of explosive residues.) All of these skin panels had pulled away from the supporting structure and had been bent and torn in a manner which indicated that, as well as fracturing in the star burst pattern, they had also petalled outwards producing characteristic, tight curling of the sheet material.

Sections of frames 700 and 720 from the area of the explosion were also recovered and identified. Attached to frame 720 were the remnants of a section of the aluminium baggage container (side) guide rail, which was heavily distorted and displayed deep pitting together with very heavy sooting, indicating that it had been very close to the explosive charge. The pattern of distortion and damage on the frames and guide rail segment matched the overall pattern of damage observed on the skins.

The remainder of the structure forming the cargo deck and lower hull was, generally, more randomly distorted and did not display the clear indications of explosive processes which were evident on the skin panels and frames nearer the focus of the explosion. Nevertheless, the overall pattern of damage was consistent with the propagation of explosive pressure fronts away from the focal area inboard of the shatter zone. This was particularly evident in the fracture and bending characteristics of several of the fuselage frames ahead of, and behind station 700.

The whole of the two-dimensional fuselage reconstruction was examined for general evidence of the mode of disintegration and for signs of localised damage, including overpressure damage and pre-existing damage such as corrosion or fatigue. There was some evidence of corrosion and dis-bonding at the cold-bond lap joints in the fuselage. However, the corrosion was relatively light and would not have compromised significantly the static strength of the airframe. Certainly, there was no evidence to suggest that corrosion had affected the mode of disintegration, either in the area of the explosion or at areas more remote. Similarly, there were no indications of fatigue damage except for one very small region of fatigue, involving a single crack less than 3 inches long, which was remote from the bomb location. This crack was not in a critical area and had not coincided with a fracture path.

No evidence of overpressure fracture or distortion was found at the rear pressure bulkhead. Some suggestion of 'quilting' or 'pillowing' of skin panels between stringers and frames, indicative of localised overpressure, was evident on the skin panels attached to the larger segments of lower fuselage wreckage aft of the blast area. In addition, the mode of failure of the butt joint at station

520 suggested that there had been a rapid overpressure load in this area, causing the fastener heads to 'pop' in the region of stringers 13L to 16L, rather than producing shear in the fasteners. Further evidence of localised overpressure damage remote from the source of the explosion was found during the full three-dimensional reconstruction, detailed later in paragraph 1.12.3.2.

An attempt was made to analyse the fractures, to determine the direction and sequence of failure as the fractures propagated away from the region of the explosion. It was found that the directions of most of the fractures close to the explosion could be determined from an analysis of the fracture surfaces and other features, such as rivet and rivet hole distortions. However, it was apparent that beyond the boundary of the petalled region, the disintegration process had involved multiple fractures taking place simultaneously - extremely complex parallel processes which made the sequencing of events not amenable to conventional analysis.

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1.12.2.2 Wing structure and adjacent fuselage area

On completion of the initial layout at Longtown it became evident that, in the area from station 1000 to approximately station 1240 the only identifiable fuselage structure consisted of elements of fuselage skin, stringers and frames from above the cabin window belts. The wreckage from in and around the crater was therefore sifted to establish more accurately what sections of the aircraft had produced the crater. All of the material was highly fragmented, but it was confirmed that the material comprised mostly wing structure, with a few fragments of fuselage sidewall and passenger seats. The badly burnt state of these fragments made it clear that they were recovered from the area of the main impact crater, the only scene of significant ground fire. Amongst these items a number of cabin window forgings were recovered with sections of thick horizontal panelling attached having a length equivalent to the normal window spacing/frame pitch. This arrangement, with skins of this thickness, is unique to the area from station 1100 to 1260. It is therefore reasonable to assume that these fragments formed parts of the missing cabin sides from station 1000 to station 1260, which must have remained attached to the wing centre section at the time of its impact. Because of the high degree of fragmentation and the relative insignificance of the wing in terms of the overall explosive damage pattern, a reconstruction of the wing material was not undertaken. The sections of the aircraft which went into the crater are colour coded grey in Appendix B, Figures B-5 to B-8.

1.12.2.3 Fin and aft section of fuselage

Examination of the structure of the fin revealed evidence of in-flight damage to the leading edge caused by the impact of structure or cabin contents. This damage was not severe or extensive and the general break-up of the fin did not suggest either a single readily defined loading direction, or break-up due to the effects of leading edge impact. A few items of fin debris were found between the northern and southern trails.

A number of sections of fuselage frame found in the northern trail exhibited evidence of plastic deformation of skin attachment cleats and tensile overload failure of the attachment rivets. This damage was consistent with that which would occur if the skin had been locally subjected to a high loading in a direction normal to its plane. Although this was suggestive of an internal overpressure condition, the rear fuselage revealed no other evidence to support this possibility. Examination of areas of the forward fuselage known to have been subjected to high blast overpressures revealed no comparable evidence of plastic deformation in the skin attachment cleats or rivets, most skin attachment failures appearing to have been rapid.

Calculations made on the effects of internal pressure generated by an open ended fuselage descending at the highest speed likely to have been experienced revealed that this could not generate an internal pressure approaching that necessary to cause failure in an intact cabin structure.

1.12.2.4 Baggage containers

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited damage consistent with being close to a detonating high explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence of explosive damage. It was evident, from the main wreckage layout, that the explosion had occurred in the forward cargo hold and, although all baggage container wreckage was examined, only items from this area which showed the relevant characteristics were considered for the reconstruction. Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to Lockerbie, whilst that from the forward hold was scattered along the southern wreckage trail.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this, two adjacent containers, one of metal construction the other fibreglass, were identified as exhibiting damage likely to have been caused by the explosion. Those parts which could be positively identified as being from these two containers were assembled onto one of three simple wooden frameworks, one each for the floor and superstructure of the metal container and one for the superstructure of the fibreglass container. From this it was positively determined that the explosion had occurred within the metal container (serial number AVE 4041 PA), the direct effects of this being evident also on the forward face of the adjacent fibreglass container (serial number AVN 7511 PA) and on the local airframe on the left side of the aircraft in the region of station 700. It was therefore confirmed that this metal container had been loaded in position 14L in agreement with the aircraft loading records. While this work was in progress a buckled section of the metal container skin was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device (IED).

The reconstruction of these containers and their relationship to the aircraft structure is described in detail in Appendix F. Examination of all other components of the remaining containers revealed only damage consistent with ejection into the high speed slipstream and/or ground impact, and that only one device had detonated within the containers on board the aircraft.

1.12.3 Fuselage three-dimensional reconstruction

1.12.3.1 The reconstruction

The two-dimensional reconstruction successfully established that there had been an explosion in the forward hold; its location was established and the general damage characteristics in the vicinity of the explosion were determined. However, the mechanisms by which the failure process developed from local damage in the immediate vicinity of the explosion to the complete structural break-up and separation of the whole forward section of the fuselage, could not be adequately investigated without recourse to a more elaborate reconstruction.

To facilitate this additional work, wreckage forming a 65 foot section of the fuselage (approximately 30 feet each side of the explosion) was transported to

AAIB Farnborough, where it was attached to a specially designed framework to form a fully three-dimensional reconstruction [Appendix B, Figures B-16 and B-17] of the complete fuselage between stations 360 & 1000 (from the separated nose section back to the wing cut out). The support framework was designed to provide full and free access to all parts of the structure, both internally and externally. Because of height constraints, the reconstruction was carried out in two parts, with the structure divided along a horizontal line at approximately the upper cabin floor level. The previously reconstructed containers were also transported to AAIB Farnborough to allow correlation of evidence with, and partial incorporation into, the fuselage reconstruction.

Structure and skin panels were attached to the supporting framework by their last point of attachment, to provide a better appreciation of the modes and direction of curling, distortion, and ultimate separation. Thus, the panels of skin which had petalled back from the shatter zone were attached at their outer edges, so as to identify the bending modes of the panels, the extent of the petalled region, and also the size of the resulting aperture in the hull. In areas more remote from the explosion, the fracture and tear directions were used together with distortion and curling directions to determine the mode of separation, and thus the most appropriate point of attachment to the reconstruction. Cabin floor beam segments were supported on a steel mesh grid and a plot of the beam fractures is shown at Appendix B, Figure B-18.

The cargo container base elements were separated from the rest of the container reconstruction and transferred to the main wreckage reconstruction, where the re-assembled container base was positioned precisely onto the cargo deck. To assist in the correlation of the initial shatter zone and petalled-out regions with the position of the explosive device, the boundaries of the skin panel fractures were marked on a transparent plastic panel which was then attached to the reconstruction to provide a transparent pseudo-skin showing the positions of the skin tear lines. This provided a clear visual indication of the relationship between the skin panel fractures and the explosive damage to the container base, thus providing a more accurate indication of the location of the explosive device.

1.12.3.2 Summary of explosive features evident

The three-dimensional reconstruction provided additional information about the region of tearing and petalling around the shatter zone. It also identified a number of other regions of structural damage, remote from the explosion, which were clearly associated with severe and rapidly applied pressure loads acting normal to the skin's internal surface. These were sufficiently sharp-edged to pre-empt the resolution of pressure induced loads into membrane tension stresses in the skin: instead, the effect was as though these areas of skin had been struck a severe 'pressure blow' from within the hull.

The two types of damage, i.e. the direct blast/tearing/petalling damage and the quite separate areas of 'pressure blow' damage at remote sites were evidently caused by separate mechanisms, though it was equally clear that each was caused by explosive processes, rather than more general disintegration.

The region of petalling was bounded (approximately) by frames 680 and 740, and extended from just below the window belt down nearly to the keel of the aircraft [Appendix B, Figure B-19, region A]. The resulting aperture measured approximately 17 feet by 5 feet. Three major fractures had propagated beyond the boundary of the petalled zone, clearly driven by a combination of hull pressurisation loading and the relatively long term (secondary) pressure pulse from the explosion. These fractures ran as follows:

(i) rearwards and downward in a stepped fashion, joining the stringer 38L lap joint at around station 840, running aft along stringer 38L to around station 920, then stepping down to stringer 39L and running aft to terminate at the wing box cut-out [Appendix B, Figure B-19, fracture 1].
(ii) downwards and forward to join the stringer 44L lap joint, then running forward along stringer 44L as far as station 480 [Appendix B, Figure B-19, fracture 2].
(iii) downwards and rearward, joining the butt line at station 740 to run under the fuselage and up the right side to a position approximately 18 inches above the cabin floor level [Appendix B, Figures B-19 and B-20, fracture 3].

The propagation of tears upwards from the shatter zone appeared to have taken the form of a series of parallel fractures running upwards together before turning towards each other and closing, forming large flaps of skin which appear to have separated relatively cleanly.

Regions of skin separation remote from the site of the explosion were evident in a number of areas. These principally were:

(i) A large section of upper fuselage skin extending from station 500 back to station 760, and from around stringers 15/19L up as far as stringer 5L [Appendix B, Figures B-19 and B-20, region B], and probably extending further

up over the crown. This panel had separated initially at its lower forward edge as a result of a pressure blow type of impulse loading, which had popped the heads from the rivets at the butt joint on frame 500 and lifted the skin flap out into the airflow. The remainder of the panel had then torn away rearwards in the airflow.
A region of 'quilting' or 'pillowing', i.e. spherical bulging of skin panels between frames and stringers, was evident on these panels in the region between station 560 and 680, just below the level of the upper deck floor, indicative of high internal pressurisation loading [Appendix B, Figure B-19, region C].
(ii) A smaller section of skin between stations 500 and 580, bounded by stringers 27L and 34L [Appendix B, Figure B-19, region D], had also been 'blown' outwards at its forward edge and torn off the structure rearwards. A characteristic curling of the panel was evident, consistent with rapid, energetic separation from the structure.
(iii) A section of thick belly skin extending from station 560, stringers 40R to 44R, and tapering back to a point at stringer 45R/station720 [Appendix B, Figure B-19 and B-20, region E], had separated from the structure as a result of a very heavy 'pressure blow' load at its forward end which had popped the heads off a large number of substantial skin fasteners. The panel had then torn away rearwards from the structure, curling up tightly onto itself as it did so - indicating that considerable excess energy was involved in the separation process (over and above that needed simply to separate the skin material from its supporting structure).
(iv) A panel of skin on the right side of the aircraft, roughly opposite the explosion, had been torn off the frames, beginning at the top edge of the panel situated just below the window belt and tearing downwards towards the belly [Appendix B, Figure B-20, region F]. This panel was curled downwards in a manner which suggested significant excess energy.

Appendix B, Figure B-21 shows a plot of the fractures noted in the fuselage skins between stations 360 and 1000.

The cabin floor structure was badly disrupted, particularly in the general area above the explosion, where the floor beams had suffered localised upward loading sufficient to fracture them, and the floor panels were missing. Elsewhere, floor beam damage was mainly limited to fractures at the outer ends of the beams and at the centreline, leaving sections of separated floor structure comprising a number of half beams joined together by the Nomex honeycomb floor panels.

1.12.3.3 General damage features not directly associated with explosive forces.

A number of features appeared to be a part of the general structural break-up which followed on from the explosive damage, rather than being a part of the explosive damage process itself. This general break-up was complex and, to a certain extent, random. However, analysis of the fractures, surface scores, paint smears and other features enabled a number of discreet elements of the break-up process to be identified. These elements are summarised below.

(i) Buckling of the window belts on both sides of the aircraft was evident between stations 660 and 800. That on the left side appeared to be the result of in-plane bending in a nose up sense, followed by fracture. The belt on the right side had a large radius curve suggesting lateral deflection of the fuselage possibly accompanied by some longitudinal compression. This terminated in a peeling failure of the riveted joint at station 800.
(ii) On the left side three fractures, apparently resulting from in-plane bending/buckling distortion, had traversed the window belt [Appendix B, Figure B-21, detail G]. Of these, the forward two had broken through the window apertures and the aft fracture had exploited a rivet line at the region of reinforcement just forward of the L2 door aperture. On the right side, the window belt had peeled rearwards, after buckling had occurred, separating from the rest of the fuselage, following rivet failure, at the forward edge of the R2 door aperture.
(iii) All crown skins forward of frame 840 were badly distorted and a number of pieces were missing. It was clearly evident that the skin sections from this region had struck the empennage and/or other structure following separation.
(iv) The fuselage left side lower lobe from station 740 back to the wing box cut-out, and from the window level down to the cargo deck floor (the fracture line along stringer 38L), had peeled outwards, upwards and rearwards - separating from the rest of the fuselage at the window belt. The whole of this separated section had then continued to slide upwards and rearwards, over the fuselage, before being carried back in the slipstream and colliding with the outer leading edge of the right horizontal stabiliser, completely disrupting the outer half. A fragment of horizontal stabiliser spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door [Appendix B, Figure B-22].
(v) A large, clear, imprint of semi-eliptical form was apparent on the lower right side at station 360 which had evidently been caused by the separating forward fuselage section striking the No 3 engine as it swung rearwards and to the right (confirmed by No 3 engine fan cowl damage).

1.12.3.4 Tailplane three-dimensional reconstruction

The tailplane structural design took the form of a forward and an aft torque box. The forward box was constructed from light gauge aluminium alloy sheet skins, supported by closely pitched, light gauge nose ribs but without lateral stringers. The aft torque box incorporated heavy gauge skin/stringer panels with more widely spaced ribs. The front spar web was of light gauge material. Leading edge impacts inflicted by debris would therefore have had the capacity to reduce the tailplane's structural integrity by passing through the light gauge skins and spar web into the interior of the aft torque box, damaging the shear connection between top and bottom skins in the process and thereby both removing the bending strength of the box and opening up the weakened structure to the direct effects of the airflow.

Examination of the rebuilt tailplane structure at AAIB Farnborough left little doubt that it had been destroyed by debris striking its leading edges. In addition, the presence on the skins of smear marks indicated that some unidentified soft debris had contacted those surfaces whilst moving with both longitudinal and lateral velocity components relative to the aircraft.

The reconstructed left tailplane [Appendix B, Figure B-23] showed evidence that disruption of the inboard leading edge, followed respectively by the forward torque box, front spar web and main torque box, occurred as a result of frontal impact by the base of a baggage container. Further outboard, a compact object appeared to have struck the underside of the leading edge and penetrated to the aft torque box. In both cases, the loss of the shear web of the front spar appeared to have permitted local bending failure of the remaining main torque box structure in a tip downwards sense, consistent with the normal load direction. For both events to have occurred it would be reasonable to assume that the outboard damage preceded that occurring inboard.

The right tailplane exhibited massive leading edge impact damage on the outboard portion which also appeared to have progressed to disruption of the aft torsion box. A fragment of right tailplane spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door and it is clear that this area of forward left fuselage had travelled over the top of the aircraft and contributed to the destruction of the outboard right tailplane.

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1.12.4 Examination of engines

All four engines had struck the ground in Lockerbie with considerable velocity and therefore sustained major damage, in particular to most of the fan blades. The No 3 engine had fallen 1,100 metres north of the other three engines, striking the ground on its rear face, penetrating a road surface and coming to rest without any further change of orientation i.e. with the front face remaining uppermost. The intake area contained a number of loose items originating from within the cabin or baggage hold. It was not possible initially to determine whether any of the general damage to any of the engine fans or the ingestion noted in No 3 engine intake occurred whilst the relevant engines were delivering power or at a later stage.

Numbers 1, 2 and 3 engines were taken to British Airways Engine Overhaul Limited for detailed examination under AAIB supervision in conjunction with a specialist from the Pratt and Whitney Engine Company. During this examination the following points were noted:

(i) No 2 engine (situated closest to the site of the explosion) had evidence of blade "shingling" in the area of the shrouds consistent with the results of major airflow disturbance whilst delivering power. (This effect is produced when random bending and torsional deflection occurs, permitting the mid-span shrouds to disengage and repeatedly strike the adjacent aerofoil surfaces of the blades). The interior of the air intake contained paint smears and other evidence suggesting the passage of items of debris. One such item of significance was a clear indentation produced by a length of cable of diameter and strand size similar to that typically attached to the closure curtains on the baggage containers.

(ii) No 3 engine, identified on site as containing ingested debris from within the aircraft, nonetheless had no evidence of the type of shingling seen on the blades of No 2 engine. Such evidence is usually unmistakable and its absence is a clear indication that No 3 engine did not suffer a major intake airflow disturbance whilst delivering significant power. The intake structure was found to have been crushed longitudinally by an impact on the front face although, as stated earlier, it had struck the ground on its rear face whilst falling vertically.

(iii) All 3 engines had evidence of blade tip rubs on the fan cases having a combination of circumference and depth greater than hitherto seen on any investigation witnessed on Boeing 747 aircraft by the Pratt and Whitney specialists. Subsequent examination of No 4 engine confirmed that it had a similar deep, large circumference tip rub. These tip-rubs on the four engines were centred at slightly different clock positions around their respective fan cases.

The Pratt and Whitney specialists supplied information which was used to interpret the evidence found on the blades and fan cases including details of engine dynamic behaviour necessary to produce the tip rub evidence. This indicated that the depth and circumference of tip rubs noted would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left.

Pratt and Whitney also advised that:

(i) Airflow disruption such as that presumed to have caused the shingling observed on No 2 engine fan blades was almost invariably the result of damage to the fan blade aerofoils, resulting from ingestion or blade failure.
(ii) Tip rubs of a depth and circumference noted on all four engines could be expected to reduce the fan rotational energy on each to a negligible value within approximately 5 seconds.
(iii) Airflow disruption sufficient to cause the extent of shingling noted on the fan blades of No 2 engine would also reduce the rotational fan energy to a negligible value within approximately 5 seconds.

1.13 Medical and pathological information

The results of the post mortem examination of the victims indicated that the majority had experienced severe multiple injuries at different stages, consistent with the in-flight disintegration of the aircraft and ground impact. There was no pathological indication of an in-flight fire and no evidence that any of the victims had been injured by shrapnel from the explosion. There was also no evidence which unequivocally indicated that passengers or cabin crew had been killed or injured by the effects of a blast. Although it is probable that those passengers seated in the immediate vicinity of the explosion would have suffered some injury as a result of blast, this would have been of a secondary or tertiary nature.

Of the casualties from the aircraft, the majority were found in areas which indicated that they had been thrown from the fuselage during the disintegration. Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section. The fragmented remains of

13 passengers who had been allocated seats around the eight missing persons were found in or near the crater formed by the wing. Whilst there is no unequivocal proof that the missing people suffered the same fate, it would seem from the pattern that the missing passengers remained attached to the wing structure until impact.

1.14 Fire

Of the several large pieces of aircraft wreckage which fell in the town of Lockerbie, one was seen to have the appearance of a ball of fire with a trail of flame. Its final path indicated that this was the No 3 engine, which embedded itself in a road in the north-east part of the town. A small post impact fire posed no hazard to adjacent property and was later extinguished with water from a hosereel. The three remaining engines landed in the Netherplace area of the town. One severed a water main and the other two, although initially on fire, were no risk to persons or property and the fires were soon extinguished.

A large, dark, delta shaped object was seen to fall at about the same time in the Sherwood area of the town. It was not on fire while in the air, however, a fireball several hundred feet across followed the impact. It was of relatively short duration and large amounts of debris were thrown into the air, the lighter particles being carried several miles downwind, while larger pieces of burning debris caused further fires, including a major one at the Townfoot Garage, up to 350 metres from the source. It was determined that the major part of both wings, which included the aircraft fuel tanks, had formed the crater. A gas main had also been ruptured during the impact.

At 19.04 hrs the Dumfries Fire Brigade Control received a call from a member of the public which indicated that there had been a "huge boiler explosion" at Westacres, Lockerbie, however, subsequent calls soon made it clear that it was an aircraft which had crashed. At 19.07 hrs the first appliances were mobile and at 1910 hrs one was in attendance in the Rosebank area. Multiple fires were identified and it soon became apparent that a major disaster had occurred in the town and the Fire Brigade Major Incident Plan was implemented. During the initial phase 15 pumping appliances from various brigades were deployed but this number was ultimately increased to 20.

At 22.09 hrs the Firemaster made an assessment of the situation. He reported that there was a series of fires over an area of the town centre extending 1† by € mile. The main concentration of the fire was in the southwest of the town around Sherwood Park and Sherwood Crescent. Appliances were in attendance at other fires in the town, particularly in Park Place and Rosebank Crescent. Water and electricity supplies were interrupted and water had to be brought into the town.

By 02.22 hrs on 22 December, all main seats of fire had been extinguished and the firemen were involved in turning over and damping down. At 04.42 hrs small fires were still occurring but had been confined to the Sherwood Crescent area.

1.15 Survival aspects

1.15.1 Survivability

The accident was not survivable.

1.15.2 Emergency services

A chronology of initial responses by the emergency services is listed below:-

Time	Event
19.03 hrs	Radio message from Police patrol in Lockerbie to Dumfries and Galloway Constabulary reporting an aircraft crash at Lockerbie.
19.04 hrs	Emergency call to Dumfries and Galloway Fire Brigade.
19.37 hrs	First ambulances leave for Dumfries and Galloway Royal Infirmary with injured town residents. (2- serious; 3- minor)
19.40 hrs	Sherwood Park and Sherwood Crescent residents evacuated to Lockerbie Town Hall.
20.25 hrs	Nose section of N739PA discovered at Tundergarth (approximately 4 km east of Lockerbie).

During the next few days a major emergency operation was mounted using the guidelines of the Dumfries and Galloway Regional Peacetime Emergency Plan. The Dumfries and Galloway Constabulary was reinforced by contingents from Strathclyde and Lothian & Borders Constabularies. Resources from HM Forces were made available and this support was subsequently authorised by the Ministry of Defence as Military Aid to the Civil Power. It included the provision of military personnel and a number of helicopters used mainly in the search for and recovery of aircraft wreckage. It was apparent at an early stage that there were no survivors from the aircraft and the search and recovery of bodies was mainly a Police task with military assistance.

Many other agencies were involved in the provision of welfare and support services for the residents of Lockerbie, relatives of the aircraft's occupants and personnel involved in the emergency operation.

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1.16 Tests and research

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity spherically propagating shock wave which will expand outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant because it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter, irrespective of charge size, thus providing a means of calculating the standoff distance of the explosive charge from the fuselage skin. Calculations suggest that a charge standoff distance of aproximately 25 inches would result in a shattered region approximately 18 to 20 inches in diameter, comparable to the size of the shattered region evident in the wreckage. This aspect is covered in greater detail in [Appendix G].

1.17 Additional information

1.17.1 Recorded radar information

Recorded radar information on the aircraft was available from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen from which it was clear that the flight had progressed in a normal manner until secondary surveillance radar (SSR) was lost.

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. The last secondary return from the aircraft was recorded at 19.02:46.9 hrs, identifying N739PA at Flight Level 310, and at the next radar return there is no SSR data, only 4 primary returns. It was concluded that the aircraft was, by this time, no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items had been ejected at high speed probably to both right and left of the aircraft.

Each rotation of the radar head thereafter showed the number of returns increasing, with those first identified across track having slowed down very quickly and followed a track along the prevailing wind line. The radar evidence then indicated that a further break-up of the aircraft had occurred and formed a parallel wreckage trail to the north of the first. From the absence of any returns travelling along track it was concluded that the main wreckage was travelling almost vertically downwards for much of the time.

A detailed analysis of the recorded radar information, together with the radar, ATC and seismic recordings is contained in Appendix C.

1.17.2 Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event measuring 1.6 on the Richter scale and, with appropriate corrections for the times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

An analysis of the seismic recording, together with the radar, ATC and radar information is contained in Appendix C.

1.17.3 Trajectory analysis

A detailed trajectory analysis was carried out by Cranfield Institute of Technology in an effort to provide a sequence for the aircraft disintegration. This analysis comprised several separate processes, including individual trajectory calculations for a limited number of key items of wreckage and mathematical modelling of trajectory paths adopted by a series of hypothetical items of wreckage encompassing the drag/weight spectrum of the actual wreckage.

The work carried out at Cranfield enabled the reasons for the two separate trails to be established. The narrow northern trail was shown to be created by debris released from the aircraft in a vertical dive between 19,000 and 9,000 feet overhead Lockerbie. The southern trail, longer and straight for most of its length, appeared to have been created by wreckage released during the initial disintegration at altitude whilst the aircraft was in level flight. Those items falling closest to Lockerbie would have been those with higher density which would travel a significant distance along track before losing all along-track velocity, whilst only drifting a small distance downwind, owing to the high speed of their descent. The most westerly items thus showed the greatest such effect. The southern trail therefore had curved boundaries at its western end with the curvature becoming progressively less to the east until the wreckage essentially fell in a straight band. Thus wreckage in the southern trail positioned well to the east could be assumed to have retained negligible velocity along aircraft track after separation and the along-track distribution could be used to establish an approximate sequence of initial disintegration.

The analysis calculated impact speeds of 120 kts for the nose section weighing approximately 17,500 lb and 260 kts for the engines and pylons which each weighed about 13,500 lb. Based on the best available data at the time, the analysis showed that the wing (approximately 100,000 lb of structure containing an estimated 200,000 lb of fuel) could have impacted at a speed, in theory, as high as 650 kts if it had 'flown' in a streamlined attitude such that the drag coefficient was minimal. However, because small variations of wing incidence (and various amounts of attached fuselage) could have resulted in significant increases in drag coefficient, the analysis also recognized that the final impact speed of the wing could have been lower.

1.17.4 Space debris re-entry

Four items of space debris were known to have re-entered the Earth's atmosphere on 21 December 1988. Three of these items were fragments of debris which would not have survived re-entry, although their burn up in the upper atmosphere might have been visible from the Earth's surface. The fourth item landed in the USSR at 09.50 hrs UTC.

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2 ANALYSIS

2.1 Introduction

The airport security and criminal aspects of the destruction of Boeing 747 registration N739PA near Lockerbie on 21 December 1988 are the subjects of a separate investigation and are not covered in this report. This analysis discusses the technical aspects of the disintegration of the aircraft and considers possible ways of mitigating the effects of an explosion in the future.

2.2 Explosive destruction of the aircraft

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage, including those exhibiting positive evidence of a detonating high performance plastic explosive. The scatter of these items about the datum line may have been due partly to velocities imparted by the force of the detonating explosive and partly by the difficulty experienced in pinpointing the location of the wreckage accurately in relatively featureless terrain and poor visibility. However, the random nature of the scatter created by these two effects would have tended to counteract one another, and a major error in any one of the eleven grid references would have had little overall effect on the whole line. There is, therefore, good reason to have confidence in the validity of the datum line.

The items used to define the datum line, included those exhibiting positive evidence of a detonating high performance plastic explosive, would have been the first pieces to have been released from the aircraft. The datum line was projected westwards until it intersected the known radar track of the aircraft in order to derive the position of the aircraft along track at which the explosive items were released and therefore the position at which the IED had detonated. This position was OS grid reference 146786 and is annotated Point C in Appendix B, Figure B-4. Point C was well within the circle of accuracy

(±525 metres) of the position at which the loud noise was heard on the CVR (Point B). There can, therefore, be no doubt that the loud noise on the CVR was directly associated with the detonation of the IED and that this explosion initiated the disintegration process and directly caused the loss of the aircraft.

2.3 Flight recorders

2.3.1 Digital flight data recordings

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to € second. These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the recording from the DFDR fitted to N739PA, which is detailed in Appendix C, showed that the recorded data simply stopped. Following careful examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19.02:50 hrs ±1 second. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or was old data from a previous recording.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when the aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

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2.3.2 Cockpit voice recorders

The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the CVR when it stopped at 19.02:50 hrs ±1 second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

2.3.3 Detection of explosive occurrences

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985, RARDE were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems. This recommendation was accepted.

Preliminary results from the trials indicate that, if a suitable sensor can be developed, its output will need to be recorded in real time and therefore it may require wiring to the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

2.4 IED position within the aircraft

From the detailed examination of the reconstructed luggage containers, discussed at paragraph 1.12.2.4 and in Appendix F, it was evident that the IED had been located within a metal container (serial number AVE 4041 PA), near its aft outboard quarter as shown in Appendix F, Figure F-13. It was also clear that the container was loaded in position 14L of the forward hold which placed the explosive charge approximately 25 inches inboard from the fuselage skin at frame 700. There was no evidence to indicate that there was more than one explosive charge.

2.5 Engine evidence

To produce the fan blade tip rub damage noted on all engines by means of airflow inclined to the axes of the nacelles would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left while all of the engines were attached to the wing.

The shingling damage noted on the fan blades of No 2 engine can only be attributed to airflow disturbance caused by ingestion related fan blade damage occurring when substantial power was being delivered. This is readily explained by the fact that No 2 engine intake is positioned some 27 feet aft and 30 feet outboard of the site of the explosion and that the interior of the intake exhibited a number of prominent paint smears and general foreign object damage. This damage included evidence of a strike by a cable similar to that forming part of the closure curtain of a typical baggage container. It is inconceivable that an independent blade failure could have occurred in the short time frame of this event. By similar reasoning, the absence of such shingling damage on blades of No 3 engine was a reliable indication that it suffered no ingestion until well into the accident sequence.

The combination of the position of the explosive device and the forward speed of the aircraft was such that significant sized debris resulting from the explosion would have been available to be ingested by No 2 engine within milliseconds of the explosion. In view of the fact that the tip rub damage observed on the fan case of No 2 engine is of similar magnitude to that observed on the other three engines it is reasonable to deduce that a manoeuvre of the aircraft occurred before most of the energy of the No 2 engine fan was lost due to the effect of ingestion (seen only in this engine). Since this shingling effect could only readily be produced as a by-product of ingestion whilst delivering considerable power, it is reasonable to assume that this was also occurring before loss of major fan energy due to tip rubbing took place. Hence both phenomena must have been occurring simultaneously, or nearly so, to produce the effects observed and must have occupied a time frame of substantially less than 5 seconds. The onset of this time period would have been the time at which debris from the explosion first inflicted damage to fan blades in No 3 engine and, since the fan is only approximately 40 feet from the location of the explosive device, this would have been an insignificant time interval after the explosion.

It was therefore concluded from this evidence that the wing with all of the engines attached had achieved a marked nose down and left roll attitude change well within 5 seconds of the explosion.

2.6 Detachment of forward fuselage

Examination of the three major structural elements either side of the region of station 800 on the right side of the fuselage makes it clear that to produce the curvature of the window belt and peeling of the riveted joint at the R2 door aperture requires the door pillar to be securely in position and able to react longitudinal and lateral loads. This in turn requires the large section of fuselage on the right side between stations 760 and 1000 (incorporating the right half of the floor) to be in position in order to locate the lower end of the door pillar. Thus both these sections must have been in position until the section from station 560 to 800 (right side) had completed its deflection to the right and peeled from the door pillar. Separation of the forward fuselage must thus have been complete by the time all three items mentioned above had fallen free.

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2.7 Speed of initial disintegration

The distribution of wreckage in the bands between the datum line and the 250, 300, 600 and 900 metre lines was examined in detail. The positions of these items of structure on the aircraft are shown in Appendix B, Figures B-10 to B-13. It should be noted that the position on the ground of these items, although separated by small distances when measured in a direction along aircraft track, were distributed over large distances when measured along the wreckage trail. All were recovered from positions far enough to the east to be in that part of the southern trail which was sufficiently close, theoretically, to a straight line for any curvature effect to be neglected.

The wreckage found in each of the bands enabled an approximate sequence of break-up to be established. It was clear that as the distance travelled from the datum line increased, items of wreckage further from the station of the IED were encountered. The items shown on the diagram as falling on the 250 metre band also include those fragments of lower forward fuselage skin having evidence of explosive damage and presumed to have separated as a direct result of the blast. However, a few portions of the upper forward fuselage were also found within the 250 metre band, suggesting that these items had also separated as a result of the blast.

By the time the 300 metre line was reached much of the structure from the right side in the region of the explosive device had been shed. This included the area of window belt, referred to in paragraph 2.6 above, which gave clear indications that the forward structure had detached to the right and finally peeled away at station 800. It also included the areas of adjacent structure immediately to the rear of station 800 about which the forward structure would have had to pivot. By the time the 600 metre line was reached, there was clearly insufficient structure left to connect the forward fuselage with the remainder of the aircraft. Wreckage between the 600 and 900 metre lines consisted of structure still further from the site of the IED.

There is evidence that a manoeuvre occurred at the time of the explosion which would have produced a significant change of the aircraft's flight path, however, it is considered that the change in the horizontal velocity component in the first few seconds would not have been great. The original groundspeed of the aircraft was therefore used in conjunction with the distribution of wreckage in the successive bands to establish an approximate time sequence of break-up of the forward fuselage. Assuming the original ground speed of 434 Kts, the elapsed flight times from the datum to each of the parellel lines were calculated to be:

Distance (metres)	250	300	600	900
Time (seconds)	1.1	1.3	2.7	4.0

Thus, there is little doubt that separation of the forward fuselage was complete within 2 to 3 seconds of the explosion.

The separate assessment of the known grid references of tailplane and elevator wreckage in the southern trail revealed that those items were evenly distributed about the 600 metre line and therefore that most of the tailplane damage occurred after separation of the forward fuselage was complete.

2.8 The manoeuvre following the explosion

The engine evidence, timing and mode of disintegration of the fuselage and tailplane suggests that the latter did not sustain significant damage until the forward fuselage disintegration was well advanced and the pitch/roll manoeuvre was also well under way.

Examination of the three dimensional reconstruction makes it clear that both main and upper deck floors were disrupted by the explosion. Since pitch control cables are routed through the upper deck floor beams and the roll control cables through the main deck beams, there is a strong possibility that movement of the beams under explosive forces would have applied inputs to the control cables, thus operating control surfaces in both axes.

2.9 Secondary disintegration

The distribution of fin debris between the trails suggests that disintegration of the fin began shortly before the vertical descent was established. No single mode of failure was identified and the debris which had struck the leading edge had not caused major disruption. The considerable fragmentation of the thick panels of the aft torque box was also very different from that noted on the corresponding structure of the tailplanes. It was therefore concluded that the mode of failure was probably flutter.

The finding, in the northern trail, of a slide raft wrapped around a flap track fairing suggests that at a later stage of the disintegration the rear of the aircraft must have experienced a large angle of sideslip. The loss of the fin would have made this possible and also subjected the structure to large side loads. It is possible that such side loading would have assisted the disintegration of the rear fuselage and also have caused bending failure of the pylon attachments of the remaining three engines.

2.10 Impact speed of components

The trajectory analysis carried out by Cranfield Institute of Technology calculated impact speeds of 120 kts for the nose section, and 260 kts for the engines and pylons. These values were considered to be reliable because the drag coefficients could be estimated with a reasonable degree of confidence. Based on the best available data at the time, the analysis also showed that the wing could have impacted at a speed, in theory, as high as 650 kts if it had flown in a streamlined attitude such that the drag coefficient was minimal. However, it was also recognized that relatively small changes in the angle of incidence of the wing would have produced a significant increase in drag with a consequent reduction in impact speed. Refinement of timing information and radar data subsequent to the Cranfield analysis has enabled a revised estimate to be made of the mean speed of the wing during the descent.

The engine evidence indicated that there had been a large nose down attitude change of the aircraft early in the event. The Cranfield analysis also showed that the rear fuselage had disintegrated while essentially in a vertical descent between 19,000 and 9,000 feet over Lockerbie. Assuming that, following the explosion, the wing followed a straight line descending flight profile from 31,000 feet to 19,000 feet directly overhead Lockerbie and then descended vertically until impact, the wing would have travelled the minimum distance practicable. The ground distance between the geographical position at which the disintegration started (Figure B-4, Point B) and the crater made by the wing impact was 2997 ±525 metres (9833 ±1722 feet). The time interval between the explosion and the wing impact was established in Appendix C as 46.5 ±2 seconds. Based on the above times and distances the mean linear speed achieved by the wing would have been about 440 kts.

The impact location of Nos 1, 2, and 4 engines closely grouped in Lockerbie was consistent with their nearly vertical fall from a point above the town. If they had separated at about 19,000 feet and the wing had then flown as much as one mile away from the overhead position before tracking back to impact, the total flight path length of the wing would not have required it to have achieved a mean linear speed in excess of 500 kts.

Any speculation that the flight path of the wing could have been longer would have required it to have undergone manoeuvres at high speed in order to arrive at the 19,000 feet point. The manoeuvres involved would almost certainly have resulted in failure of the primary wing structure which, from distribution of wing debris, clearly did not occur. Alternatively the wing could have travelled more than one mile from Lockerbie after reaching the 19,000 feet point, but this was considered unlikely. It is therefore concluded that the mean speed of the wing during the descent was in the region of 440 to 500 kts.

2.11 Sequence of disintegration

Analysis of wreckage in each of the bands, taken in conjunction with the engine evidence and the three-dimensional reconstruction, suggests the following sequence of disintegration:

(i) The initial explosion triggered a sequence of events which effectively destroyed the structural integrity of the forward fuselage. Little more then remained between stations 560 and 760 (approximately) than the window belts and the cabin sidewall structure immediately above and below the windows, although much of the cargo-hold floor structure appears to have remained briefly attached to the aircraft. [Appendix B, Figure B-24]
(ii) The main portion of the aircraft simultaneously entered a manoeuvre involving a marked nose down and left roll attitude change, probably as a result of inputs applied to the flying control cables by movement of structure.
(iii) Failure of the left window belt then occurred, probably in the region of station 710, as a result of torsional and bending loads on the fuselage imparted by the manoeuvre (i.e. the movement of the forward fuselage relative to the remainder of the aircraft was an initial twisting motion to the right, accompanied by a nose up pitching deflection).
(iv) The forward fuselage deflected to the right, pivoting about the starboard window belt, and then peeled away from the structure at station 800. During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation was apparently complete within 3 seconds of the explosion.
(v) Structure and contents of the forward fuselage struck the tail surfaces contributing to the destruction of the outboard starboard tailplane and causing substantial damage to the port unit. This damage occurred approximately 600 metres track distance after the explosion and therefore appears to have happened after the fuselage separation was complete.
(vi) Fuselage structure continued to break away from the aircraft and the separated forward fuselage section as they descended.
(vii) The aircraft maintained a steepening descent path until it reached the vertical in the region of 19,000 feet approximately over the final impact point. Shortly before it did so the tail fin began to disintegrate.
(viii) The mode of failure of the fin is not clear, however, flutter of its structure is suspected.
(ix) Once established in the vertical dive, the fin torque box continued to disintegrate, possibly permitting the remainder of the aircraft to yaw sufficiently to cause side load separation of Nos 1, 2 and 4 engines, complete with their pylons.
(x) Break-up of the rear fuselage occurred during the vertical descent, possibly as a result of loads induced by the yaw, leaving a section of cabin floor and baggage hold from approximately stations 1241 to 1920, together with 3 landing gear units, to fall into housing at Rosebank Terrace.

(xi) The main wing structure struck the ground with a high yaw angle at Sherwood Crescent.

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2.12 Explosive mechanisms and the structural disintegration

The fracture and damage pattern analysis was mainly of an interpretive nature involving interlocking pieces of subtle evidence such as paint smears, fracture and rivet failure characteristics, and other complex features. In the interests of brevity, this analysis will not discuss the detailed interpretation of individual fractures or damage features. Instead, the broader 'damage picture' which emerged from the detailed work will be discussed in the context of the explosive mechanisms which might have produced the damage, with a view to identifying those features of greatest significance.

It is important to keep in mind that whilst the processes involved are considered and discussed separately, the timescales associated with shock wave propagation and the high velocity gas flows are very short compared with the structural response timescales. Consequently, material which was shattered or broken by the explosive forces would have remained in place for a sufficiently long time that the structure can be considered to have been intact throughout much of the period that these explosive propagation phenomena were taking place.

2.12.1 Direct blast effect

2.12.1.1 Shock wave propagation

The direct effect of the explosive detonation within the container was to produce a high intensity spherically propagating shock wave which expanded from the centre of detonation close to the side of the container, shattering part of the side and base of the container as it passed through into the gap between the container and the fuselage skin. In breaking out of the container, some internal reflection and Mach stem interaction would have occurred, but this would have been limited by the absorptive effect of the baggage inboard, above, and forward of the charge. The force of the explosion breaking out of the container would therefore have been directed downwards and rearwards.

The heavy container base was distorted and torn downwards, causing buckling of the adjoining section of frame 700, and the container sides were blasted through and torn, particularly in the aft lower corner. Some of the material in the direct path of the explosive pressure front was reduced to shrapnel sized pieces which were rapidly accelerated outwards behind the primary shock front. Because of the overhang of the container's sloping side, fragments from both the device itself and the container wall impacted the projecting external flange of the container base edge member, producing micro cratering and sooting. Metallurgical examination of the internal surfaces of these craters identified areas of melting and other features which were consistent only with the impact of very high energy particles produced by an explosion at close quarters. Analysis of material on the crater surfaces confirmed the presence of several elements and compounds foreign to the composition of the edge member, including material consistent with the composition of the sheet aluminium forming the sloping face of the container.

On reaching the inner surface of the fuselage skin, the incident shock wave energy would partially have been absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of its energy would have been transmitted, as a shock wave, through the skin and into the atmosphere [Appendix B, Figure B-25], but a significant amount of energy would have been returned as a reflected shock wave, back into the cavity between the container and the fuselage skin where Mach stem shock waves would have been formed. Evidence of rapid shattering was found in a region approximately bounded by frames 700 & 720 and stringers 38L & 40L, together with the lap joint at 39L.

The shattered fuselage skin would have taken a significant time to move, relative to the timescales associated with the primary shock wave propagation. Clear evidence of soot and small impact craters were apparent on the internal surfaces of all fragments of container and structure from the shatter zone, confirming that the this material had not had time to move before it was hit by the cloud of shrapnel, unburnt explosive residues and sooty combustion products generated at the seat of the explosion.

Following immediately behind the primary shock wave, a secondary high pressure wave - partly caused by reflections off the baggage behind the explosive material but mainly by the general pressure rise caused by the chemical conversion of solid explosive material to high temperature gas - emerged from the container. The effect of this second pressure front, which would have been more sustained and spread over a much larger area, was to cause the fuselage skin to stretch and blister outwards before bursting and petalling back in a star-burst pattern, with rapidly running tear fractures propagating away from a focus at the shatter zone. The release of stored energy as the skin ruptured, combined with the outflow of high pressure gas through the aperture, produced a characteristic curling of the skin 'petals' - even against the slipstream. For the most part, the skins which petalled back in this manner were torn from the frames and stringers, but the frames and stringers themselves were also fractured and became separated from the rest of the structure, producing a very large jagged hole some 5 feet longitudinally by 17 feet circumferentially (upwards to a region just below the window belt and downwards virtually to the centre line).

From this large jagged hole, three of the fractures continued to propagate away from the hole instead of terminating at the boundary. One fracture propagated longitudinally rearwards as far as the wing cut-out and another forwards to station 480, creating a continuous longitudinal fracture some 43 feet in length. A third fracture propagated circumferentially downwards along frame 740, under the belly, and up the right side of the fuselage almost as far as the window belt - a distance of approximately 23 feet.

These extended fractures all involved tearing or related failure modes, sometimes exploiting rivet lines and tearing from rivet hole to rivet hole, in other areas tearing along the full skin section adjacent to rivet lines, but separate from them. Although the fractures had, in part, followed lap joints, the actual failure modes indicated that the joints themselves were not inherently weak, either as design features or in respect of corrosion or the conditions of the joints on this particular aircraft.

Note: The cold bond process carried out at manufacture on the lap joints had areas of disbonding prior to the accident. This disbonding is a known feature of early Boeing 747 aircraft which, by itself, does not detract from the structural integrity of the hull. The cold bond adhesive was used to improve the distribution of shear load across the joint, thus reducing shear transfer via the fasteners and improving the resistance of the joint to fatigue damage; the fasteners were designed to carry the full static loading requirements of the joint without any contribution from the adhesive. Thus, the loss of the cold bond integrity would only have been significant if it had resulted in the growth of fatigue cracks, or corrosion induced weaknesses, which had then been exploited by the explosive forces. No evidence of fatigue cracking was found in the bonded joints. Inter-surface corrosion was present on most lap joints but only one very small region of corrosion had resulted in significant material thinning; this was remote from the critical region and had not played any part in the break-up.

The cracks propagating upwards as part of the petalling process did not extend beyond the window line. The wreckage evidence suggests that the vertical fractures merged, effectively closing off the fracture path to produce a relatively clean bounding edge to the upper section of the otherwise jagged hole produced by the petalling process. There are at least two probable reasons for this. Firstly the petalling fractures above the shattered zone did not diverge, as they had tended to do elsewhere. Instead, it appears that a large skin panel separated and peeled upwards very rapidly producing tears at each side which ran upwards following almost parallel paths. However, there are indications that by the time the fractures had run several feet, the velocity of fracture had slowed sufficiently to allow the free (forward) edge of the skin panel to overtake the fracture fronts, as it flexed upwards, and forcibly strike the fuselage skin above, producing clear witness marks on both items. Such a tearing process, in which an approximately rectangular flap of skin is pulled upwards away from the main skin panel, is likely to result in the fractures merging. Secondly, this merging tendency would have been reinforced in this particular instance by the stiff window belt ahead of the fractures, which would have tended to turn the fractures towards the horizontal.

It appears that the presence of this initial ('clean') hole, together with the stiff window belt above, encouraged other more slowly running tears to break into it, rather than propagating outwards away from the main hole.

2.12.1.2 Critical crack considerations

The three very large tears extending beyond the boundary of the petalled region resulted in a critical reduction of fuselage structural integrity.

Calculations were carried out at the Royal Aerospace Establishment to determine whether these fractures, growing outwards from the boundary of the petalled hole, could have occurred purely as a result of normal differential pressure loading of the fuselage, or whether explosive forces were required in addition to the pressurisation loads.

Preliminary calculations of critical crack dimensions for a fuselage skin punctured by a 20 by 20 inches jagged hole indicated that unstable crack growth would not have occurred unless the skin stress had been substantially greater than the stress level due to normal pressurisation loads alone. It was therefore clear that explosive overpressure must have produced the gross enlargement of the initially small shattered hole in the hull. Furthermore, it was apparent from the degree of curling and petalling of the skin panels within the star-burst region that this overpressure had been relatively long term, compared with the shock wave overpressure which had produced the shatter zone. A more refined analysis of critical crack growth parameters was therefore carried out in which it was assumed that the long term explosive overpressure was produced by the chemical conversion of solid explosive material into high temperature gas.

An outline of the fracture propagation analysis is given at Appendix D. This analysis, using theoretical fracture mechanics, showed that, after the incident shock wave had produced the shatter zone, significant explosive overpressure loads were needed to drive the star-burst fractures out to the boundary of the petalled skin zone. Thereafter, residual gas overpressure combined with fuselage pressurisation loads were sufficient to produce the two major longitudinal cracks and a single major circumferential crack, extending from the window belt down to beyond the keel centreline.

2.12.1.3 Damage to the cabin floor structure

The floor beams in the region immediately above the baggage container in which the explosive had detonated were extensively broken, displaying clear indications of overload failure due to buckling caused by localised upward loading of the floor structure.

No direct evidence of bruising was found on the top panel of the container. It therefore appears that the container did not itself impact the floor beams, but instead the floor immediately above the container was broken through as a result of explosive overpressure as gases emerged from the ruptured container and loaded the floor panels. Data on floor strengths, provided by Boeing, indicated that the cabin floor (with the CRAF modification) would fail at a uniform static differential pressure of between 3.5 and 3.9 psi (high pressure below the cabin floor), and that the floor panel to floor beam attachments would not fail before the floor beams. Whilst there is no direct evidence of the pressure loading on the floor structure immediately following detonation, there can be no doubt that in the region of station 700 it would have exceeded the ultimate failure load by a large margin.

2.12.2 Indirect explosive damage (damage at remote sites)

All of the damage considered in the foregoing analysis, and the mechanisms giving rise to that damage, resulted from the direct impact of explosive shock waves and/or the short-term explosive overpressure on structure close to the source of the explosion. However, there were several regions of skin separation at sites remote from the explosion (see para 1.12.3.2) which were much more difficult to understand. These remote sites formed islands of indirect explosive damage separated from the direct damage by a sea of more generalised structural failure characterised by the progressive aerodynamic break-up of the weakened forward fuselage. All of these remote damage sites were consistent with the impact of very localised pressure impulses on the internal surfaces of the hull -effectively high energy 'pressure blows' against the inner surfaces produced by explosive shock waves and/or high pressure gas flows travelling through the interior spaces of the hull.

The propagation of explosive shock waves and supersonic gas flows within multiple, interlinking, cavities having indeterminate energy absorption and reflection properties, and ill-defined structural response, is extremely complex. Work has been initiated in an attempt to produce a three-dimensional computer analysis of the shock wave and supersonic flow propagation inside the fuselage, but full theoretical analysis is beyond present resources.

Because of the complexity of the problem, the following analysis will be restricted to a qualitative consideration of the processes which were likely to have taken place. Whilst such an approach is necessarily limited, it has identified a number of propagation mechanisms which appear to have been of fundamental importance to the break-up of Flight PA103, and which are likely to be critical in any future incident involving the detonation of high explosive inside an aircraft hull.

2.12.2.1 Shock wave propagation through internal cavities

When Mach stem shocks are produced not only are the shock pressures very high but they propagate at very high velocity parallel to the reflecting surface. In the context of the lower fuselage structure in the region of Mach stem formation, it can readily be seen that the Mach stem will be perfectly orientated to enter the narrow cavity formed between the outer skin and the cargo liner/containers, bounded by the fuselage frames [Appendix B, Figure B-25]. This cavity enables the Mach stem shock wave to propagate, without causing damage to the walls (due to the relatively low pressure where the Mach stem sweeps their surface), and reach regions of the fuselage remote from the source of the explosion. Furthermore, energy losses in the cavity are likely to be less than would occur in the 'free' propagation case, resulting in the efficient transmission of explosive energy. The cavity would tend to act like a 'shock tube', used for high speed aerodynamic research, confining the shock wave and keeping it running along the cavity axis, with losses being limited to kinetic heating due to friction at the walls.

Paragraph 1.6.3 contains a general description of the structural arrangements in the area of the cargo hold. Before proceeding further and considering how the shock waves might have propagated through this network of cavities, it should be pointed out that the timescale associated with the propagation of the shock waves is very short compared with the timescale associated with physical movement and separation of skin and structure fractured or damaged by the shock. Therefore, for the purpose of assessing the shock propagation through the cavities, the explosive damage to the hull can be ignored and the structure regarded as being intact. A further simplification can usefully be made by considering the structure to be rigid. This assumption would, if the analysis were quantitative, result in over-estimations of the shock strengths. However, for the purposes of a purely qualitative assessment, the assumption should be valid, in that the general trends of behaviour should not be materially altered.

It has already been argued that the shock wave emerging from the container was, in part, reflected back off the inner surface of the fuselage skin, forming a Mach stem shock wave which would then have tended to travel into the semi-circular lower lobe cavity. The Mach stem waves would have propagated away through this cavity in two directions:

(i) under the belly, between the frames [Appendix B, Figure B-3, detail A], and
(ii) up the left side, expanding into the cavity formed by the longitudinal manifold chamber where it joins the lower lobe cavity.

As the shock waves travelled along the cavity, little attenuation or other change of characteristic was likely to have occurred until the shocks passed the entrances to other cavities, or impinged upon projections and other local changes in the cavity. A review of the literature dealing with propagation of blast waves within such cavities provides useful insights into some of the physical mechanisms involved.

As part of a research program carried out into the design of ventilation systems for blast hardened installations intended to survive the long duration blast waves following the detonation of nuclear weapons, the propagation of blast waves along the primary passages and into the side branches of ventilation ducts was studied. The research showed that 90¡ bends in the ducts produced very little attenuation of shock wave pressure; a series of six right angle bends produced only a 30% pressure attenuation, together with an extension of the shock duration. It is therefore evident that the attenuation of shock waves propagating through the fuselage cavities, all of which were short with hardly any right angle turns, would have been minimal.

It was also demonstrated that secondary shock waves develop within the entrance to any side branch from the main duct, produced by the interaction of the primary shock wave with the geometric changes in the duct walls at the side-branch location. These secondary shock waves interact as they propagate into the side branch, combining together within a relatively short distance (typically 7 diameters) to produce a single, plane shock wave travelling along the duct axis. In a rigid, smooth walled structure, this mechanism produces secondary shock overpressures in the side branch of between 30% and 50% of the value of the primary shock, together with a corresponding attenuation of the primary shock wave pressure by approximately 20% to 25%.

This potential for the splitting up and re-transmission of shock wave energy within the lower hull cavities is of extreme importance in the context of this accident. Though the precise form of the interactions is too complex to predict quantitatively, it is evident that the lower hull cavities will serve to convey the overpressure efficiently to other parts of the aircraft. Furthermore, the cavities are not of serial form, i.e. they do not simply branch (and branch again) in a divergent manner, but instead form a parallel network of short cavities which reconnect with each other at many different points, principally along the crease beams. Thus, considerable scope exists for: the additive recombination of blast waves at cavity junctions; for the sustaining of the shock overpressure over a greater time period; and, for the generation of multiple shocks produced by the delay in shock propagation inherent in the different shock path (i.e. cavity) lengths.

Whilst it has not been possible to find a specific mechanism to explain the regions of localised skin separation and peel-back (i.e. the 'pressure blow' regions referred to in para 2.12.2), they were almost certainly the result of high intensity shock overpressures produced locally in those regions as a result of the additive recombination of shock waves transmitted through the lower hull cavities. It is considered that the relatively close proximity of the left side region of damage just below floor level at station 500, [Appendix B, Figure B-19, region D] to the forward end of the cargo hold may be significant insofar as the reflections back from the forward end of the hold would have produced a local enhancement of the shock overpressure. Similarly, 'end blockage effects' produced by the cargo door frame might have been responsible for local enhancements in the area of the belly skin separation and curl-back at station 560 [Appendix B, Figure B-19 and B-20, region E].

The separation of the large section of upper fuselage skin [Appendix B, Figure B-19 and B-20, detail B] was almost certainly associated with a local overpressure in the side cavities between the main deck window line and the upper deck floor, where the cavity is effectively closed off. It is considered that the most probable mechanism producing this region of impulse overpressure was a reflection from the closed end of the cavity, possibly combined with further secondary reflections from the window assembly, the whole being driven by reflective overpressures at the forward end of the longitudinal manifold cavity caused by the forward end of the cargo hold. The local overpressure inside the sidewall cavity would have been backed up by a general cabin overpressure resulting from the floor breakthrough, giving rise to an increased pressure acting on the inner face of the cabin side liner panels. This would have provided pseudo mass to the panels, effectively preventing them from moving inwards and allowing them to react the impulse pressure within the cavity, producing the region of local high pressure evidenced by the region of quilting on the skin panels [Appendix B, Figure B-19, region C].

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2.12.2.2 Propagation of shock waves into the cabin

The design of the air-conditioning/depressurisation-venting systems on the Boeing 747 (and on most other commercial aircraft) is seen as a significant factor in the transmission of explosive energy, as it provides a direct connection between the main passenger cabin and the lower hull at the confluence of the lower hull cavities below the crease beam. The floor level air conditioning vents along the length of the cabin provided a series of apertures through which explosive shock waves, propagating through the sub floor cavities, would have radiated into the main cabin.

Once the shock waves entered the cabin space, the form of propagation would have been significantly different from that which occurred in the cavities in the lower hull. Again, the precise form of such radiation cannot be predicted, but it is clear that the energy would potentially have been high and there would also (potentially) have been a large number of shock waves radiating into the cabin, both from individual vents and in total, with further potential to recombine additively or to 'follow one another up' producing, in effect, sustained shock overpressures.

Within the cabin, the presence of hard, reflective, surfaces are likely to have been significant. Again, the precise way in which the shock waves interacted is vastly beyond the scope of current analytical methods and computing power, but there clearly was considerable potential for additive recombination of the many different shock waves entering at different points along the cabin and the reflected shock waves off hard surfaces in the cabin space, such as the toilet and galley compartments and overhead lockers. These recombination effects, though not understood, are known phenomena. Appendix B, Figure

B-26 shows how shock waves radiating from floor level might have been reflected in such a way as produce shock loading on a localised area of the pressure hull.

2.12.2.3 Supersonic gas flows

The gas produced by the explosive would have resulted in a supersonic flow of very high pressure gas through the structural cavities, which would have followed up closely behind the shock waves. Whilst the physical mechanisms of propagation would have been different from those of the shock wave, the end result would have been similar, i.e. there would have been propagation via multiple, linked paths, with potential for additive recombination and successive pressure pulses resulting from differing path lengths. Essentially, the shock waves are likely to have delivered initial 'pressure blows' which would then have been followed up immediately by more sustained pressures resulting from the high pressure supersonic gas flows.

2.13 Potential limitation of explosive damage

Quite clearly the detonation of high explosive material anywhere on board an aircraft is potentially catastrophic and the most effective means of protecting lives is to stop such material entering the aircraft in the first place. However, it is recognised that such risks cannot be eliminated entirely and it is therefore essential that means are sought to reduce the vulnerability of commercial aircraft structures to explosive damage.

The processes which take place when an explosive detonates inside an aircraft fuselage are complex and, to a large extent, fickle in terms of the precise manner in which the processes occur. Furthermore, the potential variation in charge size, position within the hull, and the nature of the materials in the immediate vicinity of the charge (baggage etc) are such that it would be unrealistic to expect to neutralise successfully the effect of every potential explosive device likely to be placed on board an aircraft. However, whilst the problem is intractable so far as a total solution is concerned, it should be possible to limit the damage caused by an explosive device inside a baggage container on a Boeing 747 or similar aircraft to a degree which would allow the aircraft to land successfully, albeit with severe local damage and perhaps resulting in some loss of life or injuries.

In Appendix E the problem of reducing the vulnerability of commercial aircraft to explosive damage is discussed, both in general terms and in the context of aircraft of similar size and form to the Boeing 747. In that discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution.

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2.14 Summary

It was established that the detonation of an IED, loaded in a luggage container positioned on the left side of the forward cargo hold, directly caused the loss of the aircraft. The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential. The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion. The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage, allow the nose and flight deck area to detach within a period of 2 to 3 seconds, and subsequently allow most of the remaining aircraft to disintegrate while it was descending nearly vertically from 19,000 to 9,000 feet.

The investigation has enabled a better understanding to be gained of the explosive processes involved in such an event and to suggest ways in which the effects of such an explosion might be mitigated, both by changes to future design and also by retrospective modification of aircraft. It is therefore recommended that Regulatory Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft structure and systems to explosive damage.

3. CONCLUSIONS

(a) Findings

(i) The crew were properly licenced and medically fit to conduct the flight.

(ii) The aircraft had a valid Certificate of Airworthiness and had been

maintained in compliance with the regulations.
(iii) There was no evidence of any defect or malfunction in the aircraft that could have caused or contributed to the accident.
(iv) The structure was in good condition and the minimal areas of corrosion did not contribute to the in-flight disintegration.
(v) One minor fatigue crack approximately 3 inches long was found in the fuselage skin but this had not been exploited during the disintegration.
(vi) An improvised explosive device detonated in luggage container serial number AVE 4041 PA which had been loaded at position 14L in the forward hold. This placed the device approximately 25 inches inboard from the skin on the lower left side of the fuselage at station 700.
(vii) The analysis of the flight recorders, using currently accepted techniques, did not reveal positive evidence of an explosive event.
(viii) The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential.
(ix) The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion.
(x) The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage.
(xi) Containers and items of cargo ejected from the fuselage aperture in the forward hold, together with pieces of detached structure, collided with the empennage severing most of the left tailplane, disrupting the outer half of the right tailplane, and damaging the fin leading edge structure.
(xii) The forward fuselage and flight deck area separated from the remaining structure within a period of 2 to 3 seconds.
(xiii) The No 3 engine detached when it was hit by the separating forward fuselage.
(xiv) Most of the remaining aircraft disintegrated while it was descending nearly vertically from 19,000 to 9,000 feet.
(xv) The wing impacted in the town of Lockerbie producing a large crater and creating a fireball.

(b) Cause

The in-flight disintegration of the aircraft was caused by the detonation of an improvised explosive device located in a baggage container positioned on the left side of the forward cargo hold at aircraft station 700.

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4. SAFETY RECOMMENDATIONS

The following Safety Recommendations were made during the course of the investigation :

4.1 That manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and the data recoverable after power loss.

4.2 That Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

4.3 That Airworthiness Authorities consider requiring the CVR system to contain a short duration, i.e. no greater than 1 minute, back-up power supply to enable the CVR to respond to events that result in the almost immediate loss of the aircraft's electrical power supply.

4.4 That the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

4.5 That Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of aircraft structure and systems to explosive damage.

M M Charles
Inspector of Accidents
Department of Transport

July 1990

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APPENDIX A

PERSONNEL CONDUCTING THE INVESTIGATION

The following Inspectors of the Air Accidents Investigation Branch conducted the investigation:

Mr M M Charles — Investigator-in-Charge

Mr D F King — Principal Inspector (Engineering)

Mr P F Sheppard

Assistant Principal Inspector (Engineering)

Mr A N Cable

Senior Inspector (Engineering)

Mr R G Carter

Senior Inspector (Engineering)

Mr P T Claiden

Senior Inspector (Engineering)

Mr P R Coombs

Senior Inspector (Engineering)

Mr S R Culling

Senior Inspector (Engineering)

Miss A Evans

Senior Inspector (Engineering)

Mr B M E Forward

Senior Inspector (Operations)

Mr P N Giles

Senior Inspector (Operations)

Mr S W Moss

Senior Inspector (Engineering)

Mr R Parkinson

Senior Inspector (Engineering)

Mr J D Payling

Senior Inspector (Operations)

Mr C G Pollard

Senior Inspector (Engineering)

Mr C A Protheroe

Senior Inspector (Engineering)

Mr A H Robinson

Senior Inspector (Engineering)

Mr A P Simmons

Senior Inspector (Engineering)

Mr R G Vance

Senior Inspector (Engineering)

Mr R StJ Whidborne

Senior Inspector (Operations)

The Air Accidents Investigation Branch would like to thank the following organisations from the United Kingdom, United States of America, France, and Canada who participated in the investigation:

Air Line Pilot's Association International

Boeing Commercial Airplane Company

British Airways

British Army

British Geological Survey

Bureau Enquete Accidents

Canadian Aviation Safety Bureau

Civil Aviation Authority

Cranfield Institute of Technology

Federal Aviation Administration

Federal Bureau of Investigation

Independent Union of Flight Attendants

National Transportation Safety Board

Pan American World Airways

Police Service

Royal Aerospace Establishment

Royal Air Force

Royal Armaments Research and Development Establishment

Royal Navy

Royal Ordnance

Royal Signals and Radar Establishment

United Technologies International Operations (Pratt and Whitney)

The Air Accidents Investigation Branch would also like to acknowledge the excellent work of the Dumfries & Galloway Regional Council and to thank all the many voluntary organisations who gave such unstinting support to the investigation.

APPENDIX C

ANALYSIS OF RECORDED DATA

1. Introduction

This appendix describes and analyses the different types of recorded data which were examined during the investigation of the accident to Boeing 747 registration N739PA at Lockerbie on 21 December 1988.
The recorded data consists of that from the Cockpit Voice Recorder (CVR), the Digital Flight Data Recorder (DFDR), Air Traffic Control (ATC) radio telephony (RTF), ATC radar, and British Geological Survey seismic records. The time correlation of the records is also discussed.

2. Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 analogue parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

2.1 DFDR strip and examination

Internal inspection of the DFDR showed that there was considerable disruption to the control electronics circuits. The crash protection was removed and the plastic recording tape was found detached from its various guide rollers and tangled in the tape spools. There was no tension in the negator springs. This indicated that the tape had probably moved since electrical power was removed from the recorder. The position of the tape in relation to the record/replay heads was marked with a piece of splicing tape in order to quantify the movement. To ensure that no additional damage was caused to the tape it was necessary to cut the negator springs to separate the upper and lower tape reels.

The crinkling and stretching of the tape and the damage to the control electronics meant that the tape had to be replayed outside the recorder. AAIB experience has shown that the most efficient method of replaying stretched Lockheed recorder tapes is to re-spool the tape into a known serviceable recorder, in this case a Plessey 1584G.

2.2 DFDR replay

The 25 hour duration of the DFDR was satisfactorily replayed. Data relating to the accident flight was recorded on track 2. The only significant defect in the recording system was that normal acceleration was inoperative. There was one area on the tape, 2 minutes from the end, where data synchronisation was lost for 1 second.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded. The recorded data simply stopped. Figure C-1 is a graphical representation of the main flight parameters.

2.3 DFDR analysis

In order to ensure that all recorded data from the accident flight had been decoded and to examine the quality of the data at the end of the recording, a section of tape, including both the most recently recorded data and the oldest data (data from 25 hours past), was replayed through an ultra-violet (UV) strip recorder. The data was also digitised and the resulting samples used to reconstruct the tape signal on a VDU.

Both methods of signal representation were used to determine the manner by which the recorder stopped. There was no gap between the most recently recorded data and the 25 hour old data. This showed that the recorder stopped while there was an incoming data stream from the FDAU. The recorder, therefore, stopped because its electrical supply was disconnected. The tape signal was examined for any transients or noise signals that would have indicated the presence of electrical disturbances prior to the recorder stopping. None was found and this indicated that there had been a quick clean break of the electrical supply.

The last seconds of data were decoded independently using both the UV record and the digitised signal. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or if it was old data from a previous recording.

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to ? second. These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when tha aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

3. Cockpit voice recorder (CVR)

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1	Flight Engineer's RTF.
Channel 2	Co-Pilot's RTF.
Channel 3	Pilot's RTF.
Channel 4	Cockpit Area Microphone.

3.1 CVR strip and examination

To gain access to the recording tape it was necessary to cut away the the outer case and saw through part of the crash protected enclosure. No damage to the tape transport or the recording tape was found. The endless loop of tape was cut and the tape transferred to the replay equipment. The electronic modules in the CVR were crushed and there was evidence of long term overheating of the dropper resistors on the power supply module. The CAM had been crushed breaking internal wiring and damaging components on the printed circuit board.

3.2 CVR replay

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings was audible on the RTF channels. The CAM channel was particularly noisy, this was probably due to the combination of the inherently noisy cockpit of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high cockpit noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified as of either acoustic or electrical in origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual in crew behaviour. The tape record ended with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording. The sound occurred whilst the crew were copying their transatlantic clearance from Shanwick ATC.

3.3 Analysis of the CVR record

3.3.1 The stopping of the recorder

To determine the mechanism that stopped the recorder a bench test rig was constructed utilizing an A100 CVR and an A152 CAM. Figures C-2 to C-5 show the effect of shorting, earthing or disconnecting the CAM signal wires. Figure C-8 shows the CAM channel signal response to the event which occurred on Flight PA103. From this it can be seen that there are no characteristic transients similar to those caused by shorting or earthing the CAM signal wires. Neither does the signal stop cleanly and quickly as shown in Figure C-5, indicating that the CAM signal wires were not interrupted. The UV trace shows the recorded signal decaying in a manner similar to that shown in Figure C-6, which demonstrates the effect of disconnecting electrical power from the recorder. The tests were repeated on other CVRs with similar results and it is therefore concluded that Flight PA103's CVR stopped because its electrical power was removed.

Figures C-9A to C-9D show the recorded signals for the Air India B747 (AI 182) accident in the North Atlantic on 23 June 1985. These show that there is a large transient on the CAM track indicating earthing or shorting of the CAM signal wires and that recorder power-down is more prolonged, indicating attempts to restore the electrical power supply either by bus switching or healing of the fault. The Flight PA103 CVR shows no attempts at power restoration with the break being clean and final.

In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

3.3.2 Information concerning the event

Figure C-8 is an expanded UV trace of the final milliseconds of the CVR record. Three tracks have been used, the flight engineer's RTF channel which contained similar information to the P2's channel has been replaced with a timing signal. Individual sections of interest are identified by number. On the bottom trace, the P1 RTF track, section 1 is part of the Shanwick transatlantic clearance. During this section the loud sound on the CAM channel is evident.

Examination of the DFDR event recordings shows that the Shanwick oceanic clearance was being received on VHF2, the aerial for which is on the underside of the fuselage close to the seat of the explosion.
Section 2 identifies a transient, on the P1 channel, typical of an end of ATC transmission transient for this CVR. The start and finish of most of the recorded ATC transmissions were analysed and they produce a similar signature to the three shown in Figure C-10. The signature on the P1 channel more closely resembles the end of transmission signature and it is open to conjecture that this transient was caused by the explosion damaging the aerial feeder and/or its supporting structure.

Section 3 shows what is considered to be a high speed power supply transient which is evident on all the RTF channels and is probably on the CAM channel, but cannot be identified because of the automatic gain control (AGC), limiting the audio event. This transient is considered to coincide with the loss of electrical power to the CVR. Section 5 identifies the period to the end of recording and this agrees well with tests carried out by AAIB and independently by Fairchild as part of the AI 182 investigation. The typical time from removal of the electrical supply until end of recording is 110 milliseconds.

During the period identified as section 4 it is considered that the disturbances on the RTF channels are electrical transients probably channelled through the communications equipment. Section 6 identifies the 170 millisecond period from the point when the sound was first heard on the CAM until the recording stopped.

The CAM unit is of the old type which has a frequency response of 350 to 3500 Hz. The useable duration of the signal is probably confined to the first 60 milliseconds of the final 170 milliseconds and even during this period the AGC is limiting the signal. In the remaining time the sound is being distorted because power to the recorder has been disconnected. The ambient cockpit noise may have been high enough to have caused the AGC to have been active prior to the event and in this event the full volume of the sound would not be audible. Distortion from the incomplete erasure of the last recording may form part of the recorded signal.

It is not clear if the recorded sound is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case.

Additionally some of the frequencies present on the recording were not present in the original sound, but are the result of the rise in total harmonic distortion caused by the increased amplitude of the incoming signal. Outputs from a frequency analysis of the recorded signal for the same frequency of input to the CVR, but at two input amplitudes, are shown in Figures C-11 and C-12. These illustrate the effects on harmonic distortion as the signal level is increased. Finally the recorded signal does not lend itself to analysis by a digital spectrum analyser as it is, in a large measure, aperiodic and most digital signal analysis algorithms are unable to deal with a short duration signal of this type, however, it is hoped that techniques being developed in Canada will enable more information to be deduced from the end of the recording.

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985 the Royal Armaments Research and Development Establishment (RARDE) were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

Preliminary results from these trials indicates that if a suitable sensor can be developed its output will need to be recorded in real time and therefore it may require wiring into the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

4. Flight recorder electrical system

4.1 CVR/DFDR electrical wiring.

The flight recorders were located in the left rear fuselage just forward of the rear pressure bulkhead. Audio information to the CVR ran along the left hand side of the aircraft, at stringer 11. Electrical power to the CVR followed a similar route on the right hand side of the aircraft crossing to the left side above the rear passenger toilets. DFDR electrical power and signal information followed the same route as the CVR audio information.

4.2 Flight recorder power supply

The DFDR, CVR and the transponders were all powered from the essential alternating current (AC) bus. This bus was capable of being powered by any generator, however, in normal operation the selector switch on the flight engineers panel is selected to "normal" connecting the essential bus to number 4 generator. When the cockpit of Flight PA103 was examined the selector switch was found in the normal position.

4.3 Aircraft alternating current power supplies

AC electrical power to the aircraft was provided by 4 engine driven generators, see Figure C-13. Each generator was driven at constant speed through a constant speed drive (CSD) and connected to a separate bus-bar through a generator control breaker (GCB). The 4 generators were connected to a parallel bus-bar (sync bus) by individual bus tie breakers (BTBs). Control and monitoring of the AC electrical system was achieved through the flight engineer's instrument panel. In normal operation the generators operated in parallel, i.e with the BTBs closed.

4.4 Fault conditions

Analysis of the CVR CAM channel signal indicated that approximately 60 milliseconds after the sound on the CAM channel an electrical transient was recorded on all 4 channels and that approximately 110 milliseconds later the CVR had ceased recording. Within the accuracy of the available timing information it is believed that the incoming VHF was lost at the same time, indicating an AC power supply fault.

The AC electrical system was protected from faults in individual systems or equipment by fuses or circuit breakers. Faults in the generators or in the distribution bus-bars and feeders were dealt with automatically by opening of the GCBs and opening or closing of the BTBs. In the event of fault conditions causing the disconnection of all 4 generators electrical power for essential services, including VHF radio, was provided by a battery located in the cockpit.

The short time interval of 55 milliseconds after which the AC supply to the flight recorders was lost limits the basis on which a fault path analysis of the AC electrical system can be undertaken. On the available information only a differential (feeder) fault could have isolated the bus-bar this quickly, with the generator field control relay taking 20 milliseconds to trip. However, in normal operation, the generators would have been operating in parallel and the essential AC bus-bar would have been supplied via the number 4 BTB from the sync bus. If the fault conditions had continued, a further 40 to 100 milliseconds would have elapsed before the BTB opened. If the BTB was open prior to the fault it would have attempted to close and restore the supply to the essential bus. Any automatic switching causes electrical transients to appear on the CVR and data losses on the FDR. Both the CVR and the FDR indicate that a clean break of the AC supply occurred with no electrical transients associated with BTBs open or closing in an attempt to restore power. In the absence of any additional information only two possibilities are apparent:

i) That all 4 generators were simultaneously affected causing a total loss of AC electrical power. The feeders for the left and right side generators run on opposite sides of the aircraft under the passenger cabin floor. The only situation envisaged that could cause simultaneous loss of all 4 generators is the disruption of the passenger cabin floor across its entire width.

ii) That disruption of the main equipment centre, housing the control units for the AC electrical system, caused the loss of all AC power. However, again it would have to affect both the left and right sides of the aircraft as the control equipment is located at left and right extremes of the main equipment centre.

The nature of the event may also produce effects that are not understood. It is also to be noted that a sudden loss of electrical power to the flight recorders has been reported in other B747 accidents, e.g. Air India, AI 182.

5. Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event caused by the wing section crashing on Lockerbie. The seismic monitors are time correlated with the British Telecom Rugby standard. Using this and calculating the time for the various waves to reach the recording stations it was possible for the British Geological Survey to conclude that the event occurred at 19.03:36.5 hrs ± 1 second.

Attempts were made to correlate various smaller seismic events with other wreckage impacts. However, this was not conclusive because the nearest recording station was above ground and due to the high winds at the time of the accident had considerable noise on the trace. In addition, little of the other wreckage had the mass or impact velocity to stimulate the sensors.

6. Time correlation

6.1 Introduction

The sources of each time encoded recording were asked to provide details of their time standard and any known errors in the timings on their recordings. Although the resolution of the recorded time sources is high it was not possible to attach an accuracy of better than ±1 second due to possible errors in synchronising the recorded time with the associated standard. The following time sources were available and used in determining the significant events in the investigation:-

i) ATC

ATC communications were recorded along with a time signal. The time source for the ATC tape was the British Telecom "Tim" signal. Any error in setting the time when individual tapes are mounted was logged.

ii) Recorded rada data

A time signal derived from the British Telecom "Rugby" standard was included on radar recordings. The Rugby and Tim times were assumed to be of equal accuracy for timing purposes.

iii) The DFDR had UTC recorded.

The source of this time was the flight engineer's clock. This clock was set manually and therefore this time was subject to a significant fixed error as well any inaccuracy in the clock.

iv) The CVR had no time signal.

However, the CVR was correlated with the ATC time through the RTF and with the DFDR, by correlating the press to talk events on the FDR with the press to talk signature on the CVR.

v) Seismic recordings

Seismic recordings included a timing signal derived from the British Telecom Rugby standard.

6.2 Analysis and correlation of times

The Scottish and Shanwick ATC tapes were matched with each other and with the CVR tape. The CVR recording speed was adjusted by peaking its recorded 400 Hz AC power source frequency. This correlation served as a double check on any fixed errors on the ATC recordings and to fix events on the CVR to UTC. The timing of the sound on the CAM channel of the CVR was made simpler because Shanwick was transmitting when it occurred. From this it was possible to determine that the sound on the CVR occurred at 19.02:50 hrs ±1 second.

With the CVR now tied to the Tim standard it was possible to match the RTF keying on the CVR with the RTF keying events on the FDR. These events on the FDR were sampled and recorded once per second, it was therefore possible for a 1 second delay to be present on the FDR. This potential error was reduced by obtaining the best fit between a number of RTF keyings and a time correlation between the

FDR and CVR of ±? second was achieved. From this it was determined, within this accuracy, that electrical power was removed from the CVR and FDR at the same time.

From the recorded radar data it was possible to determine that the last recorded SSR return was at 19.02:46.9 hrs and that by the next rotation of the radar head a number of primary returns, some left and right of track, were evident. Time intervals between successive rotations of the radar head became more difficult to use as the head painted more primary returns.

The point at which aircraft wreckage impacted Lockerbie was determined using the time recorded by seismic activity detectors. A seismic event measuring 1.6 on the Richter scale was detected and, with appropriate time corrections for times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

7. Recorded radar information

7.1 Introduction

Recorded radar information on the aircraft was available from from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen, from this it was clear that the flight had progressed in a normal manner until Secondary Surveillance Radar (SSR) was lost. There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost. The Lowther Hill and St. Annes radars did not see this return. The Great Dun Fell radar recording was watched for 1 hour both before and after this single return for any signs of other spurious returns, but none was seen. The return was only present for one paint and no explanation can be offered for its presence.

7.2 Limitations of recorded radar data

Before evaluating the recorded radar data it is important to highlight limitations in radar performance that must be taken into account when interpreting primary radar data. The radar system used for both primary and secondary radar utilised a rotating radar transmitter/receiver (Head). This means that a return was only visible whilst the radar head was

pointing at the target, commonly called painting or
illuminating the target. In the case of this accident the rotational speeds of the radar heads varied from approximately 10 seconds for the Lowther Hill Radar to 8 Seconds for the Great Dun Fell Radar.

Whilst it was possible to obtain accurate positional information within a resolution of 0.09¡ of bearing and ± 1/16 nautical mile range for an aircraft from SSR, incorporating mode C height encoding, primary
radar provided only slant range and bearing and therefore positional information with respect to the ground was not accurate.

The structural break-up of an aircraft releases many items which were excellent radar reflectors eg. aluminium cladding, luggage containers, sections of skin and aircraft structure. These and other debris with
reflective properties produce "clutter" on the radar by confusing the radar electronics in a manner similar to chaff ejected by military aircraft to avoid radar detection.

Even when the target is not masked by clutter repetitive detection of individual targets may not be possible because detection is a function of the target effective area which, for wreckage with its irregular
shape, is not constant but fluctuates wildly. These factors make it impossible to follow individual returns through successive sweeps of the radar head.

7.3 Analysis of the radar data

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the
SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. This information was correlated with the CVR and ATC times to establish a time and position
for the aircraft at the initial disintegration.

For the purposes of this analysis the data from Great Dun Fell Radar has been presented. Figures C-14 to C-23 show a mosaic picture of the radar data i.e. each figure contains the information on the preceding
figure together with more recently recorded information. Figure C-14 shows the radar returns from an aircraft tracking 321¡(Grid) with a calculated ground speed of 434 kts. Reading along track (towards the
top left of Figure C-14) there are 6 SSR returns with the sixth and final SSR return shown decoded: squawk code 0357 (identifying the aircraft as

N739PA); mode C indicating FL310; and the time in seconds (68566.9 seconds from 00:00, i.e. 19.02:46.9 hrs).

At the next radar return there is no SSR data, only 4 primary returns. One return is along track close to the expected position of the aircraft if it had continued at its previous speed and heading. There are 2 returns to the left of track and 1 to the right of track. Remembering the point made earlier about clutter, it is unlikely that each of these returns are real targets. It can, however, be concluded that the aircraft is no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items have been ejected at high speed probably to both right and left of the aircraft. Figure C-15 shows the situation after the next head rotation. There is still a return along track but it has either slowed down or the slant range has decreased due to a loss of altitude.

Each rotation of the radar head thereafter shows the number of returns increasing with those first identified across track in Figure C-14 having slowed down very quickly and followed a track along the prevailing wind line. Figure C-20 shows clearly that there has been a further break-up of the aircraft and subsequent plots show a rapidly increasing number of returns, some following the wind direction and forming a wreckage trail parallel to and north of the original break-up debris. Additionally it is possible that there was some break-up between these points with a short trail being formed between the north and south trails. From the absence of any returns travelling along track it can be concluded that the main wreckage was travelling almost vertically downwards for much of the time.

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

8. Conclusions

The almost instant destruction of Flight PA103 resulted in no direct evidence on the cause of the accident being preserved on the DFDR. The CVR CAM track contained a loud sound 170 milliseconds before recording ceased. Sixty milliseconds of this sound were while power was applied to the recorder; after this period the amplitude decreased. It cannot be determine whether the decrease was because of reducing recorder drive or if the sound itself decreased in amplitude. Analysis of both flight recorders shows that they stopped because the electrical supply was removed and that there were valid signals available to both recorders at that time.

The most important contribution to the investigation that the flight recorders could make was to pinpoint the time and position of the event. As the timescale involved was so small in relation to the resolution and accuracy of many of the recorded time sources it was necessary to analyse collectively all the available recordings. From the analysis of the CVR, DFDR, ATC tapes, radar data and the seismic records it was concluded that the loud sound on the CVR occurred at 19.02:50 hrs ±1 second and wreckage from the aircraft crashed on Lockerbie at 19.03:36.5 hrs ±1 second, giving a time interval of 46.5 ±2 seconds between these two events. When the loud sound was recorded on the CVR, the geographical position of the aircraft, based on the evidence of recorded data, was calculated to be within 525 metres of OS Grid Reference 14827826.

Eight seconds after the sound on the CVR the Great Dun Fell radar showed 4 primary radar returns. The returns indicated a spread of wreckage in the order of 1 nautical mile across track. On successive returns of the radar, two parallel wreckage trails are seen to develop with the second trail, to the north, becoming evident 30 to 40 seconds after the first.

APPENDIX D

CRITICAL CRACK CALCULATIONS

It was assumed that the fuselage rupture and associated star-burst petalling process was driven by an expanding 'bubble' of high pressure gas, produced by the conversion of solid explosive material into gas products. As the explosive gas pressures reduced due to dissipation through the structure and external venting, the service differential pressure loading would have taken over from the explosive pressures as the principal force driving the skin fractures.

The high temperature gas would initially have been confined within the container where, because of the low volume, the pressure would have been extremely high (too high for containment) and the gas bubble would have expanded violently into the cavities of the fuselage between the outer skin and the container. This gas bubble would have continued to expand, with an accompanying fall in pressure due to the increasing volume combined with a corresponding drop in temperature.

The precise nature of the gas expansion process could not be determined directly from the evidence and it was therefore necessary to make a number of assumptions about its behaviour, based on the geometry of the hull and the area of fuselage skin which the high pressure bubble would have ruptured. Essentially, it was assumed that the gas bubble would expand freely in the circumferential direction, into the cavity between the fuselage skin and the container. In contrast, the freedom for the bubble to expand longitudinally would have been restricted by the presence of the fuselage frames, which would have partially blocked the passage of gas in the fore and aft directions. However, the pressures acting on the frames would have been such that they would have buckled and failed, allowing the gas to vent into the next 'bay', producing failure of the next frame. This sequential frame-failure process would have continued until the pressure had fallen to a level which the frames could withstand. During the period of frame failure and the associated longitudinal expansion of the gas bubble, this expansion rate was assumed to be half that of the circumferential rate.

It was assumed that venting would have taken place through the ruptured skin and that the boundary of the petalled hole followed behind the expanding gas bubble, just inside its outer boundary, i.e. the expanding gas bubble would have stretched and 'unzipped' the skins as it expanded. This process would have continued until the gas bubble had expanded/vented to a level where the pressure was no longer able to drive the petalling mechanism because the skin stresses had reduced to below the natural strength of the material.

The following structural model was assumed:

(i)

The pressurised hull was considered to be a cylinder of radius 128 inches, divided into regular lengths by stiff frames.

(ii)

The contributions of the stringers and frames beyond the petalled region were considered to be the equivalent of a reduction of stress in the skins by 20%, corresponding to an increase in skin thickness from 0.064 inches to 0.080 inches.

(iii)

Standing skin loads were assumed to be present due to the service differential pressure, i.e.. it was assumed that no significant venting of internal cabin pressure occurred within the relevant timescale.

(iv)

The mechanism of bubble pressure load transfer into the skins was:

a)

Hoop direction -conventional membrance reaction into hoop stresses

b)

Longitudinal direction - reaction of pressures locally by the frames, restrained by the skins.

The critical crack calculations were based upon the generalised model of a plate under biaxial loading in which there was an elliptical hole with sharp cracks emanating from it. This is a good approximation of the initial condition, i.e.. the shattered hole, and an adequate representation of the subsequent phase, when the hole was enlarging in its star-burst, petalling, mode.

The analyses of critical crack dimensions in the circumferential and longitudinal directions were based on established Fracture Resistance techniques. The method utilises fracture resistance data for the material in question to establish the critical condition at which the rate of energy released by the crack just balances the rate of energy absorbed by the material in the cracking process, i.e. the instantaneous value of the parameter Kr, commonly referred to as the fracture toughness Kc. From this, the relationship between critical stress and crack length can be determined.

Using conventional Linear Elastic Fracture Mechanics (LEFM) with fracture toughness data from RAE experimental work and published geometric factors relating to cracks emanating from elliptical holes,
the stress levels required to drive cracks of increasing lengths in both circumferential and longitudinal directions were calculated. The skin stresses at sequential stages of the expanding gas bubble/skin
petalling process were then calculated and compared with these data.

The results of the analysis indicated that, once the large petalled hole had been produced by explosive gas overpressure, the hoop stresses generated by fuselage pressurisation loads acting alone would have
been sufficient to drive cracks longitudinally for large distances beyond the boundaries of the petalled hole. Thus, with residual gas overpressure acting as well, the 43 feet (total length) longitudinal fractures
observed in the wreckage are entirely understandable. The calculations also suggested that the hoop fractures, due to longitudinal stresses in the skins, would have extended beyond the boundary of the petalled
hole, though the excess stress driving the fractures in this direction would have been much smaller than for the longitudinal fractures, and the level of uncertainty was greater due to the difficulty of producing
an accurate model reflecting the diffusion of longitudinal loads into the skins. Nevertheless, the results suggested that the circumferential cracks would extend downwards just beyond the keel, and upwards as
far as the window belt - conclusions which accord reasonably well with the wreckage evidence.

APPENDIX E

POTENTIAL REMEDIAL MEASURES

1. Introduction

In the following discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging
effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are
intended to serve as a catalyst rather than to lay claim to a definitive solution. On the basis of the Flight PA103 investigation, damage is likely to fall into two categories: direct explosive damage, and indirect

explosive damage.

2. Direct explosive damage

The most serious aspect of the direct explosive damage on the structure is the large, jagged aperture in the pressure hull, combined with frame and stringer break-up, which results from the star-burst rupture of the fuselage skin. Because of its uncontrolled size and position, and the naturally radiating cracks which form as part of the petalling process, the skin's critical crack length (under pressurisation loading) is likely to be exceeded, resulting in unstable crack propagation away from the boundary of the aperture. Such cracks can lead to a critical loss of structural integrity at a time when additional loads are likely to be imposed on the structure due to reflected blast pressure and/or aircraft aerodynamic and inertial loading.

A further complicating factor is that the size of this aperture is likely to be sufficiently large to allow complete cargo containers and other debris to be ejected into the airstream, with a high probability of causing catastrophic structural damage to the empennage.

3. Indirect explosive damage

Indirect explosive damage (channelling or ducting of explosive energy in the form of both shock waves and supersonic gas flows) is likely to occur because of the network of interlinked cavities which exist, in various forms, in all large commercial aircraft, particularly below cabin floor level. This channeling mechanism can produce critical damage at significant distances from the source of the explosion.

In addition to the structural damage, aircraft flight control and other critical systems will potentially be disrupted, both by the explosive forces and as a result of structural break-up and distortions. The discussion which follows focuses on possible means of limiting structural damage of the kind which occurred on Flight PA103. Undoubtedly, such measures will also have beneficial effects in limiting systems damage. However, system vulnerability can further be reduced by applying, wherever possible, those techniques used on military aircraft to reduce vulnerability to battle damage; multiplexed, multiply redundant systems using distributed hardware to minimise risk of a single area of damage producing major system disruption. Fly by wire flight control systems potentially offer considerable scope to achieve these goals, but the same distributed approach would also be required for the electronic and other equipment which, in current aircraft, tends to be concentrated into a small number of 'equipment centres'.

4. Remedial measures to reduce structural damage

Whilst pure containment of the explosive energy is theoretically possible, in an aviation context such a scheme would not be viable. Any unsuccessful attempt to contain the explosive will probably produce greater devastation than the original (uncontained) explosion since all the explosive energy would merely be stored until the containment finally ruptured, when the stored energy would be released together with massive fragmentation of the containment.

However, a mixed approach involving a combination of containment, venting, and energy absorption should provide useful gains provided that a systematic rather than piecemeal approach is adopted, and that the scheme also addresses blast channelling. The following scheme is put forward for discussion, primarily as means of identifying, by example, how the various elements of the problem might be approached at a conceptual level and to provide a stimulus for debate. No detailed engineering solutions are offered, but it is firmly believed that the requirements of such a scheme could be met from a technical standpoint. The proposed scheme is based on the need to counter a threat similar to that involving Flight PA103, i.e. a high explosive device placed within a baggage container, however, the principles should be applicable to other aircraft types.

Such a scheme might comprise several 'layers' of defence. The first two layers, one within the other, are essentially identical and provide partial containment of the explosive energy and the redirection of blast out from the compartment via pre-determined vent paths. Although the containment is temporary, it must provide an effective barrier to uncontrolled venting, preventing the escape of blast except via the pre-designated paths.

The third layer comprises a pre-determined area of fuselage skin, adjoining the outer end of the vent path, designed to rupture or burst in a controlled manner, providing a large vent aperture which will not tend to crack or rupture beyond the designated boundaries.

A fourth layer of protection has two elements, both intended to limit the propagation of shock waves through the internal cavities in the hull. The first element comprises the closure of any gaps between the vent apertures in the two innermost containment layers and the vent aperture in the outer skin. This effectively provides an exhaust duct connecting the inner and outer vent apertures to minimise leakage into the intervening structure and cavities around the cargo hold. The second element comprises the incorporation of an energy absorbing lining material within all the cavities in the lower hull, to absorb shock energy, limit shock reflection and limit the propagation of pressure waves which might enter the cavities, for example because of containment layer breakthrough.

5 Possible application to Boeing 747 type aircraft

5.1 Container Modification

The obvious candidates for the inner containment layer are the baggage containers themselves. Existing containers are of crude construction, typically comprising aluminium sheet sides and top attached to an aluminium frame with a fabric reinforced access curtain, or have sides and top of fibreglass laminate attached to a robust aluminium base section.

These containers are stacked in the aircraft in such a manner that on three sides (except for the endmost containers) the baggage within the adjoining containers provides an already highly effective energy absorbing barrier. If the container is modified so that loading access is via the outboard side of the container rather than at the end, i.e. the curtain is put on the faces shown in Figure E-1, then only the top and base are 'unbacked' by other containers, leaving the outboard face as a vent region.

The proposal is therefore that a modified container is developed in which the access is changed from the end to the outside face only, and which is modified to improve the resistance to internal pressures and thus encourage venting via the new access curtain only. How the container is actually modified to achieve the containment requirement is a matter of detail design, but two approaches suggest themselves, both involving the use of composite type materials. The first approach is to adopt a scheme for a rigid container which relies on a combination of energy absorption and burst strength to prevent uncontrolled breakout of explosive energy. The second approach is to use a 'flexible' container, i.e. rigid enough for normal use, but sufficiently flexible to allow gross deformation of shape without rupture. This, particularly if used with a backing blanket made from high performance material to resist fragmentation, could deform sufficiently to allow the container to bear against, and partially crush, adjoining containers. In this way, the shock energy transmission should be significantly reduced and the inherent energy absorption capability and mass of the baggage in adjoining containers could be utilised, whilst still retaining the high pressure gas for long enough to allow venting via the side face. Clearly, care would need to be taken to ensure that the container vent aperture remained as undistorted as possible, to ensure minimal leakage at the interface.

5.2 Cargo bay liner

The existing cargo bay liner is a thin fibreglass laminate which lines the roof and sidewalls of the cargo hold. There is no floor as such; instead, the containers are supported on rails running fore and aft on the tops of the fuselage frame lower segments. In a number of areas, there are zipped fabric panels let into the liner to provide access to equipment located behind. The liner 'ceiling' is suspended on plastic pillars approximately 2 centimeters below the bottom of the main cabin floor beams. The purpose of the liner is solely to act as a general barrier to protect wiring looms and systems components.

The proposal is to produce a new liner designed to provide the second level of containment, essentially at 'floor' and 'roof' level only [Figure E-1]. The dimensional constraints are such that potentially quite thick material could be incorporated (leaving aside the weight problem), permitting not only a rigid liner design, but semi-rigid or flexible linings backed by energy absorbing blanket materials.

The liner would be designed to provide an additional barrier at the base and roof of the containers, which unlike the sides, are not protected by adjoining containers. The outside ends of these barrier elements must effectively seal against the vent apertures in the containers, to minimise leakage into the fuselage cavities.

5.3 Structural blow-out regions.

The final element in the containment/venting part of the scheme is a line of blow-out regions in the fuselage skins, coinciding exactly with the positions of the vent apertures in the cargo containers and cargo bay liner. These should extend along the length of the cargo hold, zoned in such a way that rupture due to rapid overpressure will occur in a controlled manner. The primary function of the blow-out regions would be to provide immediate pressure relief by allowing the inevitable skin rupture to take place only within pre-determined zones, limiting the extent of the skin tearing by means of careful stiffness control at the boundary of the blow-out regions.

The structural requirements of such panels are perhaps the most difficult challenge to meet, particularly for existing designs. However, it is believed that by giving appropriate consideration to the directionality of fastening strengths, and the use of external tear straps, it should be possible to design the structure to carry the normal service loads whilst creating a pre-disposition to rupturing in a controlled manner in response to gross pressure impulse loading.

The implementation of such features will need carefully balanced design in order to provide local stiffening, sufficient to control and direct the tear processes, without creating stiffness discontinuities which could lead to fatigue problems during extended service. However, the degree of reinforcement needed at the blow-out aperture need only be sufficient to limit tearing and to sustain the aircraft long enough to complete the flight unpressurised.

All aircraft have pre-existing strength discontinuities, despite the efforts of the designers to eliminate them. By choosing the positions of butt joints, lap joints, anti-tear straps and similar structural features in future designs, so as to incorporate them into the boundary of the blow-out panel region, the natural "tear here" tendencies of such features could possibly be turned to advantage. In the case of current generation aircraft, the positions of existing lines of weakness at such features will determine the optimum position for structural blow-out areas, and hence the positions of the container and cargo bay liner blow-out panels. A limited amount of local structural reinforcement (e.g. in the form of external anti-tear straps), carried out as part of a modification program, could perhaps fine tune the tearing properties of existing lines of weakness, potentially producing significant improvements.

5.4 Closure of cavities

There are four main classes of cavity which will need to be addressed on the Boeing 747, and most other modern aircraft. These are:

(i) The channels formed between fuselage frames

(ii) The cross-ship cavities between cabin floor beams

(iii) Longitudinal 'manifold' cavities on each side of the cargo deck, running fore and aft in the space behind the upper sidewall areas of the cargo bay liner.

(iv) Air conditioning vents along the bottom of the cabin side-liner panels, which connect the side cavities below cabin floor level with the main passenger cabin.

If the containment barriers (i.e. modified cargo containers and cargo hold liner) can be made to prevent blast breakthrough into these cavities directly, then the only area where transfer can occur is at the interface between the container/cargo hold liner vent apertures and the fuselage skins at the blow-out region. This short distance will need to be sealed in order to form a short 'exhaust duct' between the container vent aperture and the fuselage skin. Since the shock and general explosive pressure will act mainly along the vent-duct axis, the pressure loading on the vent duct walls should not be excessive.

5.5 Attenuation of shock waves in structural cavities

To prevent the 'ducting' of any blast which does enter the fuselage cavities, either because of partial penetration of the containment barriers or leakage at the vent duct interfaces, the scheme requires the provision of lightweight energy absorbing material within the cavities to limit reflection and propagation of pressure waves within the cavities, and radiation of shock waves into the cabin from the conditioning air vents. Materials such as vermiculite, which are of low density yet have excellent explosive energy absorption properties, may have application in this area, perhaps in lieu of the existing insulation material.

Since the existing cavities often serve as part of the air conditioning outflow circuit, some consideration will need to be given to finding an alternative route. However, the flow rates are small compared with the total cross-sectional flow potential of the cavities and this function could be served by separate air conditioning ducts, or perhaps by restricting access to

one or two cavities only (thus limiting the risk), or
by using some form of blast valve to close off the air conditioning vents. Similarly, the requirement to vent pressure from the cabin in the event of a cargo bay decompression would also need to be addressed.

APPENDIX F

BAGGAGE CONTAINER EXAMINATION, RECONSTRUCTION AND RELATIONSHIP TO THE AIRCRAFT STRUCTURE

1. Introduction

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited blast damage. It was confirmed by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE), after detailed physical and chemical examination, that these items showed conclusive evidence of a detonating high performance plastic explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence from the effect of Improvised Explosive Device (IED). It was evident, from the main wreckage layout that the IED had been located in the forward cargo hold and, although all baggage container wreckage was examined, only items from the forward hold showing the relevant characteristics were considered for the reconstruction. This Appendix documents the reconstruction of two particular containers and, from their position within the forward fuselage, defines the location of the IED.

2 Container Arrangement

Information supplied by Pan Am showed that this aircraft had been loaded with 12 baggage containers and two cargo pallets in the forward hold located as shown in Figure F-1. Three containers were recorded as being of the glass fibre reinforced plastic type (those at positions 11L, 13L and 21L) with the remaining 9 being of metal construction.

3. Container Description

All the baggage containers installed in the forward cargo hold were of the LD3 type (lower deck container, half width - cargo) and designated with the codes AVE, for those constructed from aluminum alloy, and AVA or AVN for those constructed from fibreglass. Each container was specifically identified with a four digit serial number followed by the letters PA and this nine digit identifier was present at the top of three sides of each container in black letters/numbers approximately 5 inches tall. Detail drawings and photographs of a typical metal container are shown in Figure F-2. Each container was essentially a 5 feet cube with a 17 inch extension over its full length to the left of the access aperture. In order to fit within the section of the lower fuselage this extension had a sloping face at its base joining the edge of the container floor to the left vertical sidewall at a position some 20 inches above the floor. The access aperture on the AVE type container was covered by a blue reinforced plastic curtain, fixed to the container at its top edge, braced by two wires and central and lower edge cross bars which engaged with the aperture structure. The strength of this type of container superstructure was provided by the various extruded section edge members, attached to a robust floor panel, with a thin aluminum skin providing baggage containment and weatherproofing.

4. Container Identification

Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to the town of Lockerbie and was characteristically different from that from the forward hold, in that it was generally severely crushed and covered in mud. The forward hold debris, by comparison, was mostly recovered from the southern wreckage trail some distance from Lockerbie and had mainly been torn into relatively large sections.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this two containers, one metal and one fibreglass, were identified as exhibiting damage likely to have been caused by the IED. From the Pan Am records the metal container of these two had been positioned at position 14L, and the fibreglass at position 21L (adjacent positions, 4th and 5th from the front of the forward cargo hold on the left side). The serial numbers of these containers were respectively AVE 4041 PA and AVN 7511 PA.

5. Container Reconstruction

Those parts which could be positively identified as being from containers AVE

4041 PA and AVN 7511 PA were assembled onto one of three wooden frameworks; one each for the floor and superstructure of container 4041, and one for the superstructure of container 7511. Figures F-3 to F-9 show the reconstruction of container 4041 and Figure F-10 shows the reconstructed forward face of container 7511.
Approximately 85% of container 4041 was identified, the main missing sections being the aft half of the sloping face skin and all of the curtain. Two items were included which could not be fracture or tear matched to container 4041, however, they showed the particular type of blast damage exhibited only by items from this container.

While this work was in progress a buckled section of skin from container 4041 was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device.

Examination of all other component parts of the remaining containers from the front and rear cargo holds did not reveal any evidence of blast damage similar to that found on containers 4041 and 7511.

6. Wreckage Distribution

Those items which were positively identified as parts of container 4041 or 7511, and for which a grid reference was available, were found to have fallen close to the southern edge of the southern wreckage trail. This indicated that one of the very early events in the aircraft break-up sequence was the blast damage to, and ejection of, parts of these two containers.

7. Fuselage Reconstruction

In order to gain a better understanding of the failure sequence, that part of the aircraft's fuselage encompassing the forward cargo hold was reconstructed at AAIB Farnborough. After all available blast damaged pieces of structure had been added, the floor of container 4041 was installed as near to its original position as the deformation of the wreckage would allow and this is shown in Figure F-11. The presence of this floor panel in the fuselage greatly assisted the three-dimensional assessment of the IED location. Witness marks between this floor and the aircraft structure, tie down rail, roller rail and relative areas of blast damage left no doubt that container 4041 had been located at position 14L at the time of detonation.

8. Analysis

The general character of damage that could be seen on the reconstructions of containers 4041 and 7511 was not of a type seen on the wreckage of any of the other containers examined. In particular, the reconstruction of the floor of container 4041 revealed an area of severe distortion, tearing and blackening localised in its aft outboard quarter which, together with the results of the forensic examination of items from this part of the container, left no doubt that the IED had detonated within this container.

Within container 4041 the lack of direct blast damage (of the type seen on the outboard floor edge member and lower portions of the aft face structural members) on most of the floor panel in the heavily distorted area suggested that this had been protected by, presumably, a piece of luggage. The downward heaving of the floor in this area was sufficient to stretch the floor material, far enough to be cut by cargo bay sub structure, and distort the adjacent fuselage frames. This supported the view that the item of baggage containing the IED had been positioned fairly close to the floor but not actually placed upon it. The installation of the floor of container 4041 into the fuselage reconstruction (Figure F-11) showed the blast to have been centered almost directly above frame 700 and that its main effects had not only been directed mostly downwards and outboard but also rearwards. The blast effects on the aircraft skin were onto stringer 39L but centered at station 710 (Figure F-12). Downwards crushing at the top, and rearwards distortion of frame 700 was apparent as well as rearwards distortion of frame 720.

With the two container reconstructions placed together it became apparent that a relatively mild blast had exited container 4041 through the rear lower face to the left of the curtain and impinged at an angle on the forward face of container 7511. This had punched a hole, Figure F-10, approximately 8 inches square some 10 inches up from its base and removed the surface of this face inboard from the hole for some 50 inches. Radiating out from the hole were areas of sooting, and other black deposits, extending to the top of the container. No signs were present of any similar damage on other external or internal faces of container 7511 or the immediately adjacent containers 14R and 21R.

The above assessment of the directions of distortion, comparison of damage to both containers, and the related airframe damage adjacent to the container position, enabled the most probable lateral and vertical location of the IED to be established as shown in Figure F-13, centered longitudinally on station 700.

9. Conclusions

Throughout the general examination of the aircraft wreckage, direct evidence of blast damage was exhibited on the airframe only in the area bounded, approximately, by stations 700 and 720 and stringers 38L and 40L. Blast damage was found only on pieces of containers 4042 and 7511, the relative location and character of which left no doubt that it was directly associated with airframe damage. Thus, these two containers had been loaded in positions 14L and 21L as recorded on the Pan Am cargo loading documents. There was also no doubt that the IED had been located within container 14L, specifically in its aft outboard quarter as indicated in Figure F-13, centered on station 700.

Blast damage to the forward face of container 7511 was as a direct result of hot gases/fragments escaping from the aft face of container 4041. No evidence was seen to suggest that more than one IED had detonated on Flight PA103.

APPENDIX G

MACH STEM SHOCK WAVE EFFECTS

1. Introduction

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity shock wave which will propagate outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant for two reasons. Firstly, it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter. This geometric limitation occurs irrespective of charge size (within the range of charge sizes considered realistic for the Flight PA103 scenario), and thus provides a means of calculating the standoff distance of the explosive charge from the fuselage skin. Secondly, the Mach stem may have been a significant factor in transmitting explosive energy through the fuselage cavities, producing damage at a number of separate sites remote from the source of the explosion.

2. Mach stem shock wave formation

A Mach stem shock is formed by the interaction between the incident and reflected shock waves, resulting in a coalescing of the two waves to produce a new, single, shock wave. If an explosive charge is detonated in a free field at some standoff distance from a reflective surface, then the incident shock wave expands spherically until the wave front contacts the reflective surface, when that element of the wave surface will be reflected back (Figure G-1). The local angle between the spherical wave front and the reflecting surface is zero at the point where the reflecting surface intersects the normal axis, resulting in wave reflection directly back towards the source and maximum reflected overpressure at the reflective surface. The angle between the wave front and the reflecting surface at other locations increases with distance from the normal axis, producing a corresponding increase in the oblique angle of reflection of the wave element, with a corresponding reduction in the reflected overpressure. (To a first order of approximation, explosive shock waves can be considered to follow similar reflection and refraction paths to light waves, ref: "Geometric Shock Initiation of Pyrotechnics and Explosives", R Weinheimer, McDonnel Douglas Aerospace Co.) Beyond some critical (conical) angle about the normal axis, typically around 40 degrees, the reflected and incident waves coalesce to form Mach stem shock waves which, effectively, bisect the angle between the incident and reflected waves, and thus travel approximately at right angles to the normal axis, i.e.parallel with the reflective surface (detail "A", figure G-1).

3. Estimation of charge standoff distance from the fuselage skin

Within the constraint of the likely charge size used on Flight PA103, calculations suggested that the initial Mach stem shock wave pressure close to the region of Mach stem formation (i.e. the shock wave face-on pressure, acting at right angles to the skin), was likely to be more than twice that of the incident shock wave, with a velocity of propagation perhaps 25% greater. However, the Mach stem out-of-plane pressure, i.e.the pressure felt by the reflecting surface where the Mach stem touches it, would have been relatively low and insufficient to shatter the skin material. Therefore, provided that the charge had sufficient energy to produce skin shatter within the conical central region where no Mach stems form, the size of the shattered region would be a function mainly of charge standoff distance, and charge weight would have had little influence. Consequently, it was possible to calculate the charge standoff distance required to produce a given size of shattered skin from geometric considerations alone. On this basis, a charge standoff distance of approximately 25 to 27 inches would have resulted in a shattered region of some 18 to 20 inches in diameter, broadly comparable to the size of the shattered region evident on the three-dimensional wreckage reconstruction.

Whilst the analytical method makes no allowance for the effect of the IED casing, or any other baggage or container structure interposed between the charge and the fuselage skin, the presence of such a barrier would have tended to absorb energy rather than re-direct the transmitted shock wave; therefore its presence would have been more critical in terms of charge size than of position. Certainly, the standoff distance predicted by this method was strikingly similar to the figure of 25 inches derived independently from the container and fuselage reconstructions.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:49 PM PDT
To: Sterns@trial-law.com
Subject: **meritorious case involving aviation matters**

Dear Jerry,

Here is your personal connection to AI 182: from Canadian and Indian AAR: (Sent in next email)

"Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR."

So, important match between the DC 10 explosive decompression sudden loud sound and the AI 182 sudden loud sound. I contend they are both explosive decompression sounds and not bomb sounds. I believe you know all about DC 10 and explosive decompression sound from a ruptured/opened cargo door.

As you read the AI 182 report or portions thereof, interpret from the point of view of wiring/cargo door/explosive decompression explanation such as UAL 811, (AAR sent in next after next email.) It will all make sense and match up until the nose stays on UAL 811 and comes off for AI 182. Thereafter the evidence matches PA 103 (AAR sent by separate email) and TWA 800. AAR at **http://www.ntsb.gov/Publictn/2000/aar0003.htm**

Electronic versions are good for the 'search' feature. 'cargo door' will lead right to relevant sections.

Cheers,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

The answers to AI 182 are below:

3.4.1 Aircraft Break-up

The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer before water impact. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.

The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile to the west indicating that there was some break-up of the number 3 engine before water impact.

The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft.

The abrupt cessation of the flight recorders indicates the possibility of a massive and sudden failure of primary structure; however, there is evidence to suggest that there were ruptures in the forward and aft cargo compartments prior to any failure of the primary structure in flight.

3.4.6.50 Mr. Caiger has not said either in the report or in his statement as to what was the cause of the bang. Mr. Davis, on the other hand, is categorical in stating in his report that there was explosive decompression (meaning rapid decompression) on the aircraft. He has, however, stated in the report that there is no evidence of an explosive device. The main reason for his coming to this conclusion is that he had not been able to find low frequencies in the spectra of the CVR of Kanishka. Mr. Seshadri, on the other hand is equally vehement in concluding that an explosive device had detonated in the front cargo hold of Kanishka.

3.4.6.57 The fact that a bang was heard is evident to the ear when the CVR as well as the ATC tapes are played. The bang could have been caused by a rapid decompression but it could also have been caused by an explosive device. One fact which has, however, to be noticed is that the sound from the explosion must necessarily emanate a few milliseconds or seconds earlier than the sound of rapid decompression because the explosion must necessarily occur before a hole is made, which results in decompression. In the event of there being an explosive detonation then the sound from there must reach the area mike first before the sound of decompression is received by it. The sound may travel either through the air or through the structure of the aircraft, but if there is no explosion of a device, but there is nevertheless an explosive decompression for some other reason, then it is that sound which will reach the area mike. To my mind it will be difficult to say, merely by looking at the spectra of the sound, that the bang recorded on the CVR tape was from an explosive device.

3.4.6.59 With regard to the nature of the sound also we have 3 different opinions. Mr. Caiger is unable to give the nature of the sound, Mr. Davis says it is rapid decompression while Mr. Seshadri says it is a sound of an explosive device followed by decompression.

3.4.6.60 In the absence of any other technical literature on the subject, it is not possible for this Court to come to the conclusion as to which of the Experts is right. The only conclusion which can, however, be arrived at is that the aircraft had broken in midair and that there has been a rapid decompression in the aircraft. Just as it is not possible to say that the spectrum discloses that the bang is due to an explosive device similarly, and as has also been admitted by Mr. Caiger and Mr. Davis, it is not possible to say that the bang is due to break up of a structure.

3.4.6.61 The bang could have been due to either of the aforesaid two causes i.e. a bomb explosion or the sound emanating due to rapid decompression. The advantage of carrying out the said analysis is that a number of possible causes of the accident are eliminated. On the other hand, if the analysis is viewed in conjunction with other evidence on the record it is further possible to determine the exact nature or cause of the bang. In the present case the bang, as already noticed, could have been due to the sound originating from the detonation of a device or by reason of rapid decompression.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom

The AIB analysis was restricted to the CVR and the Shannon ATC tape. The correlation of the CVR and ATC tapes showed that the ATC recording started after the CVR had stopped recording and 1.1 ± 0.4 seconds from the start of the sudden sound. The total duration of the signal on the ATC tape was 5.4 seconds.

An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Evidence of the presence of audio warning signals buried amongst the noise was investigated with negative results. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.

' In his report, and also in the earlier part of the examination, Mr. Davis had referred to the absence of low frequency component in the spectrum and had sought to conclude that such absence showed that there was no detonation of a high explosive device. In an answer to the question put by the Court however, Mr. Davis appeared to have altered his stand. This is evident from the following deposition of Mr. Davis :-

"Court Ques Am I to understand that there must necessarily be a low frequency whenever an explosion occurs?

Ans. No. What we thought was there would be. There was only one sample of explosion in B-737. But we would need more accidents of that nature to able to say that yes we must have a low frequency component.

Court Ques: Am I to understand that the absence of a low frequency component would not therefore necessarily mean that the sound was not that of an explosion?

Ans. Because of the absence of a low frequency component we would not be able to say positively that there was an explosion or it was not explosion."

Court Ques : Would the frequency of a particular type of sound change depending upon the environment in which that sound occurs?

Ans Yes.

Court Ques If an event results in low frequency sounds in one type of environment, can it mean that the same event can result in a high frequency sound in a different environment?

Ans. That must be possible".

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:49 PM PDT
To: Jaswindersingh <jaswinderp@hotmail.com>
Subject: **Introduction**

At 8:28 PM -0800 3/11/01, Aniljit Singh wrote:

please add jaswinder singh parmar to the general list. his address is
jaswinderp@hotmail.com
he is the son in law of Ajaib Singh and is heading his defense team.

Hello, Mr. Jaswinder Singh Parmar,

My name is John Barry Smith, proponent of the 'no bomb' on AI 182 but there was a wiring/cargo door/explosive decompression.

Aniljit has informed me you are to lead the defence team for Mr. Ajaib Singh Bagri. Very good. I am at your service to answer any questions regarding the decompression explanation. I have sent many emails to Mr. Campbell and can resend them to you if you wish. There has been much discussion among the defence team for Mr. Malik about the decompression explanation and I can tell by the quality of questions from Aniljit and others that the explanation closely examined and has been taken seriously. I invite further analysis by you regarding the validity of the theory.

My latest thoughts are a three pronged defence consisting of: 1. Mr. Malik and Mr. Bagri had nothing to do with AI 182, whether it was bomb, center tank explosion, door design, or installation of wiring. 2. Most unlikely bomb. 3. Most probably wiring/cargo door/explosive decompression.

I can lead in number 3 and assist in number 2 but can't help in number 1 in establishing alibis, etc.

I've included below some thoughts on how to present the wiring/ cargo door/explosive decompression explanation to the Court and the public and the sequence to best serve Mr. Malik. I value your opinion on what sequence to follow to best present this most interesting defence. I can prepare a statement for the press regarding the wiring/cargo door/explosive decompression explanation in layman's language.

I can come up to Vancouver and testify in front of the judge on April 4th, if you think it would do any good. I think the sooner the Court and the public is exposed to the idea that there was no bomb on AI 182 and a reasonable alternative exists that's mechanical, the better they can absorb the shock of being wrong for 15 years.

Feel free to call me at home at any time for information or questions. Email is always good.

Excerpts below from previous email but relevant now:

The Crown is flying people all over the world, from Scotland to Vancouver, they have experts of their own from all over the world, they will call in people from India, they have multi million dollar agencies saying bomb and the defence can not possibly fairly and adequately provide the required standard of fairness without financial assistance as well as expert advice. I would ask for cash and a Boeing structural expert and a TSB accident investigator assigned to the case on our side. It's something to ask the judge April 4.

If the wiring/cargo door/explosive decompression explanation is brought up at 4 April hearing, then the heat will be transferred to me to justify it. I can do that. All our ducks are not in a row but the media attention on the mechanical explanation will help persuade the Crown to give us all our discovery requests. It gives legitimate hope to the accused and his supporters. It gives time for the prosecutors to prepare against the mechanical explanation but if you have faith, as I do, in the evidence, then the explanation can not be refuted no matter how much time they have. In addition, the revelation of the mechanical explanation for AI 182 on 4 April will justify to the Court to grant our request for technical assistance in the form of an assigned Canadian government official from the Transportation Safety Board. I will persuade the TSB the wiring/cargo door/explosive decompression is worthy of further investigation for AI 182, all I need is a face to face with them and my documents.

In addition, if the idea is confirmed that AI 182 may not have been a bomb, then bail proceedings may be fruitful.

Do you have the necessary four Aircraft Accident Reports? AAR for AI 182, PA 103, TWA 800, and UAL 811. I can send three and direct you the web address for the other. To understand AI 182 is to understand UAL 811.

Many Sikhs may believe your father in law did the heinous crimes he is accused of because they feel he was justified in revenge. Many Sikhs may believe he did not do the crimes because they know the man and feel he is not capable of doing the crimes but can't prove it. I know he did not do it because I know nobody did it and I can prove it. I can provide reasonable doubt a bomb exploded on AI 182, I can prove the forward cargo door ruptured/opened in flight for AI 182, and I can provide the probable cause of that door rupture as faulty wiring turning on the door unlatch motor.

Discovery evidence needed:

Aircraft:
AI 182:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the RCMP and TSB.
2. Access to all hard evidence of the wreckage which was retrieved from ocean.
3. Interviews with TSB, AAIB, and NTSB investigators who contributed to the AI 182 report through deposition or voluntary meeting.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

PA 103: The same officials who worked on the AI 182 report also worked on the PA 103 AAIB report.
1. Interviews with NTSB metallurgists and Boeing explosive expert and British law enforcement involved with the investigation.
2. Copies of all videotapes, photographs, interview notes, and sketches now held by the AAIB and Scotland Yard.
3. Access inside the hangar at Farnborough of the Pan Am 103 wreckage for at least 40 hours (five days at 8 hours a day) by at least five of your team.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

TWA 800: The same officials who worked on AI 182 and PA 103 worked on TWA 800.
1. Access to the hangar where the wreckage of TWA 800 is stored for at least 40 hours (five days at 8 hours a day) by at least

five of your team.
2. Copies of all photographs, videotapes, interviews about TWA 800 now held by FBI and NTSB.
3. Interviews with NTSB metallurgists, explosive expert and American law enforcement involved with the investigation.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

UAL 811:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the NTSB.
2. Access to any existing wreckage.
3. Interviews with NTSB metallurgists, explosive expert and American law enforcement involved with the investigation.
4. Autopsy reports.
5. Wreckage database and plots.
6. Passenger and cargo manifests.
7. CVR and FDR printouts.

Airport:
Narita:
1. Copies of all videotapes, photographs, interview notes, and sketches now held by the RCMP and TSB and Japanese airport and police authorities
2. Transcripts of the trial

Manufacturer:
Boeing:
1. Copies of all memos, data, and information about cargo doors and cargo holds on Boeing 747s.
2. Copies of all memos, data, and information about cargo doors

and cargo holds on DC-10, MD-11, and MD-12.

Airlines:
Pan Am, TWA, Air India, United Airlines:
1. Copies of all videotapes, photographs, interview notes, and sketches regarding PA 103, AI 182, TWA 800, and UAL 811
2. Access to any existing wreckage held by them.
3. Interviews with airline staff involved with the accidents.
4. Maintenance logs for the accident aircraft long before and just before the fatal flights.

Miscellaneous:
1. Copies of all data about Canadian Pacific Air Flight 003, another Boeing 747 supposed to have a bomb on board and by inference, abetted by you, sir, or your fellow Sikh, Mr. Reyat.
2. Copies of all Data about Airworthiness Directives about cargo door on commercial airliners held by FAA and NTSB databanks.
3. Bruntingthorpe 747 evidence.
4. DC 10 CVR data, explosive decompression accidents, Windsor and Paris.

Sincerely,
Barry

John Barry Smith
(831) 659-3552 phone
551 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.

US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

To: "Aniljit Singh" <aniljitsingh@hotmail.com>
From: John Barry Smith <barry@corazon.com>
Subject: Forward not aft
Cc:
Bcc:
X-Attachments:
I am sorry for the confusion but last night I re-read the crown's theory and
they have stated that the "bomb would have been located near Target 7 and 8
(rear cargo hold"

How does this affect us???

as

'There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment.'

'...cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft.'

'There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.'

4.0 CONCLUSIONS

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion

4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.

4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.

2.11.6.5 Target 47 - Aft Cargo Compartment

This portion of the aft cargo compartment roller floor was located between BS 1600 and BS 1760. Based on the direction of cleat rotation on the skin panel (target 7) and the crossbeam displacement on this structure, target 47 moved aft in relation to the lower skin panel when it was detached from the lower skin. No other significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

Dear Aniljit, the excerpts are from the AI 182 report.

It appears to me that the Kirpal commission said probable cause was "explosion occurring in the forward cargo compartment," which I agree with and is consistent with wiring/cargo door/ explosive decompression explanation. It also said no explosion in the aft compartment, which I agree with.

The report is very favorable to us because it keeps on repeating 'At this time' which we now can say, yes, in 1985 that was correct, no evidence of structural failure, but now in 2001, at our time, there is, specifically, the 1989 accident of UAL 811 which showed that in fact, a cargo door opening in flight would and did cut of electrical power to the FDR, and would make a sudden loud sound on the CVR, and would do many other strange things that match AI 182 such as frayed door from outward force.

In essence we agree with the raw findings of the AI 182 Kirpal report of an outward force in the forward cargo compartment causing the accident but disagree on the cause of the force. Not a bomb but we do understand in 1985 that conclusion may have been reached. Only now, in hindsight, with more evidence of a similar nature, is the true probable cause revealed and it is not a bomb, but wiring/cargo door/explosive decompression. Matching

UAL 811 to AI 182 is the magic mystery solver. We do have the evidence that indicates that structural failure of the aircraft was the lead event in this occurrence.

I appreciate you going over and over the reports, that is so important. We will have to almost memorize them. There is much in there to support our explanation which coupled with the new evidence of UAL 811 confirm the guesses of Mr. Davis in 1985. When the raw data is read in all the AAR, it is apparent the accurate evaluations are made, it is only when it gets 'interpreted' that it swings toward the political 'bomb'. We must concentrate on the facts and the data that really match UAL 811 to AI 182 and is incontrovertible.

I may have unintentionally offended Parmajit and I wish to apologize. If you see him, tell him I fully understand and respect any decision he makes regarding his contribution to our purpose and wish him good luck in his endeavors.

Regarding all the forensic and chemical evidence you sent:

The medical information is based on recovery of 131 bodies of 329. Regardless of what anyone says, others could say, well the evidence of bomb damage in on the bodies not recovered. The only thing we can say for sure is that usually when real bombs go off on airplanes there is conclusive proof of the bomb damage on the victims; and explosive decompression gives damage to humans such as baro trauma. It also causes damage to metal similar to a bomb force. The evidence of AI 182 is lacking in the conclusive proof of bomb damage to the recovered victims which may mean there was no bomb. There is human damage on AI 182 victims such as baro trauma which is consistent with explosive decompression which may mean there was explosive decompression. There is damage on the airframe of AI 182 consistent of explosive decompression such as outward force on the metal which may mean there was explosive decompression. There is no chemical conclusive proof of a bomb explosion on AI 182 which may mean there was no bomb.

A bomb would cause explosive decompression but would appear on the CVR before the sound of the explosive decompression. In 1985 they did not have the CVR of UAL 811 to match with AI 182 and did not know the sudden loud sound and the abrupt power cut of AI 182 was possible by ruptured cargo door in flight.

In summary, the conclusive evidence of bomb explosion on humans and machine is absent and or real bomb explosion, the proof is clearly there. That is reasonable doubt as to ba bomb right there and good enough to win acquittal for Mr. Malik if the jury were fair. Next, the evidence which supports explosive decompression is present on the humans and machine which demonstrates that explosive decompression of a non-chemical nature occurred. Again the raw data of chemical analysis and forensic autopsy supports the wiring/cargo door/explosive decompression and mitigates against a bomb...when viewed objectively.

It is interesting to conjecture if UAL 811 had happened just before or just after AI 182 and the matching similarities would have quickly become apparent, how the probable cause would have been. I say it would have been wiring/cargo door/explosive decompression explanation. But in the absence of the matching mechanical cause of UAl 811, they went with the political decision, against the Sikhs. A wrong choice with tragic consequences years later for UAL 811, PA 103, and TWA 800.

Please keep up these interesting questions, it is better that we get our explanations clear and supported with proof now among ourselves than later in front of the TV or the attorney on the witness stand.

What do you think of the three pronged approach for defence? 1. Mr. Malik had nothing to do with AI 182, whether it was bomb, center tank explosion, door design, or installation of wiring. 2. Most unlikely bomb. 3. Most probably wiring/cargo door/ explosive decompression.

When are you going to announce to the Court the mechanical alternative decompression explanation as a defence?

When do you think it is advisable to make a press statement? I can start work on that now, if you wish.

Sincerely,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:49 PM PDT
To: "Jaspreet S. Malik" <jsmalik@wwdb.org>
Subject: **AAR 92/02**

hey Barry!

My last e-mail was not meant to convey a sense of mistrust. I just don't want to send a resume. I'm 25 years old and other than graduating from law school have no experience of any relevance to this case.

I also prefer contact via e-mail but you can see that you can occasionally find miscommunication there as well.

Jaspreet

Dear Jaspreet, fine. Oh, to be 25 again....

Yes, email is good, I worry about the quick emotions that result in flames. Many times I have fired off a email and regretted it later. Oh, well.

The UAL 811 report is essential to understand AI 182. I'll add it to the end of this. I assume you already have the electronic version of AI 182. My website at www.corazon.com has details of all.

Narinder is coming down again tomorrow and we work up a plan on this explosive decompression explanation.

Sincerely,
Barry

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NTSB/AAR-92/02
(SUPERSEDES NTSB/AAR-90/01)
NATIONAL
TRANSPORTATION
SAFETY

BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION--
LOSS OF CARGO DOOR IN FLIGHT
UNITED AIRLINES FLIGHT 811
BOEING 747-122, N4713U
HONOLULU, HAWAII
FEBRUARY 24, 1989
U.S. GOVERNMENT PRINTING OFFICE: 1989 0-942-365
NTSB/AAR-92/02 PB92-910402
NATIONAL TRANSPORTATION
SAFETY BOARD
WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989
Adopted: March 18, 1992 Notation 5059C
Abstract: This report explains the explosive decompression resulting from the loss of a cargo door in flight on United Airlines flight 811, a Boeing 747-122, near Honolulu, Hawaii, on February 24, 1989. The safety issues discussed in the report are the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, and emergency response. Recommendations concerning these issues were made to the Federal Aviation Administration, the State of Hawaii, and the U.S. Department of Defense.
CONTENTS

EXECUTIVE SUMMARY

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.

The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.

A year after the accident, the Safety Board was uncertain that the cargo door would be located and recovered from the Pacific Ocean. The Safety Board decided to proceed with a final report based on the available evidence without the benefit of an actual examination of the door mechanism. The original report was adopted by the Safety Board on April 16, 1990, as NTSB/AAR-90/01.

Subsequently, on July 22, 1990, a search and recovery operation was begun by the U.S. Navy with the cost shared by the Safety Board, the Federal Aviation Administration, Boeing Aircraft Company, and United Airlines. The search and recovery effort was supported by Navy radar data on the separated cargo door, underwater sonar equipment, and a manned submersible vehicle. The effort was successful, and the cargo door was recovered in two pieces from the ocean floor at a depth of 14,200 feet on September 26 and October 1, 1990.

Before the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.

Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.

The issues in this investigation centered around the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

As a result of this investigation, the Safety Board issued safety recommendations concerning cargo doors and other nonplug doors on pressurized transport category airplanes, cabin safety, and emergency response.

NATIONAL TRANSPORTATION SAFETY BOAR

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

EXPLOSIVE DECOMPRESSION-- LOSS OF CARGO DOOR IN FLIGHT UNITED AIRLINES FLIGHT 811 BOEING 747-122, N4713U HONOLULU, HAWAII FEBRUARY 24, 1989

1. FACTUAL INFORMATION

1.1 History of the Flight

On February 24, 1989, United Airlines (UAL) flight 811, a Boeing 747-122 (B-747), N4713U, was being operated as a regularly scheduled flight from Los Angeles, California (LAX) to Sydney, Australia (SYD), with intermediate stops in Honolulu, Hawaii (HNL) and Auckland, New Zealand (AKL).

The flightcrew assigned to the LAX/HNL route segment reported no difficulty during their flight.

A flightcrew change occurred when flight 811 arrived at HNL. The oncoming captain stated that he and his crew reported to UAL operations 1 hour and 15 minutes prior to the flight's scheduled departure time from HNL. The crew had completed a 34-hour layover (rest period) in HNL.

The captain reviewed the flight plan, the weather, pertinent NOTAMs, and maintenance records, and signed the Instrument Flight Rules (IFR) clearance before boarding the airplane.

Flight 811 departed HNL gate 10 at 0133 Honolulu Standard Time (HST), 3 minutes after the scheduled departure time, with 3 flight crewmembers, 15 cabin crewmembers, and 337 passengers. The flightcrew attributed the short delay to cabin crew problems with arming the 5L cabin door emergency exit slide and the normal securing of the 2L door after a somewhat extended passenger boarding process. The second officer stated that all cabin and cargo door warning lights were out prior to the airplane's departure from the gate. He said that he dimmed the annunciator panel lights at his station while the airplane was departing the gate area.

The captain was at the controls when the flight was cleared for takeoff on HNL runway 8R at 0152:49 HST. The auxiliary power unit (APU), which was used during the takeoff, was shutdown shortly after making the initial power reduction to climb thrust. The flightcrew reported the airplane's operation to be normal during the takeoff and during the initial and intermediate segments of the climb. The flightcrew observed en route thunderstorms both visually and on the airplane's weather radar, so they requested and received clearance for a deviation to the left of course from the HNL Combined Center Radar Approach Control (CERAP). The captain elected to leave the passenger seat belt sign "on."

The flightcrew stated that the first indication of a problem occurred while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed (IAS) of 300 knots. They heard a sound, described as a "thump," which shook the airplane. They said that this sound was followed immediately by a "tremendous explosion." The airplane had experienced an explosive decompression. They said that they donned their respective oxygen masks but found no oxygen available. The airplane cabin altitude horn sounded and the flightcrew believed the passenger oxygen masks had deployed automatically.

The captain immediately initiated an emergency descent, turned 180(to the left to avoid a thunderstorm, and proceeded toward HNL. The first officer informed CERAP that the airplane was in an emergency descent and appeared to have lost power in the No. 3 engine. The appropriate 7700 emergency code was placed in the airplane's radar beacon transponder and an emergency was declared with CERAP at approximately 0220 HST. The No. 3 engine was shut down shortly after commencing the descent because of heavy vibration, no N1 compressor indication, low exhaust gas temperature (EGT), and low engine pressure ratio (EPR).

The second officer then left the cockpit to inspect the cabin area and returned to inform the captain that a large portion of the forward right side of the cabin fuselage was missing. The captain subsequently shut down the No. 4 engine because of high EGT and no N1 compressor indication, accompanied by visible flashes of fire. The flightcrew initiated fuel dumping during the descent to reduce the airplane landing weight.

The airplane was cleared for an approach to HNL runway 8L. The final approach was flown at 190 to 200 knots with the No. 1 and No. 2 engines only. During flap extension, the flightcrew observed an indication of asymmetrical flaps as the flap position approached 5(. The flightcrew decided to extend inboard trailing edge flaps to 10(for the landing. The right outboard leading edge flaps did not extend during the flap lowering sequence. The airplane touched down on the runway, approximately 1,000 feet from the approach end, and came to a stop about 7,000 feet later. The captain applied idle reverse on the Nos. 1 and No. 2 engines and employed moderate to heavy braking to stop the airplane. At 0234 (HST), HNL tower was notified by the flightcrew that the airplane was stopped and an emergency evacuation had commenced on the runway.

After the accident, UAL ramp service personnel, who had been involved with the cargo loading and unloading of flight 811 before takeoff from HNL, stated that they had opened and closed the forward cargo door electrically. They said that they had observed no damage to the cargo door. The ramp service personnel said that they had verified that the forward cargo door was flush with the fuselage of the airplane, that the master door latch handle was stowed, and that the pressure relief doors were flush with the exterior skin of the cargo door.

The dispatch mechanic stated that, in accordance with UAL procedures, he had performed a "circle check" prior to the airplane's departure from the HNL gate. This check included verification that the cargo doors were flush with the fuselage of the airplane, that the master latch lock handles were stowed, and that the pressure relief doors were flush or within 1/2 inch of the cargo door's exterior skin. He said a flashlight was used during this inspection.

The second officer stated that, in accordance with UAL Standard Operating Procedures (SOP) he had performed an operational check of the door warning annunciator lights as part of his portion of the cockpit preparation. The second officer also stated that he used a flashlight while performing an exterior inspection, again in accordance with UAL procedures. The exterior inspection was conducted while ramp service personnel were performing cargo loading operations and the cargo doors were open. He stated that he had observed no abnormalities or damage.

1.2 Injuries to Persons

Injuries Flightcrew Cabincrew Passengers Others Serious *Lost in flight. An extensive air and sea search for the passengers was unsuccessful.

1.3 Damage to the Airplane

The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward.

Examination of all structure around the area of primary damage disclosed no evidence of preexisting cracks or corrosion. All

fractures were typical of fresh overstress breaks.
Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos. 3 and 4. No damage was noted on the left side of the airplane, including engines Nos. 1 and 2.
The right wing had sustained impact damage along the leading edge between the No. 3 engine pylon and the No. 17 variable camber leading edge flap. Slight impact damage to the No. 18 leading edge flap was noted.
There was a break and scuff in the wing leading edge aft of engine No. 4 and a scuff in the wing leading edge outboard of engine No. 4. There was a large indentation (to a depth of nearly 8 inches) in the area just above the outboard landing light, and the landing light covers were broken. There was a small puncture in the upper surface of the No. 14 krueger flap and impact damage to the wing leading edge just aft of the No. 14 krueger flap. There was a gash on the upper wing surface aft of the No. 14 krueger flap and leading edge, as well as punctures to the wing leading edge aft of the number 16 krueger flap. The under wing surface aft of the krueger flaps also sustained impact damage.
The right wing also had sustained damage at the wing-to-body fairing and two flap track canoe fairings.1 Wing-to-body fairing damage was limited to surface scraping forward of and below the wing. The outboard surface of the No. 6 flap track canoe fairing revealed a slightly more significant gouge mark. The most severe damage was evident on the inboard surface of the No. 8 flap track canoe fairing, where three separate punctured areas were observed. The trailing edge flaps were not damaged.
The leading edge of the right horizontal stabilizer had several dents. The most severe dents, located 8 to 10 feet from the stabilizer root, were approximately 3 inches wide and 1 inch deep. No punctures were found. The vertical stabilizer had multiple small and elongated indentations with a maximum

depth of 1/2 inch near the right base of the leading edge. A small gouge and two small scrapes were noted at midspan of the upper rudder.

A piece of cargo container was found lodged between the No. 3 engine pylon (inboard) and the wing underside. The piece of metal had severed the pneumatic duct for the leading edge flaps. Various nicks and punctures were evident on the inboard side of the No. 3 engine pylon. The No. 4 engine pylon had a small puncture near the leading edge of the wing.

The external surfaces of the No. 3 engine inlet cowl assembly exhibited foreign object damage including small tears, scuffs and a large outwardly directed hole. The entire circumference of all the acoustic (sound attenuator) panels installed on the inlet section of the cowl had been punctured, torn, or dented. None of the No. 3 engine cases were penetrated by objects, nor was there evidence of fire damage to any visible engine components and accessories. The

leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage.

External damage to the No. 4 engine inlet and core cowls was confined to the inboard side of the inlet cowl assembly. The damage consisted of one major scuff mark, four lesser scuff marks and one crescent- shaped cut. The sound attenuator panels that were installed in the inlet area of the inlet cowl assembly had not been penetrated. The No. 4 engine fan blade airfoils had sustained both soft and hard object damage from foreign objects.

The cargo door separation resulted in the loss of fuselage shell structure above the cargo door, along with main cabin floor structure below seats 8GH through 12GH (see figure 3). The missing floor area extended inboard from the interior of the right side fuselage wall to the inboard seat track of seats 8GH through 12GH.

The supply and fill lines from the flightcrew oxygen bottle, and the supply line for the passenger oxygen system had been broken below the cabin floor inboard of the missing cargo door.

The two cabin pressurization out-flow valves, located on the underside of the fuselage, aft of the rear cargo compartment, were found fully open. The two over-pressure relief valves located on the forward left side of the airplane were found in the normal closed position. These valves were removed and bench tested. (See section 1.16.3, Pressurization System.) The majority of the cabin floor-to-cargo compartment blowout panels were found activated. The blowout panels are designed to relieve excess pressure differential following an explosive decompression to prevent catastrophic damage to the cabin floor structures.

The estimated damage to the airplane was $14,000,000, based on UAL's costs to repair it.

1.4 Other Damage

No other property damage resulted from this accident.

1.5 Personnel Information

The crew consisted of 3 flight crewmembers (the captain, the first officer, and the second officer) and 15 cabin crewmembers. (See appendix B.)

1.6 Aircraft Information

1.6.1 General

On February 24, 1989, the United Airlines B-747 fleet consisted of 31 airplanes, including: 2 B-747-222B, 11 B-747-SP, 5 B-747-123, and 13 B-747-122 series airplanes. N4713U was equipped with four Pratt & Whitney model JT9D engines.

The accident airplane, serial No. 19875, registered in the United States as N4713U, was manufactured as a Boeing 747-122 transport category airplane by the Boeing Commercial Airplane Company (Boeing), Seattle, Washington, a Division of the Boeing Company. N4713U, the 89th B-747 built by Boeing, was manufactured in accordance with Federal Aviation Administration (FAA) type certificate No. A20WE, as approved on December 30, 1969. The airplane was certificated in accordance with the provisions of 14 CFR Part 25, effective February 1, 1965. The maximum calculated takeoff weight for flight 811 was 706,000 pounds. The flight plan data showed an actual takeoff weight of 697,900 pounds. The center of gravity (CG) for takeoff was computed at 20.4 percent mean aerodynamic chord (MAC). The forward and aft CG limits were 12 and 29.7 percent MAC, respectively.

At the time of the accident, N4713U had accumulated 58,815 total flight hours and 15,028 flight cycles. N4713U had not been involved in any previous accident. Records indicated that the airplane had been inspected and maintained in accordance with the General Maintenance Program as defined in UAL Operations Specifications and in accordance with the FAA approved Aircraft and Powerplants Reliability Program. The records indicated that all required inspection and maintenance actions had been completed within specified time limits and all applicable airworthiness directives (AD) had been accomplished or were in the process of being accomplished, with the exception of AD 88-12-04, which was applicable to the B-747 lower lobe cargo door, and which had only been complied with partially. (See section 1.6.8 for explanation).

1.6.2 Cargo Door Description and Operation

Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Electrical power for operation of the cargo door switches and actuators is supplied from the ground handling bus, which is powered by either external power or the APU. See figure 17 for a diagram of the cargo door electrical circuitry. The engine generators cannot provide power to the ground handling bus.

APU generator electrical power to the ground handling bus is interrupted when an engine generator is brought on line after engine start. The APU generator "field" switch can be reengaged by the flightcrew, if necessary on the ground, to power the ground handling bus. The air/ground safety relay automatically disconnects the APU generator from the ground handling bus, if it is energized, when the airplane becomes airborne and the air/ground relay senses that the airplane is off the ground.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with pull-in hook pins on the sides of the door frame. (See figure 4 for cargo door components).

The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. Figure 5 depicts a lock sector and latch cam in an unlocked and locked condition.

Figure 4.--Boeing 747 lower lobe forward cargo door.

Figure 5.--Cargo door latch cam and lock sector in unlocked and locked ositions.

The door has three electrical actuators for opening/closing and latching of the door. One actuator (main actuator) moves the door from the fully open position to the near closed position, and vice versa. A second actuator (pull-in hook actuator) moves the pull-in hooks closed or open, and the third actuator (latch actuator) rotates the latch cams from the unlatched position to the latched position, and vice versa. The latch actuator has an internal clutch, which slips to limit the torque output of the actuator.

Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull- in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator. The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The B-747 cargo door has eight (8) view ports located beneath the latch cams for direct viewing of the position of the cams by means of alignment stripes. Procedures for using these view ports for verifying the position of the cams were not in place or required by Boeing, the FAA, or UAL (see 1.17.5 for additional information).

Closing the door manually is accomplished through the same sequence of actions without electrical power. The door actuator mechanisms are manually driven to a closed and latched position by the use of a one-half inch socket driver. The door can also be opened manually with the use of the socket driver. There are separate socket drives for the door raising/lowering mechanism, the pull-in hooks, and the latches.

Operating procedures for the normal electrical operation of the forward and aft cargo doors are outlined in the UAL Maintenance Manual (MM). Authorization for deferral of maintenance on the door power system is contained in the UAL B-747 Minimum Equipment List (MEL). In addition, operating procedures for dispatching aircraft with an inoperative door electrical power system (manual operation) are specified in the operator's MEL. The UAL MM differs from Boeing's recommended MM. UAL had modified Boeing printed material or replaced pages with their own methods and procedures for conducting maintenance functions. The modifications to the manufacturer's MM were accepted by the FAA through "approval" by the FAA Principal Maintenance Inspector (PMI). Electrical cargo door open/close operations in the UAL and Boeing MM's are approximately the same, except the final "Caution" statement differs in methods to ensure that the latch cams are closed:

United Airlines Maintenance Manual

CAUTION DO NOT FORCE HANDLE. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

Boeing Airplane Company Maintenance Manual

CAUTION DO NOT FORCE HANDLE. IF RESISTANCE IS FELT, CHECK LATCH ALIGNMENT STRIPES THROUGH VIEWING PORTS IN DOOR. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

The following step in Boeing's MM does not appear in the UAL MM: "Check that the Cargo Door Warning Light on flight engineer panel goes out." The UAL flightcrew checklist includes a check of the warning light as part of the cockpit procedures for dispatch.

Prior to the issuance of AD-88-12-04 (see 1.6.8), UAL ramp service personnel only operated the cargo doors electrically. Manual operation was accomplished only by maintenance personnel. AD-88-12-04 required the additional procedure of recycling the master latch lock handle following manual operation of the latch actuator.

1.6.3 UAL Boeing 747 Special Procedures--Doors

The Safety Board's investigation revealed that UAL had published a "special maintenance procedure" in the UAL MEL for manual operation of the cargo door. The Maintenance Manual Special Procedures, 5-8-2-52, dated January 1988, were incorporated into UAL's MEL for use by maintenance controllers and work foremen in issuing instructions or procedures to mechanics. The procedure allowed the use of a special 1/2-inch socket drive wrench as the primary tool for use in manually opening or closing the cargo door. The document further authorized, as an alternate tool, an air-driven torque-limiting screwdriver. UAL procedures required approval by San Francisco Line Maintenance and the station maintenance coordinator before an air-driven screwdriver could be used to operate the doors of a B-747 airplane with an inoperative cargo door power system.

At the Safety Board's public hearing, the FAA PMI and the FAA B-747 maintenance inspector for UAL testified that prior to the accident they were unaware of an FAA authorization for UAL's use of an air-driven torque-limiting screwdriver on B-747 cargo doors. However, the FAA's approval for the use of the tool was noted in the MEL section of the airline's maintenance manual. The original approval had occurred before the current inspectors assumed their respective positions. Both testified that they had not reviewed UAL's B-747 MEL because they assumed that the previous inspectors had reviewed it.

According to UAL, the calibration/adjustment for the torque-limited air-driven screwdrivers was tested every six months. Safety Board investigators found no records for the calibration/adjustment of the power tools used to manually open and close UAL B-747 cargo doors.

The Safety Board received statements from UAL supervisory maintenance personnel at all UAL stations and contract facilities for B-747 operations indicating that air-driven screwdrivers had not been used by maintenance personnel to open or close the forward cargo door on N4713U in the months prior to the accident.

1.6.4 UAL Maintenance Program

Airplanes operated by UAL are maintained under an FAA-approved continuous airworthiness maintenance program, as required by 14 CFR Part 121, Subpart L. The requirements of the UAL maintenance program are detailed in their Operations Specifications, dated November 21, 1988. Generally, UAL has an overall in-house capability to perform virtually all of the maintenance required on its own airframes and powerplants. All of the required major airframe and powerplant maintenance for N4713U had been performed at the UAL maintenance facility in San Francisco, California.

UAL's maintenance and inspection program is scheduled either at specific flight hour or calendar intervals. These maintenance and inspection programs are designated as: Service No. 1, Service No. 2, or A, B, C, MPV, and D Checks.

The work scope of Service Checks consists of a general inspection of the airplane and engines, including servicing of consumable fluids, oxygen, and tire pressures. The Service No. 1 check involves an inspection at each maintenance facility where the airplane lands. The Service No. 2 check is performed at a maintenance facility where the airplane is scheduled for at least 12 hours of ground time. The maximum time interval between Service No. 2 Checks is not to exceed 65 flight hours.

The "A" Check is performed at intervals not to exceed 350 flight hours. This check includes an extended inspection of the cockpit, cabin, cargo compartments, landing gear, tires, and brakes. It does not include a detailed inspection of the cargo doors.

The Phase Check ("B" Check) is scheduled on a calendar basis, not to exceed 131 days. The scope of the "B" Check contains items of inspection such as interior safety equipment and functional verification of various aircraft systems and components. It does not include a detailed inspection of the cargo doors.

The "C" Check is heavy maintenance oriented and is scheduled on a calendar basis, every 13 months. The "C" Check work scope is substantial and includes:

structural inspection items;

corrosion repair;

prevention and inspection of critical flight control systems; and,

a detailed inspection of the cargo doors.

The Mid-Period Visit (MPV) Check is a heavy maintenance inspection that is scheduled at intervals not to exceed 5 years. Items requiring scheduled overhaul are contained in the check as well as inspections of the airplane structure and interior.

The D Check, completes the routine scheduled B-747 maintenance plan and is scheduled at intervals not to exceed 9 years. The work scope is very similar to the MPV Check and consists of heavy maintenance to the airplane structure, landing gear, interior, and airplane systems, including the cargo doors.

1.6.5 Maintenance Records Review

A review of the airplane's history indicated that the forward and aft cargo doors were the original doors and neither had been removed for repair or replaced for cause. There was no record of major repair to either door or adjacent airplane structure.

The forward cargo door's forward mid-span latch pin had been removed because of gouging of the pin surface, during the last "C" check on

November 28, 1988. According to the available maintenance documents, including the most recent "D" check, a full cargo door rigging check had not been accomplished. UAL maintenance personnel indicated that no rigging of the forward or aft cargo doors was required during the following checks:

1. "D" check accomplished April 1984;
2. "C" checks accomplished November 11, 1987, and November 28, 1988; and,
3. "B" checks accomplished March 21, 1988 and July 27, 1988;

The records prior to the "D" check in 1984 and the "C" check accomplished in November 1987 were not required to be retained. This procedure complies with FAR 121.380.

The logbook of N4713U was reviewed and all numbered pages were in sequential order with none missing. The airplane had been released for flight by UAL, HNL Maintenance, in accordance with UAL procedures. The Los Angeles to HNL segment of flight 811, on February 23, 1989, generated four logbook discrepancy entries. All items were cleared by HNL maintenance and none were related to the cargo door. No new deferred items were generated and no current deferred items were corrected. The Maintenance Release document for flight 811 indicated that all deferred items were in accordance with the UAL Minimum Equipment List (MEL) and none referenced the forward cargo door.

UAL stores its maintenance information in an "electronic logbook," entitled Aircraft Maintenance Information System (AMIS). This system tracks on a daily and worldwide basis the flightcrew defect reports, all nonroutine maintenance defects, and maintenance corrective actions for the UAL airplane fleet. The system follows an Airline Transport Association (ATA) chapter format. According to UAL, the AMIS information is used as part of UAL's FAA approved maintenance reliability program affording the capability to assess trends at any given time.

A complete history of N4713U was reviewed for the following ATA Chapters:

Chapter-00-Miscellaneous

No significant items associated with the cargo door systems.

Chapter-21-Air Conditioning and Pressurization

An entry, dated August 19, 1988, indicated "Auto and Standby pressure controllers were erratic." UAL maintenance cleared this item as "Checked per Maintenance Manual Chapter (MM) 21-31-00.

Chapter-31-Instruments (Not related to any specific system)

No significant items associated with the cargo door systems.

Chapter-52-Doors (Cargo door section only)

During the period September 7, 1988, through November 1, 1988, a series of five discrepancies on the forward cargo door's electrical opening and closing system were noted. Ground handling personnel were required to operate the door by the manual system. On November 1, 1988, UAL maintenance corrective action for this discrepancy was signed off as, "replaced power unit [lift mechanism] per Maintenance Manual Chapter 52-34-02.

An expanded AMIS history of the N4713U forward cargo door system was prepared beginning December 1, 1988, and continuing until the date of the accident. The history tracked the airplane by each flight and station transited.

During the period December 5, 1988, through December 23, 1988, eight defect reports regarding the opening and closing of the forward cargo door were entered into the system. The reported defects involved problems with the cargo door not always operating with the normal electrical system. Appendix E contains the details of the writeups and corrective actions.

During the period December 23, 1988, through February 23, 1989, two forward cargo door discrepancies were noted on N4713U. On January 3, 1989, the discrepancy was, "Manual lock seals broken." The corrective action was signed off as, "recycled [door] per placard on door and documented. No door problems." On January 15, 1989, the discrepancy was, "cargo door seal, lower aft corner is torn and loose from retainer." The corrective action was "repaired seal." There were no further

recorded discrepancies.
On February 23, 1989, a written discrepancy noted "Aft cargo door damaged aft lower corner." The corrective action listed, "Interim repair per (EVA) LM-8-433. Accomplish permanent repair within 60 flight hours."

Chapter-53-Structures (Fuselage)

During the period March 1988, through February 24, 1989, one defect was noted for each of the forward and aft cargo doors on N4713U.

Forward Cargo Door.--On September 6, 1988, the discrepancy was, "Approximately six inches of forward cargo door jamb damaged center of lower side sealing surface." The corrective action was, "Installed doubler and sealed area."

Aft Cargo Door.--On April 22, 1988, the discrepancy was, "Aft cargo door rear sill latch does not spring up to lock." The corrective action was, "Replaced latch."

1.6.6 Service Difficulty Report Information

A review was made of the Service Difficulty Reports (SDRs) for ATA Chapter 52 for all UAL Boeing 747 airplanes. Thirty-nine SDRs were recorded over the period January 31, 1983, through March 21, 1989. The following summarizes data concerning the forward and aft cargo doors:

cases of corrosion;
cases of cracking;
cases of door open (false) indications;
cases where cabin did not pressurize;
cases of cabin pressure loss; and
case of dent caused by ground equipment.

None of the noted SDR cases were recorded for N4713U.

1.6.7 Service Letters and Service Bulletins

Boeing issues information to its customers via Service Letters (SL's) and Service Bulletins (SB's) to inform operators of reported and anticipated difficulties with various airplane models. Twelve

SL's provided guidance for maintenance or information applicable to the B-747 cargo doors. Twenty-nine SB's provided guidance for maintenance or information applicable to the B-747 cargo door.

SB-747-52-2097, "Pressure Relief Door Shroud Installation--Lower Lobe and Side Cargo Doors," was issued on June 27, 1975. Revision 1 to SB-747-52-2097 was issued November 14, 1975. In general, the SB recommended the installation of shrouds on the inboard sides of the cargo door pressure relief door openings. The purpose of the shrouds was to prevent the possibility of the pressure relief doors being rotated (blown) to the closed position during the pressurization cycle. This condition could only occur if the master latch lock handle had been left open and the flightcrew failed to note the cargo door open warning before takeoff.

UAL records for N4713U indicated that SB-747-52-2097 had been complied with and the shrouds had been installed on the forward and aft cargo doors. However, examination of the aft cargo door on N4713U revealed that the shrouds were not in place. UAL could not find records to verify if the shrouds had been installed or if they had been removed from either door.

1.6.8 Airworthiness Directives

There had been 141 Airworthiness Directives (ADs) issued that were applicable to the accident airplane. Two ADs were pertinent to the cargo door. AD 79-17-02-R2 ("Inspection of Fore and Aft Lower Cargo Door Sill Latch Support Fittings,") required an inspection every 1,700 flight hours. The second, AD 88-12-04 ("To Insure That Inadvertent Opening Of The Lower Cargo Door Will Not Occur In Flight,") issued on May 13, 1988, required an initial one time inspection of the cargo door latch locking mechanisms within 30 days of issuance of the AD, and certain repetitive inspections until terminating action for the AD was taken.

The circumstances of a Pan American World Airways (Pan Am), Boeing 747-122 cargo door opening in flight (see 1.17.1 for details) led to the issuance of Boeing Alert Service Bulletins (ASB) 52A2206 on April 8, 1987, and 52A2209 on August 27, 1987, entitled, "Doors - Cargo Doors Lower Lobe Forward and Aft Cargo Doors, Latch Locking System Tests, Operation and Modification." Tests and investigation revealed that latch lock sectors would, in some instances, not restrain the latch cams from being driven open manually or electrically. Movement of the latch cams without first moving the lock sectors to the stowed [unlocked] position would cause bending, gouging, and breaking of the sectors. The FAA issued AD-88-12-04 to make the provisions of SB's 52A2206 and 52A2209 mandatory.

The terminating action for AD 88-12-04 called for installing steel doublers to add strength to the lock sectors to prevent the latch cams from being able to be driven to the open position manually or electrically with the sectors in the locked position. AD 88-12-04 also required that, if the door could not be operated normally (electrically), a trained and qualified mechanic was to open and close the door manually, rather than ramp service personnel. Further, the AD required an inspection of the lock sectors for damage once a cargo door was restored to electrical operation after any malfunction had required manual operation of the door. The amount of time allowed for completing the terminating action portion of AD 88-12-04 was either 18 months or 24 months, from the issue date of the AD, depending on the Boeing 747 model series. Terminating action for the AD had not been accomplished on N4713U prior to the accident, nor was it required since, for this airplane, the deadline for compliance with the terminating action was January 1990. According to UAL, N4713U was scheduled for completion of the terminating action in April 1989, when the airplane was scheduled for other heavy maintenance.

During the Safety Board's investigation it was determined that a clerical error was made by UAL personnel, while attempting to expedite the processing of an advanced copy of a Notice of Proposed Rulemaking (NPRM 87-NM-148-AD), preceding AD 88-12-04. The error involved the omission of one line of text during the typing of the document. Because of that error, the portion of the text of the NPRM (and the final text of the AD) was left out of UAL's maintenance procedures. The omitted text required an inspection of the B-747 cargo door lock sectors every time a cargo door was restored to normal (electrical) operation after manual operation was required.

The UAL maintenance internal auditing system, including quality assurance personnel, did not detect the omission until after the accident. UAL personnel stated that, for unknown reasons, no one within the maintenance or quality assurance programs had reviewed the final AD language for comparison with the UAL maintenance procedure.

A review by Safety Board investigators of forms used by UAL to verify compliance with applicable FAA AD's issued indicated that all of the applicable mandatory ADs were satisfied within their specified time limits. The list provided by UAL to the FAA as part of the FAA's oversight responsibilities showed compliance with AD-88-12-04, with the exception of the terminating action.

Section 1.17.3 contains information relevant to the B-747 cargo door corrective actions taken since the accident.

1.7 Meteorological Information

The accident occurred in night visual meteorological conditions. No adverse weather was experienced, although the flight did have to deviate around thunderstorms during the descent.

1.8 Aids to Navigation

There were no navigational problems.

1.9 Communications

There were no radio communication difficulties between flight 811 and air traffic control (ATC). Members of the flightcrew did not have any difficulty in verbally communicating with each other; however, attempts to communicate with the cabin crewmembers by interphone were unsuccessful following the explosive decompression.

1.10 Aerodrome Information

After the explosive decompression, the airplane returned to HNL, a 14 CFR Part 139 certificated airport on the island of Oahu, Hawaii. The airport is located about 4 miles west of Honolulu, Hawaii.

HNL is a "joint use" airport that is used by the State of Hawaii, the U.S. Air Force, general aviation, commercial, air carrier, air taxi, and military aircraft. Aircraft Rescue and Fire Fighting (ARFF) services are provided by State and Hickam Air Force Base ARFF units. Prior to the emergency landing at Honolulu, flight 811 requested that all available rescue and medical equipment to be on hand when they landed. When the crash alarm was broadcast, all civilian and military fire units responded and were in position in 1-minute at pre-designated stations at runway 8 left.

The Safety Board's investigation revealed that there was no direct radio communications between the State Airport vehicles and Hickam ARFF vehicles. Because there were no direct radio communications, the Chief of the airport's units had to drive his vehicle to the vehicle of the Chief of the Hickam units to coordinate the positioning of ARFF units prior to the landing of United 811.

The Hickam vehicles are painted olive drab camouflage. During the response, the Chief of the State ARFF vehicles observed a near collision between a State and a Hickam vehicle. He attributed this to the camouflaged Hickam vehicle not being visually conspicuous in spite of the fact that each of the vehicles had a red rotating beacon operating. The response took place on a moonless night and in light rain.

1.11 Flight Recorders

The airplane was equipped with a Sundstrand model 573 digital type Flight Data Recorder (DFDR) and a Sundstrand model AV557-B Cockpit Voice Recorder (CVR).

Examination of the data plotted from the DFDR indicated that the flight was normal from liftoff to the accident. The recorder operated normally during the period. However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent.

The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.

1.12 Wreckage and Impact Information

An extensive air and surface search of the ocean conducted immediately following the accident failed to locate the portions of the airplane lost during the explosive decompression. However, the Safety Board, as well as other parties to the investigation, pursued several avenues to search for and recover the cargo door. Navy radar near Honolulu tracked debris that fell from the airplane when the cargo door was lost. Refinement of the radar data led to a probable "splashdown" point in the ocean. Further assistance from the Navy regarding the ocean currents and drift information led to a probable location of the cargo door and

associated debris on the ocean floor.
The undersea search operation was begun on July 22, 1990, using the Orion, a state-of-the-art Navy side-scanning sonar "fish." Searching in the area selected by analysis of radar data and undersea currents, the Orion located a debris field on its first pass over the 14,200-foot-deep ocean floor. The second pass located a significant sonar target, which later analysis indicated was probably the cargo door. Since the Orion is only capable of searching, the debris field was marked with transponders for use during the subsequent recovery phase.
On September 14, 1990, the recovery ship Laney Chouest sailed from Pearl Harbor with the manned, deep-sea submersible Sea Cliff. Safety Board, FAA, Boeing, and UAL engineering staff assisted the recovery team aboard the Laney Chouest. After four dives in the area previously identified as the debris field, only pieces of cargo container and other small debris from the airplane had been recovered. (It appears that the significant target identified by the Orion was a piece of cargo container rather than the cargo door.) On the following dive, however, the lower portion of the cargo door was located and recovered. The fuselage structure above the cargo door was located and raised to the surface on the sixth dive, but heavy seas prevented its recovery. The upper portion of the door was recovered during the Sea Cliff's seventh dive on October 1, 1990. Afterward, it was decided that no further effort could be justified to recover the fuselage structure above the cargo door, and the recovery mission was terminated.
Following recovery of the cargo door, each piece was sprayed with a corrosion inhibitor. The ship promptly returned to Pearl Harbor, and the retrieved door portions were removed and examined before being shipped to Seattle, Washington, for detailed examinations under the supervision of Safety Board staff.
Visual examinations on the recovery ship and in Pearl Harbor

confirmed that the cargo door lock sectors were in the locked position and that the latch cams were in the nearly open position. Figure 6 depicts the position of the lock sectors and cams as recovered from the ocean. There was no evidence of progressive fractures in the door structure.

The cost for the search mission was $193,000, and the cost for the recovery mission was $250,000. These costs were shared by the Safety Board, the FAA, UAL, and Boeing. Section 1.16 contains information on the examination of the recovered wreckage.

1.13 Medical and Pathological Information

Appendix D contains a list of injuries.

1.14 Fire

There was no fire in the cabin or fuselage. The fires in engines No. 3 and 4 were extinguished after the engines were shut down.

1.15 Survival Aspects

The fatal injuries were the result of the explosive nature of the decompression, which swept nine of the passengers from the airplane.

At 0210, the FAA notified the U.S. Coast Guard that a United Airlines, Inc., B-747, with a possible bomb on board, had experienced an explosion and was returning to HNL. The Coast Guard Cutter, Cape Corwin, departed Maui at 0248 to search the area for debris and the missing passengers. Ultimately, 4 shore commands, 13 surface/air units, and approximately 1,000 persons took part in the combined search and rescue (SAR) operation. The search was t™ erminated at 1200 on February 26, 1989, without recovery of any passenger bodies.

The flight attendants had approximately 20 minutes to prepare the cabin and the passengers for an imminent ocean ditching, and subsequently, for an emergency evacuation. During the 20 minutes they attended to injured flight attendants and passengers, attached the face masks to their emergency oxygen bottles, helped each other don life preservers, helped numerous passengers don life preservers, held up safety cards and life vests to call attention to these items for passengers to use, briefed "helper" passengers to assist in the evacuation, cleared debris away from the exit doors and aisles, closed the doors of the storage compartment above doors 2 left and 2 right, prepared the cabin for an emergency evacuation, and told the passengers to brace for impact.

Several problems were experienced by the flight attendants and the passengers following the decompression, while preparing for a possible ditching, and preparing for the emergency evacuation. These problems included difficulties encountered by flight attendants in connecting face masks to their portable oxygen bottles, the lack of a sufficient number of megaphones, limited visibility from a flight attendant seat, overhead storage compartment doors opening, and donning and fastening life preservers.

Federal Aviation Regulation 14 CFR 25.1447 (c)(4) requires that "portable oxygen equipment must be immediately available for each cabin attendant." Those portable oxygen bottles on N4713U, which were readily available, were not immediately usable because the masks were not attached to the regulators. The flight attendants reported difficulties in attaching the masks to the regulators.

The aft purser ran back to the flight attendant jumpseat at door 5-left for a portable oxygen bottle. However, she found no bottle at this location (none was installed). She then ran back to the 4-left jumpseat, by which time she was "light headed." After the aft purser reached jumpseat 4-left, flight attendant No. 14, who was already sitting there, placed an oxygen mask on her face. The aft purser further stated, "considering the fact that in this case there was no other available source of oxygen, you can't imagine how horrible I felt going back there needing oxygen but finding no oxygen bottle at 5-left. It was terrifying."

A portable emergency oxygen bottle was not required to be stowed at the flight attendant seat at exit 5-right; however, one was stowed in the right coat closet behind the flight attendant seat. In addition, the left side closet and rest rooms were physically separated from the right side closet and rest rooms. This arrangement requires a flight attendant, who was seated at exit 5-left to walk around to the right side of the cabin to obtain the oxygen bottle.

Communication between the flight attendants and passengers was very difficult because of the high ambient noise level in the cabin after the decompression, even though the public address (PA) system was operational. Flight attendants were located at each of the 10 exit doors, yet there were only two megaphones required to be on the airplane; one located at door 1-left and another located a 4-left.

The flight attendants, who were responsible for each of these two doors, used the megaphones to broadcast commands to passengers in their immediate areas and to other flight attendants in preparation for the landing and subsequent evacuation. The other 13 flight attendants (including the one deadheading flight attendant) had to shout, use hand signals, and show passengers how to prepare for the evacuation by holding up passenger safety cards, so passengers could review the information and also know how to put on their life preservers.

As soon as the decompression occurred, the flight attendant in the upper deck business class section went to her jumpseat and donned her oxygen mask, life preserver, and restraint system. While she waited for instructions, and because of intense cabin noise she had to communicate with passengers by holding up a safety card and a life preserver. Passengers sitting in the front rows, in turn, showed safety cards and life preservers to other passengers seated behind them. Eventually everyone understood that they were to read the safety card and put on their preservers.

However, the 5 foot 3 1/2 inch flight attendant stated that her jumpseat was so low that she could not directly observe the passengers in the 4th row (last).

A two door overhead stowage compartment that had formerly stored a life raft was located above each exit door. These compartments contained blankets and passenger carry-on luggage. At doors 2-left and 2-right the doors of each compartment had opened downward and blocked each exit. Also the contents of the compartments fell to the floor at the exits. The doors had to be closed before the evacuation because they partially blocked the exit.

The chief purser was not able to tighten the life preserver's two straps around her waist and needed the deadheading flight attendant to tighten them for her. Several flight attendants and passengers had difficulties connecting the two straps around their waists. One flight attendant helped about 36 passengers don their preservers.

Safety Board investigators and United Airlines personnel examined several life preservers from each of the types of preservers produced by five manufacturers. The strap of one manufacturer's preserver was very difficult to tighten around the waist while another from the same manufacturer was easy to tighten. The two vests had different strap material and strap adjustment fittings. Also, the straps are very difficult, if not impossible, to tighten when they are pulled at an acute angle from the wearer's body, i.e. from about 45 to 70 degrees. Holding the hands and straps closer to the waist facilitates easier adjustment of the straps.

1.16 Tests and Research

1.16.1 Cargo Door Hardware Examinations

1.16.1.1 Before Recovery of the Door

The following forward cargo door closing and latching components were returned to the Safety Board's Materials

Laboratory for analysis after they were documented in place on the airplane:

Two pull-in hook pins, one from the lower end of the forward side of the door body cutout forward frame, and one from the lower end of the aft side of the body cutout aft frame, with housings;

Two mid-span pins, one from the forward side of the door body cutout forward frame, and one from the aft side of the door body cutout aft frame.

All components were initially examined while installed on the airplane. All eight forward cargo door latch pins, with housings, were removed for further laboratory examination. Also, for comparison, one of the latch pins, with housing, from the aft cargo door was also removed. For orientation purposes, the eight lower latch pin assemblies are referred to by number, with the No. 1 latch pin being the most forward on the lower door sill, and the No. 8 pin being the most aft. When referencing a circumferential location on the latch pins or mid-span pins, a clock position was used. The clock code was oriented looking forward with 12 o'clock being straight up and 9 o'clock being directly inboard.

Based on the orientation of the latching mechanisms, the fully unlatched latching cams would first contact the latch pins from about the 1:15 o'clock position to the 7:15 position as the door was closed. As the cams are being latched around the pins, they would rotate approximately 80(, making contact with the pins from about the 4:15 position to the 10:15 position (See figure 7).

Detailed examination of the exposed surface of the pins (the portion of the pins extending from the housings) revealed various types of wear and damage. In general, all of the forward door cargo latch pins had smooth wear over the entire portion of the pin area contacted by the cams during normal closing and opening of the door. The pins also had distinct roughened (smeared) areas between the 6:15 and the 7:30 positions (See figure 8). The roughened areas had evidence of "heat tinting" and transfer of cam material to the surface of the pins. On pins 1 and 8 the roughened areas extended past the pin bottom to the 5:00 position. The 7:30 position approximately corresponds to the area on the pin where the lower surface of the cam would be relative to the pin when the latch cams are in the unlatched or nearly unlatched position.

The forward pull-in hook pin was not significantly bent, but the structure to which it was attached was deformed outward, so the hook pin was deflected significantly outward. Three of the four bolts holding the aft pull-in hook pin had sheared, so the hook pin was also deflected outward. Both hook pin ends were damaged, but neither pin was significantly deformed along its length. There was significant heat tinting on the damaged area of the forward hook pin. Boeing engineering calculations determined that the pull-in hook pins would fail at a 3.5 psi differential cabin pressure with the latch cams unlatched.

The forward mid-span latch pin was relatively undamaged. The aft mid-span latch pin had definite areas of damage. Both pins had wear areas where the cams would contact the pins during latching.

1.16.1.2 After Recovery of the Door

The documentation of the recovered cargo door was divided into four areas: 1) door structure, 2) master latch lock system, 3) latch system, and 4) hook system. A description of the recovered door follows.

1. Door Structure:

The cargo door had fractured longitudinally near the mid-span lap joint near stringer 34R, just beneath the mid-span torque tubes. Except for an area of missing skin between frames 2 and 3 and a portion of frame webs where the upper latch lock torque tube had torn out, the frames and skin of the upper door

piece mated to the lower door piece.2 Several areas of the upper door skin along the longitudinal fracture were bent back. In addition, a large area of lower door skin between frame 6 and the aft door edge had peeled downward from the fracture line. The two door pieces are shown together in Figures 9 and 10.
Examinations of the fracture surfaces of the skin and frames revealed no evidence of pre-existing cracks. All fractures were typical of overstress separation.
Seven of the eight lock sector slots in the lower beam showed evidence of contact and scraping by the lock sectors. Only the No. 1 lock sector slot was undamaged, although the bracket forward and above the No. 1 slot did appear to have been damaged by contact from the lock sector (slots numbered 1-8, forward-aft).
The direction of the scraping on the slots could not be determined conclusively.
The decal covering the latch actuator manual drive port was found broken circumferentially around the edge of the port cover, which was loose and rotated from its normal position (See figure 11). There was an impression in the decal similar to a Phillips-head screw slot in line with the center of the retainer screw securing the cover. There was also a 0.06-inch-long linear slit from 10 to 4 o'clock approximately centered over the retainer screw head (See figures 12 and 13). There was no rotational tearing and no loss of decal material in the area covering the screw head location. During examinations of the door at Boeing, it was noted that the retainer bracket on the inside of the latch actuator manual drive port cover was bowed outward; the port cover was not deformed. The retainer bracket on the inside of the hook actuator manual drive port cover was similarly bowed outward, and the port cover was bowed outward.
The hinge that attaches the cargo door to the fuselage is comprised of several hinge sections--those attached along the upper edge of the cargo door and those along the fuselage just

above the cargo door cutout--interconnected with hinge pins. The hinge pins and all hinge sections from N4713U's forward cargo door were intact; all hinge sections rotated relatively easily. All attach bolts from the hinge sections on the door remained attached; conversely, no bolts remained attached to the hinge sections on the fuselage. Several areas on the hinge sections, such as the fuselage hinge sections, showed evidence of contact from the door during overtravel (See figure 14). In addition, the fuselage forward hinge sections

were slightly bent. The upper flange of the door, to which the door hinges are attached, was not deformed. The forward cargo door can rotate open 143 degrees before the hinge would deform, permitting the door to contact the fuselage above.

Examination of the outer skin contour of the upper door piece revealed that it had been crushed inward. There were also many areas on the outer skin where blue and red paint transfer marks could be seen. These marks were generally forward of the aft pressure-relief door, and the blue marks were located above the red marks. The UAL paint pattern incorporates red and blue stripes along the fuselage above the cargo door. Figure 15 is a plot of the documented paint marks on the upper door piece.

There was no evidence of the pressure relief door shrouds found on the forward door; however, most of the inner door lining to which the shrouds attach was missing.

2. Master Latch Lock System:

All eight lock sectors were found in the locked position--actually past the fully locked position. They had been pulled through the lock sector slots in the lower beam of the cargo door. (When they are fully locked, the lock sectors should be recessed in the lower beam approximately 3/8 inch). All lock sectors had deflected off the high shoulder of the latch cams due to interference with the partially unlatched cams. Prior to disassembly of the components, the interference between the cams and the lock sectors was

removed by rotating the cams to the latched position.
Examination of the lock sectors disclosed that the bottom of the lower arm of each lock sector was gouged. For seven of the eight lock sectors, the distance from the main gouge area to the location of the interference between the latch cam and the lock sector was approximately 0.75 inch. (The No. 2 lock sector was corroded and had fractured at the location of the large gouge common to the other seven lock sectors. Consequently, it was not in contact with the No. 2 latch cam when the door was retrieved).
The master latch lock handle housing and trigger were found relatively flush with the door outer skin. The top of the handle was recessed approximately 0.50 inch inward from flush, and the bottom of the handle was protruding approximately 0.40 inch outward from flush (See figure 16). This
Figure 15.--Documented paint marks on outer skin of upper door piece. Dashed line is approximately 8 degrees from horizontal.
position of the handle indicates that the lock sectors were in a position past fully locked. The fuse pin was found in three pieces but was heavily corroded. The handle housing was undamaged.
Two of the three connecting rods between the master latch lock handle and the lock sector torque tube were bowed slightly, but they were otherwise intact. No deformation was observed on any section of the lock sector torque tube, although one of the six bearings assembled on the torque tube had been damaged. The No. 3 bearing inner race and its torque tube locator sleeve were displaced forward approximately 0.20 inch from the bearing housing centerline. The outer race was broken and pushed forward out of the housing.
The lower two connecting rods between the lock sector torque tube and the torque tube below the pressure-relief doors were undamaged; however, the upper connecting rod had separated at the upper, tapered end. The torque tube below the pressure-relief doors were missing, and the pressure-relief door connecting rods

had separated at the lower, tapered end. The remaining portion of each rod was undamaged, but the forward pressure-relief door was jammed open into the cutout.

3. Latch System:

All eight lower latch cams were found in a nearly unlatched position, and all of them were binding against the lock sectors except the No. 2 cam (lock sector No. 2 had broken). Latch cams 1-6 were approximately 62 degrees from the fully latched position, and cams 7 and 8 were approximately 70 degrees from fully latched. Full rotation of the latch cams is 80 degrees.

Several of the lower latch cams contained compression and smearing damage on the lower lip of the latch cam cavity ("lower" relative to an open cam). This damage is consistent with the forceful movement of the cams across the latch pins.

The four rods between the latch actuator torque tube and the four bellcranks containing the latch cams were attached and undamaged. No section of the latch actuator torque tube was damaged, and the bearings/supports along the tube were intact.

The latch actuator was removed and later disassembled. No anomalies were found.

4. Pull-in Hook System:

The forward and aft pull-in hooks were found near the closed position. Both of them exhibited wear patterns consistent with contact with the pull-in hook pins during door operation. For both the forward and aft hooks, the inboard edge of the pull-in hook channel contained compression and smearing damage consistent with a forceful movement of the hooks over the pins while the hooks were in the closed or nearly closed position.

1.16.2 Forward Cargo Door Electrical Component Examinations

1.16.2.1 Before Recovery of the Door

Several electrical components associated with the operation of the forward cargo door were examined on the airplane and were then removed for further testing. These components included the No. 2 ground handling power bus relay, the air/ground safety relay, the No. 1 auxiliary power circuit breaker, and the outside and inside door control switches. All of these components were tested for both single faults and intermittent failures. The test results showed that all of the switches/relays were functional, although a loose wire connection was found on the outside door control switch. This loose wire connection showed evidence of overheated insulation on the two terminal lugs that attach to terminal No. 5, and there was evidence of a burn (arc point) on the top of the screw head for terminal No. 5. Terminal No. 5 is associated with power for the door "close" cycle, and not the door "open" cycle.

An electrical continuity check was performed on the cockpit cargo door warning light system components that remained with the airplane. This check confirmed the integrity of the circuit from the door area to the cockpit. The examination of the two bulbs that comprise the forward cargo door warning light revealed that one bulb was inoperative. The other bulb, which is in parallel with the inoperative bulb, was found operative. The illumination of the display legend, which reads "FWD CARGO DR" on the flight engineer's panel, was discernible with one bulb inoperative. A functional check of the circuit, which allows the cockpit warning lights to be dimmed during night operations, was also performed. The check consisted of removing the card containing this circuit and installing it in another B-747. The test was satisfactory in that the dim/bright circuit functioned properly.

1.16.2.2 After Recovery of the Door Switches--General

The cargo door was recovered with all of its position sensing switches installed in their proper locations. The electrical junction box was found attached to the door but damaged. The switches recovered and examined were: S2 Master Latch Lock; S3 Door

Warning; S4 Latch Close; S5 Hook Position; S6 Fwd Mid-Span Latch Open; S7 Door Close; S8 Hook Close; and S9 Aft Mid-Span Latch Open. Figure 17 provides a diagram of the cargo door's electrical circuitry.

Five of the eight position-sensing switches installed on the door had evidence of external damage to the switch housing. The damage on four switches (S2,S3,S4,S8) consisted of primarily compression dimpling on the housing. The S5 switch exhibited mechanical impact damage on the switch housing and mounting bracket. The striker assembly for switch S8 was loose (2 of 3 rivet fasteners sheared). The electrical wiring recovered with the door exhibited signs of tensile separation from overload at all failure points examined.

Each switch was photographed and its installed position was documented. Electrical continuity readings were taken with an ohmmeter across the poles of each switch at the first point of wire separation as found on the door. After the readings were recorded, all switches were removed from the door so that photographs and x-rays of each switch could be taken. Electrical continuity readings were retaken.

Disassembly of each switch consisted of: (1) drilling two holes in the switch housing to release trapped water from the switch (2) cutting a small window in the switch housing to examine the internal basic switches (3) removing the housing, (4) removing the internal bracket, and (5) removing basic switch covers.

During the drilling step, water was released from every switch when the holes were drilled in the switch housing. The water was filtered into a glass container. The quantity was not measured but appeared to be less than 5 mL. The residue from the filtered water trapped on the filter media had a blue-green color.

After the switch housing was removed, an ohmmeter was connected across the 1-2 poles of the switches that would not transfer electrical continuity (S2,S3,S4,S6,S7) when actuated. The rivets were then drilled out of the internal bracket. After the last of the two rivets were drilled out, the switch contacts

Figure 17b.--Diagram of cargo door electrical circuitry.

transferred to the other pole on S2, S3, and S4. On S6, the used3 basic switch was held closed by its plunger. S7 transferred after the switch housing and water inside were removed.

During removal of the basic switch covers, a trend was noted in the discoloration of some of the basic switches. The used switch had a reddish-brown coloration. The unused switch was not discolored.

Each switch was found to be wired correctly to its poles and through its contacts within the basic switches. All contacts operated with light finger pressure after removal of the basic switch covers. There was no evidence of pitting, excessive corrosion, or heat distress in the contacts of any of the switches.

The following sections detail pertinent observations concerning each switch.

The S2 master latch lock is given particular significance because of its function to protect against inadvertent door operation and is thus described in more detail. It is a single-pole double-throw (SPDT) switch used to sense the unlocked position of the door lock sectors. The switch is mounted in the aft lower corner of the door. A bracket attached to the No. 7 lock sector depresses the switch when the door lock sectors are rotated to their unlocked position. When the bracket attached to the lock sector contacts the switch plunger and depresses it, the circuit path through the switch is closed and 28VDC electrical control power to the door is established. When the force on the plunger is relaxed, the circuit is opened and 28VDC electrical control circuit is removed.

The wires leading to the S2 switch had been cut by the team after the recovery in an attempt to test continuity through the switch. The door recovery team reported that it found continuity through the 1-3 contacts but not through the 1-2 contacts. The switch plunger was actuated by the recovery team. The recovery team noted that the switch did not transfer continuity during these tests. The operation of the switch plunger would normally transfer continuity. Subsequent detailed examination of the S2 switch confirmed the findings of the recovery team.

The area around the upper face of the internal bracket was bent toward the basic switches and had evidence of corrosion residue. The bracket was found broken. The switch contacts transferred from the 1-3 actuated position to the 1-2 nonactuated position when the bracket was removed. Scanning electron microscope examination of the fracture surfaces revealed evidence of overload and corrosion.

The external switch housing was dented. The final examination performed on the switch consisted of removing the plastic covers on the basic switches. Prior to removal of the basic switch covers, it was noted that the cover to the used basic switch was cracked. The contacts functioned normally when exercised by light finger pressure.

Microscopic examination revealed a black discoloration near one of the lower contact posts of the used basic switch. Energy dispersive spectrometric examination of the residue disclosed the presence of gold, iron, magnesium, sodium, and chlorine. No mechanical or electrical anomalies were detected with the basic switch contacts.

Additional testing was performed by Boeing on switches of a similar design to those used on the accident airplane's cargo door. The testing was conducted to identify conditions that would result from salt water immersion at a pressure depth of 14,200 feet for 18 months. The testing verified that external damage to the switch housing occurred at pressure depths of 7,000 feet and greater. Switch seal leakage and subsequent internal corrosion was also noted. None of the testing performed by Boeing duplicated internal switch damage that caused basic switch

contact closure or internal damage to the switch support bracket.
Wiring:
The electrical wiring recovered with the cargo door was documented in place before being removed for further tests. About 40 percent or 112 feet of wire from the original length of approximately 274 feet was recovered and examined. Of this amount, about 46 feet of wire installed in the aircraft forward of the cargo door was not examined. Most of the wires leading from the door to the fuselage were not recovered. There was no visible external evidence of burning, arcing, or heat distress in any of the wires removed. Several areas of wire insulation damage were found.
Thirty five wires were identified that could provide a possible short circuit path that could drive the latch actuator open with or without failures of other door electrical components if the ground handling bus was energized. The wires were schematically coded by function. Wires coded (-..-..-) were denoted for wiring that provides open command logic to the latch actuator. Wires coded (--.--.--.) were denoted for additional wiring enabled by an activated (failed) S2 switch. Wires coded (-o-o-o-o) were denoted for wiring providing 28VDC power from the C285 circuit.
Potential short circuit paths were identified for the cargo door that could provide 28VDC to the latch actuator control circuit relay. These potential short circuit paths can cause the latch actuator to drive the latches toward their open position if 115VAC power is available to the latch actuator motor. The potential short circuit paths include two bare wires shorting against each other, bare wire-to-metal structure-to-bare wire contact, wire to conductive fluid (such as water) to wire, or a combination of the aforementioned.
Conductive contact of (-o-o-o-o) or (--.--.--) coded wire with (-..-..-) coded wire could potentially result in providing a 28VDC circuit path to the latch actuator open circuit. Direct wire-to-wire paths

are coded in Figure 17 as defined above. The two-wire short circuit paths are identified as wire pairs consisting of wire 101-20 shorting with any of the following wires; 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

If the S2 master latch lock switch fails in the "Not Locked" position, there are additional wire pairs that provide short circuit paths. These are coded in Figure 17 as (--.--.--) to (-..-..-..) wire pairs.

Short Circuit Wire Damage Simulation Tests:

Tests were conducted by Boeing and United to simulate typical examples of bare wire short circuiting to determine the extent of visible wire damage that would be expected in the 28VDC cargo door control circuit.

United performed tests on BMS 13-42 wire, the wire type used in the B-747 cargo door control circuit. Visible electrical short circuit damage on bare BMS 13-42 wire surfaces was difficult to create at 28VDC. Surface damage was considered visible when detected by microscopic examination at 15X magnification. United testing simulated the relay coil resistance variations that would be found during typical in-service conditions. A current of 1.0 A at 28VDC created visible surface damage on momentary bare wire-to-bare wire contact. Multiple contacts at 1.0 A provided a more positive indication. A single momentary contact between two bare BMS 13-42 wires with 0.160 A at 28VDC did not create visible surface damage. Contact between a BMS 13-42 bare wire and Alclad 2024-T3 metal (airplane and cargo door structure) with 0.160A at 28VDC did not create visible surface damage.

Boeing performed wire tests on BMS 13-48 20 gauge wire. The test setup used the MS27418-2B door latch actuator control relay in parallel with the 60B00311-2 door restraint solenoid, the actual electrical loads used in the B-747 cargo door latch actuator control circuit. A single momentary contact of a bare 28VDC power wire, with a bare wire connecting to the relay of the solenoid, showed small pithead area developed at the point of wire contact that was visible without magnification.

Wire Examination Procedure:

All of the recovered wires were examined in the Safety Board's Materials Laboratory on a mylar sheet to simulate their installed positions. Labels were used to identify the coded wires using the manufacturer's original wire identification numbers imprinted on each wire's insulation. Wire pairs for direct electrical short circuiting were located in two common wire bundles installed on the cargo door. One common wire bundle was associated with the P3 plug connector, the other with the P4 plug junction box. The wire bundles were examined visually for areas of obvious insulation damage. Each individual wire was also examined with a stereo-microscope. Representative wire damage features were photographed.

Wire Damage Found:

Seven wires numbered 101-20, 102-20, 105-20, 107-20, 108-20, 122-20, and 135-20 had visible damage located near a 3.8 inch position as measured from the P3 plug pin tips. This common position on the wire corresponds to a 360-degree loop in the wire bundle, which is located immediately below the junction box. Figures 18 and 19 show typical wire damage. Wire 122-20 had an open insulation area approximately 0.25 inch long. The other four wires had flattened insulation damage areas.

In the P4 plug connector wire bundle, three wires displayed insulation damage. Wires 113-20, 121-20, and 124-20 had transverse insulation nicks, which exposed bare conductors. All three had insulation nicks 3 inches from the P4 plug pin tips; wires 121-20 and 124-20 had additional insulation nicks 34 inches from the plug pin tips. The two P4 insulation damage locations corresponded to wire bundle clamp positions.

1.16.3 Pressurization System

The pressure relief valves located on the left side of the fuselage in the forward cargo compartment were removed from the airplane and subjected to bench tests at the UAL maintenance facility in San Francisco, California. No significant anomalies were discovered and both valves performed within specified tolerances.

1.16.4 General Inspection of Other UAL Airplanes

During the on-scene phase of the investigation, the Safety Board investigators examined six other B-747 airplanes while they were on the ground at HNL (four UAL airplanes and two operated by other carriers) to observe routine cargo door operations and to assess the condition of latching components. Generally, the door operations were normal. During the examination of latch pins on these airplanes, it was noted that most had a smooth wear ridge at the 9:00 position (looking forward) or were undamaged. All wear areas on the pins were smooth.

During electrical operation of the aft cargo door on one of the other UAL B-747 airplanes (N4718U), the pull-in hooks did not pull the door fully closed and the latch cams completed the closure. During operation of the latch cams, the bottom of the door moved, first circumferentially downward and then inboard. This additional movement was approximately 1/4 inch. A definite "thunking" noise was discernible as the door moved to its closed position at the end of cam rotation. On one occasion, the door would not open under electrical power. The door was "kicked" by a UAL mechanic, power was reapplied, and the door opened properly. Examination of the door by UAL mechanics, disclosed that the riveted plate holding the aft pull-in hook switch striker was loose.

All eight lower latch pins for the forward cargo door on N4718U exhibited a smooth ridge near the 9:00 position. Pins No. 1 and 2 also showed a smooth ridge at the 6:30 position with a smooth wear area between the 6:30 and 9:00 position. The forward and aft midspan cams of both forward and aft cargo doors had a heavy gouge mark corresponding to the end of the midspan latch pin. N4718U was subsequently removed from service for repair of the aft cargo door latching mechanisms.

1.17 Additional Information

1.17.1 Previous Cargo Door Incident

On March 10, 1987, a Pan American Airways B-747-122, N740PA, operating as flight 125 from London to New York, experienced an incident involving the forward cargo door. According to Pan Am and Boeing officials who investigated this incident, the flightcrew experienced pressurization problems as the airplane was climbing through about 20,000 feet. The crew began a descent and the pressurization problem ceased about 15,000 feet. The crew began to climb again, but about 20,000 feet, the cabin altitude began to rise rapidly again. The flight returned to London.

When the airplane was examined on the ground, the forward cargo door was found open about 1 1/2 inches along the bottom with the latch cams unlatched and the master latch lock handle closed. The cockpit cargo door warning light was off.

According to the persons who examined the airplane, the cargo door had been closed manually and the manual master latch lock handle was stowed, in turn closing the pressure relief doors and extinguishing the cockpit cargo door warning light. Subsequent investigation on N740PA revealed that the latch lock sectors had been damaged and would not restrain the latch cams from being driven open electrically or manually. It was concluded by Boeing and Pan Am that the ground service person who closed the cargo door apparently had back-driven (opened) the latches manually after the door had been closed and locked. The damage to the sectors, and the absence of other mechanical or electrical failures supported this conclusion.

Further testing of the door components from N740PA and attempts to recreate the events that led to the door opening in flight revealed that the lock sectors, even in their damaged condition, prevented the master latch lock handle from being stowed, until the latch cams had been rotated to within 20 turns (using the manual 1/2 inch socket drive) of being fully closed. A full cycle, from closed to open, is about 95 turns with the manual drive system.

1.17.2 FAA Surveillance of UAL Maintenance

The Denver, Colorado, FAA Flight Standards District Office (FSDO) holds the operating certificate for United Airlines, Inc. The FAA FSDO in San Francisco, California, has the primary surveillance and oversight responsibility for UAL maintenance.

The FAA's PMI has the responsibility to oversee an airline's compliance with Federal Regulations with respect to maintenance, preventive maintenance, and alteration programs. The PMI determines the need for, and then establishes work programs for, surveillance and inspection of the airline to assure adherence to the applicable regulations. A portion of the PMIs position description reads as follows:

Provides guidance to the assigned air carrier in the development of required maintenance manuals and recordkeeping systems. Reviews and determines adequacy of manuals associated with the air carrier's maintenance programs and revisions thereto. Assures that manuals and revisions comply with regulatory requirements, prescribe safe practices, and furnish clear and specific instructions governing maintenance programs. Approves operations specifications and amendments thereto.

Determines if overhaul and inspection time limitations warrant revision.

Determines if the air carrier's training program meets the requirements of the FARs, is compatible with the maintenance program, is properly organized and effectively conducted, and results in trained and competent personnel.

Directs the inspection and surveillance of the air carrier's continuous airworthiness maintenance program. Monitors all phases of the air carrier's maintenance operation, including the following: maintenance, engineering, quality control, production control, training, and reliability programs.

At the Safety Board's public hearing on this accident, the PMI for United Airlines at the time of the flight 811 accident stated that he was trained as an FAA air carrier inspector and had been assigned to United Airlines since November 25, 1985. In addition to attending the normal FAA indoctrination course, he had received training in accident investigation, compliance enforcement, nondestructive testing, enforcement, and composite materials. To qualify for the position of PMI, he had completed a 3-week management training course at Lawton, Oklahoma. This was supplemented by a 2-week course on management training systems.

According to the PMI, FAA surveillance of UAL B-747 maintenance activities was organized around the daily work schedule of the FAA air safety inspector, specifically assigned to the UAL B-747 fleet by the PMI. The schedule for surveillance is normally prepared a year in advance by the FAA computerized Work Planning Management System (WPMS). Each FAA inspector is assigned specific responsibilities in the surveillance and monitoring of the airplane fleet to which he is assigned.

The PMI stated that assigned inspectors conducted surveillance of the UAL airplanes while they were in light or heavy maintenance and when they were released to service or in the process of preparing for a flight. Postflight surveillance was also performed. He said, as a routine, the inspectors visually inspected the airplanes and reviewed the airplane log records either during en route checks, while in flight, or upon termination of various flights. He said that inspectors conduct spot ramp inspections; however, they do not routinely observe ramp service operations as part of the surveillance program.

He said that FAA inspectors are not required to inspect the airplanes, but merely are to observe ramp service activities. Deficiencies or malfunctions were to be noted. The assigned inspector or the PMI would then report these observations to the UAL quality assurance liaison person or directly to UAL management.

The PMI stated that the FAA had conducted five special surveillance inspections of UAL in the previous 3 years and 5 months. The last special inspection, an MEL Survey Inspection, was completed in 1988. That inspection primarily addressed how many deferred maintenance items were being carried or deferred on each aircraft during a specified time period.

The PMI stated that his office does not approve the method by which the carrier complies with an AD, unless specified in the AD. However, a scheduled surveillance method was in place to review the carrier's AD compliance process and the ADs applicable to certain fleets. Each assigned inspector had a schedule for performing this oversight in his work program. The PMI or his staff review a monthly report from the carrier listing ADs applicable to a particular fleet and their compliance. The FAA's surveillance of the carrier's AD compliance process involved a review of this list, not actual shop visits to verify compliance.

The inspector assigned to the UAL B-747 fleet stated that approximately 30 percent of his time was spent on actual ramp maintenance surveillance. Other activities included: en route inspections, station inspections, meetings, classes and administrative paper work. Spot ramp inspections were scheduled as a normal routine, as well as by mandate in a particular AD.

The PMI stated that foreign contract maintenance bases were inspected once a year at a minimum. The PMI had the prerogative to use geographical surveillance inspectors

(inspectors from other FAA offices), or inspectors from his office more familiar with UAL maintenance procedures to conduct inspections or investigations.

The PMI and the B-747 maintenance inspector assigned to UAL testified that, prior to this accident, they were not aware of any problems involving the operation of B-747 cargo doors, including the problems reported with N4713U during December 1988. The PMI testified that he could always use more inspectors to "conduct more in-depth surveillance and monitor UAL's fleet more adequately."

The extensive documentation of maintenance performed on UAL B-747 airplanes was forwarded to the PMI's official library by US mail. The data were ultimately channeled to the B-747 maintenance inspector. The PMI and maintenance inspector testified that the voluminous paperwork and work schedules precluded their monitoring the information to determine trends on problem areas.

1.17.3 Corrective Actions

On March 31, 1989, the FAA issued telegraphic (AD) ADT 89-05-54. This AD superseded AD 88-12-04 and required certain procedures to be accomplished when operating the cargo doors. These included: confidence checks of the door mechanical and electrical systems, inspections of the door locking mechanisms, and repairs if necessary. The AD also accelerated the schedule for terminating action to place steel doublers on the latch lock sectors, and it reinstituted the procedures for using the eight view ports to verify the position of the latch cams, after the door is latched and locked.

The FAA, in conjunction with the Air Transport Association, the manufacturers, and other interested parties, are collectively working to address the human factor issues in the readability and understandability of ADs and SBs by line maintenance personnel. They are also reviewing the entire range of design, maintenance, and operation of outward opening doors to develop advisory information for pertinent parties.

FAA representatives stated at the Safety Board's public hearing that the FAA is increasing their operations and airworthiness inspector staffing by approximately 1,000 new hires in the next 3 fiscal years.

The PMI for UAL at the time of the accident stated at the Safety Board's public hearing that, as a result of the accident, "we have intensified our surveillance on the cargo door activities to the point where the assigned inspectors and inspectors who are not assigned to that particular fleet, 747s, are doing night surveillance, early morning surveillance, and we have intensified our surveillance on the cargo door in watching the operation of the cargo door to comply with the Airworthiness Directive."

On August 23, 1989, the Safety Board issued three safety recommendations (A-89-92 through -94) to the FAA. The recommendations urged the FAA to:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams.

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently.

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions.

Section 4.0 contains the FAA's response to the recommendations and the status of the followup actions.

On October 12, 1989, the FAA issued NPRM 89-NM-148-AD, which proposed the amendment of ADT-89-05-54. The proposed revisions would require modification of the warning systems for the forward and aft cargo door, and the main deck cargo door, if installed. The modifications would provide visual warnings to flightcrew and ground crew when the doors are not fully closed, the latch cams are not rotated to the closed position, or the lock sectors are not in the locked position. Further, the source for the warning signal would monitor the position of the latch cams. Public comments for the NPRM were due by December 27, 1989.

Boeing has completed tests that have verified the integrity of the upgraded latch lock sectors to prove that the latch cams cannot be back-driven through the lock sectors mechanically or electrically. Boeing also has been conducting tests on the B-747 cargo door to evaluate the effects of unrepaired damage and abuse on the latch/lock system. The tests, which determined the allowable damage limits on the latch lock system and mechanism support structures, were completed in March 1990. Additionally, Boeing conducted tests to evaluate any unlatching tendencies under cabin pressure loads. These tests were completed in November 1990 and included the measurement of loads in the latch system as the latch cams are rotated incrementally from the fully latched position to the unlatched position under pressurization loads.

The first series of tests included electrical backdriving of the latch cams into the lock sectors (both steel and steel reinforced were tested) with a modified latch actuator (the maximum output torque of the modified latch actuator was roughly twice that of a normal, torque-limiting latch actuator.) During these tests, the maximum cam rotation was 22.2 degrees against steel reinforced lock sectors and 18.8 degrees against the all-steel lock sectors.

During the second set of tests, which measured the effects of internal pressure loads on partially unlatched cams, it was discovered that pressurization did not create any significant loads in the latch mechanism with the door fully closed and the latch cams positioned up to 45 degrees from the fully latched position. Both series of tests show that if the latch cams were somehow electrically backdriven by a latch actuator that had no torque-limiting ability, the steel or steel-reinforced lock sectors would limit the amount of cam rotation such that the partially unlatched cams would still prevent pressure loads from forcing the door open.

1.17.4 Boeing 747 Cargo Door Certification

Title 14 CFR 25.783, Amendment 25-15, effective October 24, 1967, was the original certification basis for Boeing 747 cargo doors. Specifically, Part 25.783(e) and (f) applied to doors for which the initial opening movement is outward (non-plug type doors). Those rules specified that:

(e) There must be a provision for direct visual inspection of the locking mechanism by crewmembers to determine whether external doors, for which the initial opening movement is outward (including passenger, crew, service, and cargo doors), are fully locked. In addition, there must be a visual means to signal to appropriate crewmembers when normally used external doors are closed and fully locked.

(f) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure.

Amendment 25-23, effective May 8, 1970, added the following text to paragraph (f): "...or failure of a single structural element." Amendment 25-23 did not apply to the initial certification basis for the B-747.

Amendment 25-54, effective October 14, 1980, expanded Part 25.783 (e), (f), and (g) to read:

(e) There must be a provision for direct visual inspection of the locking mechanism to determine if external doors, for which the initial opening movement is not inward (including passenger, crew, service and cargo doors), are fully closed and locked. The provision must be discernible under operational lighting conditions by appropriate crewmembers using a flashlight or equivalent lighting source. In addition, there must be a visual warning means to signal the appropriate flight crewmembers if any external door is not fully closed and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed and locked indication is improbable for doors for which the initial opening movement is not inward.

(f) External doors must have provisions to prevent the initiation of pressurization of the airplane to an unsafe level if the door is not fully closed and locked. In addition, it must be shown by safety analysis that inadvertent opening is extremely improbable.

(g) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure or failure of a single structural element.

At the Safety Board's public hearing, the FAA and the Boeing representatives acknowledged that during certification of the Boeing 747 the loss of a lower lobe cargo door was not considered to be an "acceptable event." Therefore, redundant mechanical devices and operational procedures were incorporated to protect against loss of the door in flight. Initial FAA certification approval of the Boeing cargo door design and operation included the installation and use of eight view ports on the door for ground personnel to observe the alignment of paint stripes on the latch cams with arrows on the latch pin support fitting, thereby complying with the requirements of 14 CFR 25.783(e), which require a ". . . provision for direct visual inspection of the door locking mechanism ...," to determine if the door is closed and

locked.
In correspondence dated November 24, 1969, and May 15, 1970, Boeing requested that the FAA approve the use of a visual inspection of the pressure relief doors of the cargo doors as an alternate method for determining the locked condition of the door. This design also provided a visual indication to the flightcrew via the cargo door warning light on the flight engineer's warning light annunciator panel. Boeing's request stated that this means of compliance "... provides a simpler check whereby only the pressure relief doors need to be checked ...," by the ground crew, in lieu of actually observing the latch cams and alignment stripes through the eight view ports. Boeing also provided a Failure Analysis to support its request. The conclusion of the Failure Analysis reads: "Any failure, mechanical or electrical, within the latching system which results in open latches will always be indicated by open pressure relief doors." The FAA approved their alternate method on June 8, 1970. Subsequently, the procedures for maintaining the view ports and the alignment stripes in a serviceable condition,
which had been included in the UAL MM were removed. Also, the provision for observing the alignment stripes as part of the door closing procedure were not required for B-747 airline operators.
At the Safety Board's public hearing, a Boeing witness, in answer to a question relative to Boeing's possible consideration of modifications or design changes to the B-747 cargo door indication system to install a position switch directly on the latch cams, stated, "We are looking into the best possible designs that would provide indication on the cams and door closed, both exterior to the aircraft and in the flight deck. We are going to look into that.... However, we want to achieve the required indication in the most reliable method and we have not yet determined what that will be, or any changes (that) are necessary, or would

make it more reliable than the way the system operates currently."

1.17.5 Advisory Circular AC 25.783-1

Advisory Circular (AC) 25.783-1 was issued December 10, 1986, on the subject, "Fuselage Doors, Hatches, and Exits." AC 25.783-1 set forth the acceptable means of compliance with the provisions of Part 25 of the FAR's dealing with the certification of fuselage doors. Specifically, it provides for an acceptable method for showing compliance with the provisions of Part 25.783, Amendment 25-54.

Neither the provisions of Part 25.783, Amendment 25-54, nor the guidelines of AC 25.783-1 were part of the certification basis of the Boeing 747.

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.

The airplane was being prepared for flight at the UAL maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.

The aft cargo door was cranked open manually, the C-288 circuit breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident.

With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage.
UAL personnel notified the Safety Board of the occurrence, and the airplane was examined at JFK by representatives of the Safety Board, United Airlines, and Boeing. After the wires in the damaged area were electrically isolated, electrical operation of the door was normal when the door was unlocked. When the door was locked (master latch lock handle closed), activation of the door control switches had no effect on the door. This indicated that the S2 master latch lock switch was operating as expected (removing power from the door when it was locked). After the on-site examinations, the wiring bundle was cut from the airplane and taken to the Safety Board's materials laboratory for further examination.
The wiring bundle with the damaged wires contained all electric control wires (28 volt DC) and power wires (115 volt AC) that pass between the fuselage and the aft cargo door. From the forward side of the J-4 junction box, the bundle progresses in the forward direction, just above the forward pressure relief door, then upward, following the forward lift actuator arms. The

bundle then enters an empty space between two floor beams, where the bundle has an approximate 180-degree bend when the door is closed. From this location, the wiring bundle progresses inboard, through a fore-to-aft intercostal between two floor beams. The wiring bundle then splits, with wires going in several directions.

The bundle is covered by the flexible conduit approximately from the lower end of the lift actuator arms to the fore-to-aft intercostal between the floor beams.

The conduit covering the wiring bundle is intended to prevent the wire bundle from being damaged during opening and closing of the door and during cargo handling operations. The conduit is a sealed flexible interconnector consisting of a convoluted helical brass innercore covered by a bronze braid. The innercore is soldered at every other convolute, and should be capable of withstanding pressures exceeding 1,000 pounds per square inch (psi). Boeing has indicated that the conduit is an evolutionary improvement and that it has been installed on all B-747 airplanes produced since 1981 (from line number 489 on). Airplane N152UA was delivered in April 1987.

Airplanes produced prior to 1981, including N4713U, used a bungee retraction system, to retract the cargo door wire bundle. Guidelines for the replacement of the bungee sys tem with the flexible conduit were covered in Boeing Service Bulletin 747-752-2170, dated August 1981. The service bulletin was prompted by reports that the wire bundle bungee retraction system had not retracted the wire bundle sufficiently to prevent trapping the bundle between the cargo door and the door frame. UAL did not perform the retrofit on N4713U, which was line number 89, nor was the company required to do so.

Examination of the wires in the damaged area on the wiring bundle revealed that four of the wires were similar in appearance, with insulation breaches that progressed through to the underlying conductor. Adjacent to the breach on these four wires, the insulation was blackened, as if it had been burned. Another wire contained an extensive breach but no evidence of burned insulation. The damaged area was located on the bundle at a position approximately corresponding to a conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism. This support bracket was found bent in the forward direction. In addition, mechanical damage was noted on adjacent components in this area.

A second damaged area was noted on the wiring bundle at a position approximately corresponding to the conduit swivel clamp at the elbow between the two arms of the forward lift actuator mechanism. Wires in this area were missing portions of their exterior coating, but no breaches to the underlying conductors were noted.

The exterior braid on the conduit contained minor rub marks and was slightly kinked at a position corresponding to the area on the wires with breached insulation. Additional examinations revealed that the innercore of the conduit contained multiple circumferential cracks in the areas corresponding to the damage areas on the wires. The cracks were in the convoluted innercore directly adjacent to the inside diameter of the conduit.

The lock sectors, latch cams, and latch pins from the aft cargo door were examined on the incident airplane and were generally in excellent condition. There was no evidence to suggest that the cams had ever been electrically (or manually) driven into or through the lock sectors.

Boeing also informed the Safety Board that, in May of 1991, a B-747 operated by Quantas was found to have chafing of the wires in the wire bundle to the aft cargo door. This airplane also had a flexible conduit protecting the wires, and the chafing was located approximately at the standoff pin on the bracket at the upper arm of the forward lift actuator.

The Safety Board determined that the chafing of the wires on the airplane involved in the JFK occurrence was caused by, or was greatly accelerated by, the circumferential cracks in the conduit and that the cracks in the conduit were caused either by repeated flexing of the conduit as the cargo door opens and shuts or by unusual stresses on the conduit generated concurrently with damage to the conduit guide bracket and attached standoff pin on the upper end of the forward lift actuator upper arm.

A portion of the wire bundle for the forward cargo door on many B-747 airplanes is also covered by a flexible conduit that is very similar to the conduit for the aft cargo door. However, there are substantial differences between the orientation of the flexible conduits for the two doors, and the Safety Board has not become aware of problems associated with the flexible conduit for the forward door.

Nevertheless, because of the concerns about the chafed wires and possible electrical short circuits, on August 28, 1991, the Safety Board recommended that the FAA:

Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between the fuselage and aft cargo door to require an expedited inspection of:

(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test method or visual examination);

(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;

(3) the flexible conduit for the presence of cracking in the convoluted innercore.

Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an appropriate cyclic interval. (Class II, Priority Action) (A-91-83)

Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in A-91-83. (Class II, Priority Action) (A-91-84)

The FAA responded to these safety recommendations on November 1, 1991, stating that it agreed with the intent of the recommendations and that the issuance of an NPRM was being considered to address the issues in the safety recommendations. The Safety Board replied on November 27, 1991, classifying each of the recommendations as "Open--Acceptable Response," pending the completion of the rulemaking process. Since that exchange of correspondence, the FAA has published an NPRM which is now being reviewed by the Safety Board. Safety Recommendations A-91-83 and -84 will continue to be classified as "Open--Acceptable Response" until an acceptable final rule is published.

2. ANALYSIS

2.1 General

This analysis is based on the facts gathered during the initial investigation phase, without the benefit of the evidence from the cargo door, updated to include the findings from the subsequent examinations of the door after it was recovered.

The flightcrew and flight attendants were trained and qualified in accordance with the applicable Federal regulations and UAL standards and requirements. There were no air traffic control or weather factors related to the cause of this accident.

The airplane had been properly maintained, with the exception of certain requirements pertaining to the cargo doors. Those discrepancies will be discussed in detail in this analysis.

The evidence examined by the Safety Board during its investigation revealed conclusively that this accident was precipitated by the sudden loss of the forward lower lobe cargo door, which led to an explosive decompression. There was no evidence of preexisting metal fatigue or corrosion in the structure surrounding the cargo door. All breaks were the result of overload at the time of the loss of the door. There was no evidence of a bomb or similar device that caused an explosion on the airplane.

The explosive decompression of the cabin when the cargo door separated caused the nine fatalities. The floor structure and seats where the nine fatally injured passengers had been seated were subjected to the destructive forces of the decompression and the passengers were lost through the hole in the fuselage. Their remains were not recovered. Most of the injuries sustained by the survivors were caused by the events associated with the decompression, such as baro-trauma to ears, and cuts and abrasions from the flying debris in the cabin. Other injuries were incurred during the emergency evacuation.

The loss of power to the Nos. 3 and 4 engines was caused by foreign object damage when debris were ejected from the cargo compartment and cabin during the explosive decompression. The debris also caused damage to the right wing leading edge flap pneumatic ducting, and other areas along the right side and empennage of the airplane.

During the approach to HNL, all of the leading edge flaps had extended, except the outboard sections 22 through 26 on the right wing. The reason that they failed to extend probably was the damage to the pneumatic duct caused by the ejected debris. The pneumatic pressure probably was too low to actuate the most outboard flaps to the extended position.

The failure of the flightcrew and passenger oxygen systems was caused by structural deformation and damage to the supply lines in the area adjacent to the cargo door and failed fuselage structure.

The Safety Board's analysis of this accident concentrated on the reasons for the loss of the cargo door and the events that led to its loss in flight. The analysis included an evaluation of the design, certification, and approval processes for the B-747 cargo doors, and the operational, maintenance, and inspection processes for the doors. Also, the analysis included an evaluation of the historical events that had occurred over the past months and years that eventually led to this accident.

2.2 Loss of the Cargo Door

The calculated pressure differential at the time of the loss was about 6.5 psi, which would have exerted a load on a properly closed and locked door that was substantial, but well within design limits.

There was no evidence of a structural problem with the cargo door that could have caused it to fail from metal fatigue or corrosion. Although the cargo door was recovered in two pieces on the floor of the ocean, there was no evidence of a preseparation structural failure of the door. All fractures and damage found on the door were determined to be the result of the sudden opening of the door rather than the cause. The evidence showed that the door was intact when it flew open violently and that its integrity was compromised when it struck the upper fuselage structure and most likely when it struck the water. The fracture in the cargo door occurred just below the midspan latch cams. Paint marks on the outer surface of the door that matched upper fuselage structure paint pattern, damage to the latch pins, pull-in hooks and hook pins, as well as damage to the floor structure near the upper door hinge area were consistent evidence that the door was intact when it flew open.

The evidence was also conclusive that the failure of the door did not result from the failure of the structure surrounding the door.

The damage to the cabin floor beam structure, adjacent to the cargo door hinge area, showed that decompression loads in the cabin broke the beams downward when pressure was released from the cargo compartment. The fuselage skin above the door was torn away during the decompression as the door separated violently from the airplane. Unfortunately, the upper skin structure was not recovered from the sea.

There are no reasonable means by which the door could open in flight with the cams properly closed and locked. If the lock sectors were in proper condition, and were properly situated over the closed latch cams, the lock sectors had sufficient strength to prevent the cams from vibrating to the open position during ground operation and flight. Thus, the only ways in which the cargo door could open while in flight involve the placement of the cams in a partially latched or unlatched position. Either the latching mechanisms were forced open electrically through the lock sectors after the door was secured, or the door was not properly latched and locked before departure. Then the door opened when the pressurization loads reached a point at which the latches could not hold.

2.3 Partially Closed Door

Examination of the eight latch pins that had been removed from the lower sill of the forward cargo door revealed smooth wear patterns where the latch cams had normally rotated around the pins. These wear patterns indicate that interference had existed during normal operation between the cams and the pins over an extended period of time. All eight pins also had roughened areas from approximately the 6:15 position to the 7:30 position (clock references are as looking forward, 9:00 being directly inboard). The 7:30 position corresponds closely to the area where the lower surface of the cam first contacts the pin as the door reaches the nearly closed position, before the cams are rotated to the latched position.

The hoop stresses generated by pressurization of the airplane create a bearing load against the cam/pin contacting points. Even if the cams are in the unlatched position, and the airplane is pressurized, this bearing load could act as a frictional latch between the cams and the pins and would tend to keep the door in the closed position.

Transferred cam material and heat tinting of the pin surface was found to extend from the point where the cam-to-pin interface at the near fully open position of the latch cams (7:30 position) to a position corresponding to the bottom of the pin (6:15 position). This evidence was found on the roughened areas on all of the pins. The heat tinting and metal transfer are indicative of the high stress and rapid movement of the cam across the pin when the door separation occurred. Therefore, the location of this evidence indicates the probable location of the cams just before, and at the time of, separation of the door. The Safety Board concludes that these markings and their location on the pins resulted from a very fast, high bearing stress, separation of the cams across the pins, when the cams were in or very close to the unlatched position. Further, examination of the recovered cargo door confirmed that the latch cams were in a nearly unlatched position at the time the separation occurred. The lock sectors were found in the locked position jammed against the cams. Therefore, the cargo door latch cams had been closed, the master latch lock handle had been closed, and the lock sectors had moved to the locked position. Subsequently, the cams had been back-driven to the near-open position, deforming the lock sectors.

The pull-in hooks and pull-in hook pins would also counteract the pressurization loads in the outward direction, providing that the latch cams were not engaged on the latch pins and carrying the pressurization loads. However, Boeing studies showed that the pull-in hooks would fail at a pressure differential of about 3.5 psi, assuming that the cams are in the unlatched position and that there is no bearing load on the pins. Therefore, based on the probable pressure differential of about 6.5 psi just before the door separated, it is concluded that forces other than the pull-in hooks/pins were holding the door closed. Since the flightcrew and passengers reported no pressurization difficulties until the explosive decompression, it is reasonable to conclude that the door was being held closed by the bearing stresses of the cam-to-pin interfaces as well as by the pull-in hooks.

The Safety Board believes that the approximate 1.5 to 2.0 seconds between the first sound (a thump) and the second very loud noise recorded on the CVR at the time of the door separation was probably the time difference between the initial failure of the latches at the bottom of the door, and the subsequent separation of the door, explosive decompression, and destruction of the cabin floor and fuselage structure. The door did not fail and separate instantaneously; rather, it first opened at the bottom and then flew open violently. As the door separated, it tore away the hinge and surrounding structure as the pressure in the cabin forced the floor beams downward in the area of the door to equalize with the loss of pressure in the cargo compartment.

Three possible theories to explain why the latch cams could have been in a partially latched condition during flight are examined: (1) they were never closed fully before the door was "locked" before takeoff. (2) they were backdriven manually after the door had been fully latched and locked or (3) they were back-driven electrically after the door had been fully latched and locked.

2.4 Incomplete Latching of the Door During Closure

The Safety Board considered the possibility that the master latch lock handle had not been closed before the airplane departed the gate, and the possibility that the shrouds recommended by SB-747-52-2097 for the cargo door pressure relief doors were not installed on the forward door. If this were the case, it is possible that this condition allowed the pressure relief doors to be rotated

closed when the airplane pressurized.
The Safety Board believes that these events were very unlikely based on the statements of the ramp personnel, line maintenance personnel, and the flightcrew. The ramp and maintenance personnel would have to have missed seeing the master latch lock handle in the unstowed position and the pressure relief doors open before departure. Also, the flightcrew would have to have missed seeing the cockpit cargo door warning light indication.
The examination of the recovered forward cargo door did not provide confirmation that the pressure relief door shrouds were actually installed on the forward door, although UAL records showed that they had been installed on both cargo doors of N4713U, in accordance with SB-747-52-2097. However, the shrouds were found not to be installed on the aft door, contrary to UAL records, and therefore may not have been installed on the forward door. Without the shrouds, the pressure relief doors could have rotated shut during the pressurization cycle. Because the closure of the pressure relief doors would back-drive the lock sectors, this scenario would presume previous damage to the sectors, which would permit the sectors to move over the unlatched cams.
Before recovery of the cargo door, the Safety Board believed that the lock sectors might have been damaged some time prior to the accident flight to the extent that they could have been moved to the locked position even though the latching cams were not fully closed.
During closure of the door, the latch actuator may not be able to rotate the cams to the fully closed position because of excessive binding forces between the latch cams and pins. This could occur if the cargo door is misaligned (out of rig) or if the pull-in hooks do not pull the door in far enough to properly engage the cams around the pins. There is sufficient evidence of wear on the pins

and from the previous discrepancies with the door to indicate that the door was misaligned and not properly rigged.

The smooth wear areas found on the pins from N4713U are signs of heavy contact (interference) between the cams and pins during numerous past closings and openings of the door. This wear, other evidence from the door, and the maintenance history of the door, suggest strongly that the door was out of rig during the weeks and months before the accident.

The wear pattern damage to the pull-in hook pins also showed interference during the normal ground operations prior to the accident. This is further evidence of an out-of-rig door. It is also possible that the excessive binding force acting over a period of time precipitated a failure of the latch actuator. Regardless of the reason(s), the conditions of the latch pins and pull-in hook pins showed prolonged out-of-rig operation.

Most of the previous discrepancies with the forward cargo door on N4713U during December 1988 involved problems with closing the door electrically. These problems always occurred when the airplane was fully or nearly fully loaded, just before departure. The trouble-shooting and corrective actions by UAL maintenance, which on some occasions only involved cycling the door and finding it functional, were performed when the airplane was not fully loaded, during overnight maintenance inspections. The flexing of the fuselage with a full load of fuel, cargo, and passengers could have caused distortion of the door frame and resulted in misalignment between the cams and pins. In this case, the pull-in hooks may not have pulled the door fully in before the cam actuator attempted to latch the door. The wear evidence on the latch pins from N4713U suggests that this event had been occurring before the accident.

Safety Board investigators also witnessed this event during inspection and operation of the aft door on another UAL B-747, N4718U, in HNL. It was noted that the door on N4718U was not being pulled in fully by the pull-in hooks, so the latch cams completed the closing cycle with significant interference and "thunking" sounds. In fact, the out-of-rig door on N4718U failed to operate electrically at one point during its examination.

By design, any attempt to close the master latch lock handle and move undamaged lock sectors into place would not be successful unless the cams were rotated to near the fully latched position. This condition was substantiated by Boeing tests. Even with severely damaged lock sectors, as found on the Pan Am B-747, if the cams were more than 20 turns from the fully closed position on the Pan Am airplane, the master latch lock handle could not be stowed. Examination of the recovered N4713U door indicated that the door lock sectors were generally intact and jammed against the cams that had been back-driven into the lock sectors. Consequently, if the latch cams had been in the nearly unlatched position as found on the recovered door at the time the cargo handler attempted to move the master latch lock handle, the interference between the cams and the lock sectors would have prevented the master latch lock handle from moving to the closed position. Furthermore, this interference would have prevented the closure of the pressure relief doors as the airplane pressurized, irrespective of the possible absence of the pressure relief door shrouds. This conclusion is supported by extensive testing of the latch/lock mechanisms following the recovery of the door.

Therefore, based upon the examination of the lock sectors and the tests that were conducted, the Safety Board concludes that the latches were fully closed and that the locking handle was placed in the stowed position after the cargo was loaded.

2.5 Manual Unlatching of the Door Following Closure

It is possible that the cams could have been manually back-driven (about 95 turns) after the door had been secured; however, the UAL ramp personnel involved with dispatching the flight stated that the door was operated electrically. Furthermore, it seems unlikely that the ramp personnel would have driven the manual latch actuator 95 turns toward the open position after the door was fully latched.

The placard/seal located over the latch actuator manual drive on the recovered door was found with damage that initially suggested it had been previously compromised. If this were the case, it would indicate that someone may have used the manual drive to operate the door latches on an earlier flight or possibly immediately before the accident flight. However, the Safety Board believes that an insertion of a screw driver and rotation of the plate retaining screw would have caused rotational tearing around the circumference of the screw head. There was no such tear. Rather, the damage to the placard/seal was more consistent with that which would occur from impact and underwater pressure forces. Therefore, the evidence strongly suggests that manual operation of the latch actuator by ground service personnel after the door was properly closed is unlikely.

2.6 Electrical Unlatching of the Door Following Closure

2.6.1 Conditions or Malfunctions Required to Support Hypothesis

It was determined in 1987, after the Pan Am incident, that the locking sectors for B-747's, including those installed on N4713U, could be overcome by the force of the latch cam actuator, electrically or mechanically. If the latch cam actuator had been energized for some reason with the originally designed unstrengthened lock sectors installed, the latch actuator motor was capable of driving the latch cams open through properly positioned lock sectors, whether they were damaged or undamaged. Therefore, the locking sectors installed as original equipment for B-747's, and those installed on N4713U, would not perform the locking function as intended by the design. They would not "lock" the latches in place as implied by the name "lock sectors."

The investigation has shown that there are several conditions that must be met before the latch actuator will electrically drive the latch cams to the unlatched position on the B-747 after the door has been properly closed and locked. First, the ground handling power bus must be energized by having external power connected, or the APU must be operating and the APU generator field switch in the cockpit must be set to power the bus via the No. 2 ground handling power relay. Second, the air/ground relay must be in the "airplane on the ground" position. These two conditions are normally present when the airplane is on the ground before engine startup. Third, there must be a signal to the door open position in one of the two door open/close switches. Fourth, the S2 master latch lock switch, which cuts off power to the door actuators when the handle is stowed, must sense "not locked."

Therefore, it would take several independent conditions and some failures to provide for electrical power to be available to drive the door open electrically once it is closed and locked. The number of conditions and combinations depend upon the phase of operation of the airplane.

While the airplane was on the ground, before engine startup, with the master latch lock handle stowed, the external power connected (or with the APU running), and the ground handling bus powered, an "open" signal to the cargo door latch actuator would have occurred if any of the following combinations of conditions had been met: (1) a malfunction of the S2 master latch lock switch and the placement by someone of one of the door control switches to the "open" position; (2) a malfunction of the S2 master latch lock switch and certain short circuits; or (3) a two-wire short circuit path consisting of wire 101-20 shorting with any of the following wires: 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

While the airplane was on the ground, after engine startup, and with the cargo door master latch lock handle stowed and the APU running, an "open" signal to the door latch actuator would have occurred if the following conditions had been met: (1) an energized ground handling bus resulting from the flightcrew reenergizing the APU generator field or failure of the No. 2 ground handling power relay; (2) a malfunction of the S2 master latch lock switch; (3) a malfunction of either of the door open/close switches or the placement of the switch in the "open" position by someone. An "open" signal would have also occurred had certain wire short circuits been present with condition (1) alone, or with conditions (1) and (2).

Regardless of the cause, electrical power to the latch actuator would have had to persist for the time necessary to rotate the cams to the nearly open position. If the electrical power had been applied for a longer time, the latch cams could have opened fully and caused the pull-in hooks to rotate open, a situation that would have prevented the airplane from pressurizing after takeoff. However, it is also possible that the latch actuator stalled before they opened fully because of the forces of the interference between the lock sectors and the cams as they were back-driven.

After takeoff, electrical operation of the door latch actuator would have required: (1) the APU to be running; (2) malfunction of the air/ground relay, (3) malfunction of the No. 2 ground handling power relay; and (4) malfunction of the S2 master latch lock switch and one of the cargo door open/close switches or a short circuit of the aforementioned wire pairs. Although the flightcrew could conceivably energize the ground handling bus from the APU by actuating the APU generator "field" switch, there was no evidence that they did so.

Thus, regardless of the phase of operation, either a wiring short circuit or a failure of the S2 master latch lock switch combined

with some other anomaly or action would be required to cause the latches to move toward the open position. Before the recovery of the door, the Safety Board was able to examine two of the electrical relays and the door open/close switches from N4713U that would have to have failed to allow electrical operation of the cargo door in flight, with the APU
running. These were the No. 2 ground handling power relay, the air/ground relay, and the internal and external door open/close switches. The examination of the relays and switches revealed no evidence of a single fault or conditions that might have caused an intermittent failure mode. The arcing noted on the No. 5 terminal of the outside door control switch was on the door "close" circuit and could not have been related to a short to the open mode. Further, because the flightcrew did not note a cargo door warning light, and the fact that the airplane was able to be pressurized, confirms that the master latch lock handle was in the closed position before takeoff. This position would actuate the master latch lock switch to disconnect power to the door opening actuators.

According to the flightcrew testimony and the pilots' comments recorded on the CVR during the flight, the APU was shut down shortly after takeoff and remained in that condition. Engine generators cannot power the ground handling bus from which the cargo door actuating mechanisms are powered. Once the APU was shut down, there was no power available to any of the cargo door electrical components. Therefore, an electrical actuation of the latch cam actuator at the time of the door loss was not possible.

The Safety Board believes that there is another reason why the opening of the door could not have been caused by electrical actuation shortly before the explosive decompression. Because the door carries the structural loads (hoop stresses) through its hinge and latches, the latch cams would be heavily loaded against the latch pins when the airplane was pressurized to the 6.5 psi differential pressure that was calculated to have been present at the time of the decompression. In that case, the torque limiter within the actuator would probably slip well before the actuator could achieve the torque necessary to drive the cams open against the frictional lock produced by the high bearing stresses resulting from pressurization.

2.6.2 Electrical Switches and Wiring Examinations--Recovered Door

All cargo door position sensing switches (S2 through S9) were found installed in their proper position. The cargo door recovery team found the S2 master latch lock switch in the "not-locked" position immediately after the door was aboard the recovery ship. This position would be consistent with the master latch lock handle being open. Further tests of the S2 switch revealed damage that probably resulted from the pressures under the sea. The only notable exception was a broken internal bracket that may have affected the operation of the switch prior to the accident. Other similar switches did not exhibit this failure. It is therefore possible that the S2 master latch lock switch failed prior to the accident, allowing more possibilities for electrical short circuits to power the latch actuator. Nevertheless, despite extensive testing, it could not be determined whether the S2 switch was functional before the accident.

The examination of 35 wires that remained with the recovered cargo door revealed several areas of damaged insulation that could have permitted an electrical short circuit to power the latch actuator. However, no evidence was noted of arcing that was indicative of short circuits. Furthermore, a significant number of the wires that had the potential for allowing for short circuits to power the latch actuator were not recovered. Testing conducted by Boeing and by UAL was inconclusive regarding whether a short circuit would have left detectable evidence of arcing.

Therefore, the Safety Board was unable to determine whether the latch actuator was inadvertently powered by a short circuit in the cargo door wires.

The incident involving a UAL Boeing 747 at JFK Airport on June 13, 1991, confirmed that electrical short circuits in the cargo door wiring could cause the door to open. In this case, the short circuits were in the fuselage-to-cargo door wiring bundle where the bundle was covered by a flexible conduit. Although N4713U did not have a flexible conduit installed at the forward door position, its wiring was routed over the top of the door hinge where exposure to damage could occur. That portion of the wiring from N4713U was not recovered from the sea. The wires located at the door hinge area are more susceptible to in-service damage from movement during the open/close cycle, as compared with the wires mounted on the door that are normally static.

Following the incident at JFK, UAL directed that the circuit breaker that terminates power to the cargo doors be pulled after the door is closed and before departure of every B-747 flight. UAL obtained approval for this practice from the FAA and requested Boeing and the FAA to make such a practice part of the approved manual for the airplane. Neither Boeing nor the FAA acted on UAL's request.

Nevertheless, the Safety Board believes that the FAA should initiate rulemaking to include design considerations for nonplug transport category aircraft cargo doors that would deactivate the electrical circuitry to the door actuators after the doors are closed and locked. The catastrophic nature of the loss of a cargo door dictates the need to provide additional redundancies and fail-safe features in the door mechanisms to supplement the hardware safety features.

2.6.3 Possibility of Electrical Malfunction

Due to the lack of physical evidence, the Safety Board was unable to conclude that an electrical short caused the cargo door actuator to move the latch cams to the nearly open position, allowing the door to separate when the cabin pressure exceeded the load-carrying capability of the door latches. Neither could this possibility be eliminated. A momentary actuation of the door open switch by someone on the ground in the presence of a faulty S2 switch could also have caused the latches to open through the closed lock sectors. However, no evidence has been found that someone actuated the switch after the door was initially closed and locked.

The Safety Board concludes that it was not possible for the cargo door to have opened electrically at the time of the loss of the door. There was no power to the ground handling bus to power the actuator, even if there had been an electrical short. Further, the Safety Board concludes that it is highly improbable that an electrical short could have caused the latches to open after the airplane was airborne. Although the ground handling bus could conceivably have been powered, failures of other components that were tested as functional would also have been necessary.

The Safety Board believes that the electrical operation of the latch actuators from the fully closed and locked position most likely occurred before the engines were started when the ground handling bus was powered. The precise source of the electrical actuation could not be determined. Once the engines were started, the possibility of an electrical short decreases significantly because the ground handling bus is disengaged from the APU when the engines start. There was no evidence that the flightcrew reengaged the ground handling bus.

Because the preaccident condition of the S2 master latch lock switch could not be determined, it could also not be determined whether its proper functioning would have prevented the accident. The Safety Board did not determine whether damaged cargo door wires or a malfunctioning S2 switch could have been found by UAL maintenance had they been more aggressive in troubleshooting the cargo door problem in the weeks prior to the accident.

2.7 Design, Certification, and Continuing Airworthiness Issues

The Safety Board's analysis of this accident went beyond the conclusions about how the door failed. The Safety Board also examined the initial design and certification of the B-747 cargo door, and the continuing airworthiness system that should have prevented this accident, to identify the breakdowns in this system that led to the accident. As is the case with most aviation accidents, there are many factors that led up to the actual failure of the door on flight 811.

The Safety Board found that there were multiple opportunities during the design, certification, operation, and maintenance of the forward cargo door for N4713U for persons to have taken actions that could have precluded the accident involving flight 811. The circumstances that led to this accident exemplify the need for human factors considerations in the promulgation of regulations, the application of regulatory policies, the design of airplane systems, and the quality of airline operational and maintenance practices.

The first opportunity to prevent this accident occurred during the design and certification of the B-747 cargo door mechanical systems, when the design was chosen and approved, which allowed for the overriding of the lock sectors by either mechanical or electrical actuation. It is apparent that the original design was not tested sufficiently to verify that the locking sectors in fact "locked" the latch cams in the closed position. This shortcoming should have become apparent during the initial certification testing and approval process. Later, it should have become apparent when Boeing applied for, and the FAA granted, an alternative method of compliance with the certification regulations (25.783 [e]) that permitted the elimination of operational practices that included a visual verification of the cargo door latch positions via view ports in the doors.

The failure mode analysis performed by Boeing, and the FAA's acceptance of its content in granting the exemption, probably were based on the assumption that the lock sectors would always prevent the master latch lock handle from being in a stowed position when the latch cams were not fully closed. This assumption was not valid, as evidenced by the findings in 1987 following the Pan Am incident that the lock sectors could not prevent the latch cams from being driven from the fully latched position with the master latch lock handle stowed, while a false indication was provided to the flightcrew that the cargo door was properly latched and locked. At the time that Boeing sought approval of the alternative compliance, Boeing and the FAA should have reviewed the design and required testing of the door latch/lock mechanisms to verify their integrity. Thus, the procedure for direct viewing of the latches via the view ports before the airplane could be dispatched should not have been eliminated without adequate verification that the lock sectors were totally effective.

The next opportunity for the FAA and Boeing to have reexamined the original assumptions and conclusions about the B-747 cargo door design and certification was after the findings of the Turkish Airline DC-10 accident in 1974 near Paris, France. The concerns for the DC-10 cargo door latch/lock mechanisms and the human and mechanical failures, singularly and in combination, that led to that accident, should have prompted a review of the B-747 cargo door's continuing airworthiness. In the Turkish Airlines case, a single failure by a ramp service agent, who closed the door, in combination with a poorly designed latch/lock system, led to a catastrophic accident. The revisions to the DC-10 cargo door mechanisms mandated after that accident

apparently were not examined and carried over to the design of the B-747 cargo doors.
Specifically, the mechanical retrofit of more positive locking mechanisms on the DC-10 cargo door to preclude an erroneous locked indication to the flightcrew, and the incorporation of redundant sensors to show the position of the latches/locks, were not required to be retrofitted at that time for the B-747. Of similar concern is the fact that the cargo doors for the L-1011 required redundant latch/lock indication sensors at initial certification, during the approximate same time frame the DC-10 and B-747 were certificated.
More recently, when Boeing and the FAA learned about the circumstances of the Pan Am cargo door opening incident in March 1987, more timely and positive corrective actions should have been taken. The Safety Board believes that the findings of that incident investigation should have called into question the assumptions and conclusions about the original design and certification of the B-747 cargo door, especially the alternative method for verifying that the door was latched and locked that was sought by Boeing and was granted by the FAA. Since a B-747 cargo door opening in flight was considered to be an "unacceptable event", once a door did come open in flight, the FAA and Boeing should have acted much quicker to prevent another failure.
It took nearly 16 months from the date of the Pan Am Incident (March 10, 1987) until the FAA issued AD-88-12-04 (July 1, 1988). And then, the AD allowed 18 or 24 months, depending on the model B-747, from the date of its issuance for compliance with the terminating actions of the AD. The fact that Boeing had issued an Alert SB as a result of the Pan Am incident is an indication of the apparent urgency with which Boeing treated this issue. Alert SB's are issued for "safety of flight" reasons, while regular SB's deal with "reliability" and not necessarily safety of flight items.

Despite this, the terminating action, issued as
revision 3 to the Alert SB, on August 27, 1987, was not mandated by the FAA for 11 months.

The Safety Board found no evidence that the FAA or Boeing reassessed the original design and certification conclusions regarding the safety of the B-747 cargo door during this period.

Several opportunities for preventive action were also missed by UAL during this period. First, UAL delayed the completion of the terminating actions of Alert SB 52A2206 (Rev 3 and AD-88-12-04. In fact, there was no evidence that UAL had intended to comply with the terminating action of the Alert SB, until it was mandated by the FAA.

It is understandable that an airline would not take its aircraft out of service to incorporate revisions that do not appear to be safety critical. Although by definition an Alert SB is safety related, there was no implication from Boeing's and FAA's actions regarding this matter that urgency was required. The airlines rely on the airframe manufacturers and the FAA to evaluate the need for urgent airworthiness actions that might take airplanes out of revenue service. In this case, UAL had scheduled completion of its B-747 fleet modifications in accordance with the terminating actions for AD-88-12-04 before the final allowable date; however, the schedule was based on other heavy maintenance schedules to prevent unnecessary down-time of its airplanes.

UAL personnel stated after the UAL 811 accident that its personnel did not fully appreciate the importance, or safety implications, of the terminating actions, or they would have incorporated the improvements much earlier. The usual difficulties in setting short suspense dates for performing terminating actions in AD's, such as parts availability, did not seem to exist in this case, because the parts were not complex components and probably could have been fabricated fairly quickly in-house by most airlines.

Human performance certainly contributed to UAL's failure to incorporate an important inspection step into its maintenance program as mandated by AD-88-12-04. When UAL obtained an advance draft copy of the forthcoming NPRM that eventually led to the AD, the airline began preparing its work orders to implement the forthcoming the AD requirements into its B-747 fleet (30 airplanes at the time). UAL developed its maintenance work sheets from the text of the draft NPRM, which was virtually identical to the text of the final rule. As a result of a clerical error, one of the important inspection steps required by the AD was omitted.

Apparently, UAL maintenance personnel never compared the work sheets they received with the actual requirements of the AD, or if they did, the omission was not detected. FAA inspectors responsible for oversight of UAL's maintenance program also did not detect this error because normal surveillance of AD compliance merely involved verifying the correctness of UAL's paperwork that listed the applicable AD's and compliance dates. The inspectors did not actually verify UAL's compliance action by shop visits, or by comparison of work sheets with AD provisions. These omissions by the UAL maintenance and quality assurance personnel, and the limitations of the FAA surveillance procedures were probably significant in setting the stage for the events that led to the actual cause of the door separation from N4713U.

Another matter of concern is the quality of UAL's trend analysis program. There was no indication that the repeated discrepancies with the forward cargo door on N4713U "raised a flag" within the UAL maintenance department. A quality assurance or trend analysis program should have detected an adverse trend and should have prompted efforts to resolve the repeated problems. If it had, any faults in the door electrical system or damage to mechanical components might have been detected.

In summary, the Safety Board concludes that there were several opportunities wherein Boeing, the FAA, and UAL could have taken action during the initial design and certification of the B-747 cargo door, as well as during the operation and maintenance of the cargo door installed on N4713U, to ensure the continuing airworthiness of the cargo door. The Safety Board further concludes that these deficiencies and oversights contributed to the cause of this accident.

2.8 Survival Aspects

The Hickam ARFF units and the airport's ARFF units operated on separate radio networks and thus they could not communicate directly on-scene by radio. This situation required them to communicate by voice. Although the two ARFF services had a common radio frequency (as per the Airport Emergency Plan), procedures for its use had not yet been developed. The Safety Board believes that such communication procedures should be expeditiously developed.

The use of camouflage paint schemes on military ARFF vehicles may be appropriate for military purposes; however, the Safety Board believes that camouflage is not appropriate for ARFF vehicles that are operated at a joint- use airport. It is obvious that these vehicles must be conspicuous to be seen by other responding vehicles and by persons who are involved in the accident, such as airport and airline personnel, crew and passengers, and off-airport firefighting and rescue vehicles.

The National Fire Protection Association Standards recommend for primary firefighting, rapid intervention and combined agent vehicles, that, "Paint finish shall be selected for maximum visibility and shall be resistant to damage from firefighting agents."4 Furthermore, Federal Aviation Regulation 14 CFR 139.319 (f) (2) requires emergency vehicles, "Be painted or marked in colors to enhance contrast with the background environment and optimize daytime and nighttime visibility and identification."

Further guidance for the high visibility color of ARFF vehicles is provided in a Federal Aviation Administration Advisory Circular where the vehicle paint color is specified as, "lime yellow" Dupont No. 7744 UH or its equivalent.5

Because flight attendants are vital to the safety and survival of the passengers following a decompression, measures should be taken to prevent flight attendants from being incapacitated by hypoxia. The Safety Board believes that oxygen masks should be attached to the emergency oxygen bottles to avoid any delay in their use in order to be in compliance with the intent of 14 CFR 25.1447 (c)(4). Therefore, the FAA should direct its inspector staff to survey B-747 airplanes for compliance with 14 CFR 25.1447(c)(4), and correct deficiencies found.

In this accident, the use of megaphones was vital because of the inability to be heard over the public address (PA) system. Title 14CFR 121.309 (f)(1) requires one megaphone on each airplane with a seating capacity of more that 60 and less that 100 passengers; 14 CFR 121.309 (f)(2) requires two megaphones in the cabins on each airplane with a seating capacity of more than 99 passengers. As this decompression demonstrated, additional megaphones are necessary on wide-body and large narrow-body airplanes to ensure communication in the cabin during emergencies when the PA system is inoperative.

Had there been a need for an immediate evacuation, or a water ditching, rapid egress would not have been possible at doors 2-left and 2-right because they were blocked by open storage compartments and spilled contents. The possibility also exists that a compartment door could release during a hard landing or turbulence and swing down and injure a flight attendant. Thus, the Safety Board believes that improved latches should be installed and the downward movement of stowage compartments doors should be restricted to prevent the doors from striking a seated flight attendant or block the exit door.

The Safety Board believes that the problems with life preserver donning and adjustment demonstrated in this accident should be addressed by the FAA. The straps and fittings on life preservers need to be evaluated to determine where improvements can be made, and clearer donning instructions should be developed. TSO-C13d, Life Preservers 1/3/83 prescribes the minimum performance standards for life preservers. With regard to donning, the TSO requires:

Donning. It must be demonstrated that an adult, after receiving only the customary preflight briefing on the use of life preservers, can don the life preserver within 15 seconds unassisted while seated. It must be demonstrated that an adult can install the life preserver on another adult, a child, or an infant within 30 seconds unassisted. The donning demonstration is begun with the unpackaged life preserver in hand.

Based on flight attendant interviews and information obtained from passengers these donning times were exceeded in many instances.

The Safety Board has made numerous recommendations to the FAA in the past regarding needed improvements in life preserver donning instructions, donning procedures, and timing of donning.6 The FAA has adopted most of the Safety Board's recommendations in its April 23, 1986, revision to TSO-C13e, Life Preservers, which now requires the wearer to be able to secure the preserver with no more than one attachment and make no more than one adjustment for fit. Also, donning tests are required for age groups of users starting with 20-29 years and ending with 60-69 years. At least 60% of the test subjects in each age group must be able to don then life preserver within 25 seconds unassisted with their seatbelts fastened starting with the life preserver in its storage package. TSO-C13e contains requirements that would have eliminated some of the problems that passengers had in this accident in correctly donning and

adjusting their life preservers.
The Safety Board has recommended (A-85-35 through-37) to the FAA to amend 14 CFR 121, 125, and 135 to require air carriers to install life preservers that meet TSO-C13e within a reasonable time. The FAA adopted TSO-C13e on April 23, 1986, and originally had specified an effective date of April 23, 1988, after which all newly manufactured life preservers approved under the TSO system would have to meet the requirements of TSO-C13e. The objective of the cut off date was to introduce life preservers into the fleets with the higher performance level as specified in TSO-C13e by assuring that replacement articles met the higher standards. On March 3, 1988, the FAA rescinded the cut off date to seek further public comments of fleet retrofit in accord with the proposed rulemaking. See Section 4.0 for FAA action and status of the recommendations.

3. CONCLUSIONS

3.1 Findings

1. There were no flightcrew or cabincrew factors in the cause of the accident or injuries.
2. There were no air traffic control or weather factors in the cause of the accident.
3. The airplane had not been maintained in accordance with the provisions of AD-88-12-04 that required an inspection of the cargo door locking mechanisms after each time the door was operated manually and restored to electrical operation. However, this circumstance was determined not to be a factor in the accident.
4. All but one of the electrical components remaining with the airplane or found with the cargo door that were necessary to have malfunctioned in order to cause an inadvertent electrical opening of the cargo door after dispatch were found to function properly.
5. The forward cargo door lock sectors were found in the locked position (actually in an "over-locked" position) and jammed against the latch cams. The latch cams were found in the

nearly open position.

6. The latch actuator manual drive port seal was found damaged from the forces involved in the separation of the door and did not indicate that the drive port had been used to open the door latches manually before the accident.

7. Electrical continuity tests indicated that the S2 master latch lock switch was in the "not locked" position when it was recovered with the cargo door. Because it had sustained damage from being submerged in the sea, its preaccident condition could not be determined.

8. An S2 switch functioning as found after recovery would permit electrical power to the door during ground operation so that additional failure modes or activation of the door control switch could result in movement of the latching cams.

9. All other switches associated with operation of the cargo door were found damaged from being submerged in the sea; however, they were determined to be properly installed and probably functional.

10. Short circuit paths in the cargo door circuit were identified that could have led to an uncommanded electrical actuation of the latch actuator; this situation occurred most likely before engine start, although limited possibilities for an uncommanded electrical actuation exist after engine start while an airplane is on the ground with the APU running.

11. It was not possible for electrical short circuits to command the cargo door to open at the time of the loss of the door, and it is highly improbable that such an event occurred when the airplane was airborne during the short period while the APU was running.

12. Insulation breaches were found on recovered portions of the cargo door wires that could have allowed short circuiting and power to the latch actuator, although no evidence of arcing was noted. All of the wires were not recovered, and tests showed that

arcing evidence may not be detectable.
13. An uncommanded movement of cargo door latches that occurred on another UAL B-747 on June 13, 1991, was attributed to insulation damage and a consequent short between wires in the wiring bundle between the fuselage and the moveable door. Because the S2 switch functioned properly on that airplane, movement of the latches would not have occurred after the door was locked.
14. UAL's maintenance trend analysis program was inadequate to detect an adverse trend involving the cargo door on N4713U. This circumstance was determined not to be a factor in the accident.
15. FAA oversight of the UAL maintenance and inspection program did not ensure adequate trend analysis and adherence to the provisions of airworthiness directives. This circumstance was determined not to be a factor in the accident.
16. The smooth wear patterns on the latch pins of the forward cargo door installed on N4713U were signs that the door was not properly aligned (out of rig) for an extended period of time, causing significant interference during the normal open/close cycle.
17. The rough heat-tinted wear areas on the latch pins of the forward cargo door installed on N4713U marked the positions of the cams at the time the door opened in flight.
18. The design of the B-747 cargo door locking mechanisms did not provide for the intended "fail-safe" provisions of the locking and indicating systems for the door.
19. Boeing's Failure Analysis, which was the basis upon which the FAA granted an alternative method of compliance with the provisions of 14 CFR 25.783(e), was not valid as evidenced by the findings of the Pan Am incident in 1987, and the accident involving flight 811.
20. Boeing and the FAA did not take immediate action to

require the use of the cam position view ports following the Pan Am incident, and did not include this requirement in the provisions of the Alert Service Bulletins or AD-88-12-04.

21. There were several opportunities for the manufacturer and the FAA to have taken action during the service life of the Boeing 747 that might have prevented this accident.

22. The fact that the crash fire rescue vehicles responding to this accident did not use a common radio frequency led to problems in communication among the responding vehicles.

23. The camouflage paint scheme of the military fire rescue units led to reduced visibility of these units and resulted in at least one near-collision.

24. Megaphones were used in flight to communicate with passengers because of the high ambient noise level. However, more megaphones would have afforded better communication in all parts of the cabin.

25. Some flight attendants and passengers had difficulties tightening straps of their life preservers around their waists because of the fabric used, the design of the adjustment fittings, and the angle the straps were pulled.

26. Articles that fell to the floor from stowage bins above the L-2 and R-2 exits and galley service items had to be cleared away from the exits before the emergency evacuation could be initiated.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

4. RECOMMENDATIONS

As a result of the investigation, including evidence from the recovered cargo door and a June 13, 1991, incident involving the uncommanded electrical operation of a cargo door on a UAL Boeing 747 at JFK Airport, the National Transportation Safety Board recommends that the FAA:

Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits. (Class II, Priority Action) (A-92-21)

As a result of this investigation, on August 23, 1989, the Safety Board issued the following safety recommendations to the FAA:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams. (Class II, Priority Action)(A-89-92)

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently. (Class II, Priority Action)(A-89-93)

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions. (Class II, Priority Action)(A-89-94)

The FAA responded to Safety Recommendations A-89-92 through -94 on November 3, 1989. During its evaluation of Safety Recommendation A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with AD 88-12-04, cannot be overridden during mechanical or

least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this, Safety Recommendation A-89-92 has been classified as "Closed--Reconsidered."

The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all jetpowered transport-category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight. The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100 certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as "Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using nonplug doors and that the FAA should not be limiting this review to only those transports which

are jetpowered.
On November 29, 1990, Boeing issued service bulletin number 747-52-2224 applicable to all 747-100, 747-200, and 747-300 airplanes to add a new "door latch" switch to all 747 cargo doors. In addition to the door warning switch that monitors the position of the pressure relief doors, the new door latch switch is activated by the latch cam bellcrank to separately sense the position of the latch cams. The existing "door closed" switch is also replaced with a double pole switch. The additional pole is used to separately sense the position of the door. Another single pole switch is also added to redundantly sense the position of the door. If any of these switches are not actuated, the warning light on the flight engineer's panel and a new light added to pilot's glareshield panel will be illuminated. The modification also requires installation of new cargo door control panels on the forward and aft lower cargo doors. The new panel incorporates an additional light to indicate proper door locking.
The FAA mandated the incorporation of this service bulletin within 18 months by AD 90-09-06, Amendment 39-6581, effective May 29, 1990.
Also, as a result of this accident, on May 4, 1990, the National Transportation Safety Board issued the following safety recommendations to the FAA:
Amend 14 CFR 25.1447(c)(4) to require that face masks be attached to the regulators of portable emergency oxygen bottles. (Class II, Priority Action) (A-90-54)
Require, in accordance with the requirements of 14 CFR 25.1447 (c)(4), that a portable oxygen bottle be located at the flight attendant stations at exit door 5 right and at exit door 5 left in B-747 airplanes. (Class II, Priority Action) (A-90-55)
Require that no articles be placed in storage compartments that are located over emergency exit doors. (Class II, Priority Action) (A-90-56)

Amend 14 CFR 121.309(f) to require a readily accessible megaphone at each seat row at which a flight attendant is stationed. (Class II, Priority Action) (A-90-57)
Take corrective action to improve direct visibility to passengers from the upper level flight attendant jumpseat in the B-747 airplanes using eye reference data contained in Federal Aviation Administration report FAA-AM-75-2 "Anthropometry of Airline Stewardesses." (Class II, Priority Action) (A-90-58)
Issue an Airworthiness Directive to require that stronger latches be installed in oversized storage compartments that formerly held liferafts on all B-747 airplanes and also limit the distance that these compartments can be opened. (Class II, Priority Action) (A-90-59)
Demonstrate for each make and model of life preserver that it can be donned, adjusted, and tightened within the elapsed time required by TSO-C13d. Direct particular attention to the ease with which straps pass through adjustment fittings when the straps are pulled at all possible angles. (Class II, Priority Action) (A-90-60)
Establish a cutoff date of [within 1 year of this recommendation letter] after which all life preservers manufactured for passengercarrying aircraft would be required to meet the specifications of TSO-C13e. (Class II, Priority Action) (A-90-61)
The FAA first responded to these safety recommendations in a July 26, 1990, letter. Further responses to various safety recommendations in the group came in letters dated October 26, 1990 (A-90-59); May 13, 1991 (A-90-58); September 23, 1991 (A-90-55, -56, and -59); and March 9, 1992 (A-90-59). The current status of each safety recommendation is:
A-90-54: "Open--Acceptable Response," pending outcome of potential rulemaking initiative by the FAA.
A-90-55: "Open--Unacceptable Response," pending a review by the FAA of B-747 airplanes for compliance with portable oxygen bottle placement and securement requirements and for

modifications that do not meet the intent of the type certification.
A-90-56: "Open--Unacceptable Response," pending a reexamination by the FAA of the potential for contents of compartments spilling out during an emergency and obstructing passengers.
A-90-57: "Open--Unacceptable Response," pending the FAA's review of its position regarding a requirement for multiple megaphones on passenger airplanes.
A-90-58: "Closed--Reconsidered" as a result of the Safety Board's acceptance of the FAA position that the cabin jumpseat design on B-747's does not constitute an unsafe condition.
A-90-59: "Open--Acceptable Response," pending the issuance of an Airworthiness Directive to require stronger latches on oversized storage compartments on B-747 airplanes.
A-90-60: "Open--Acceptable Response," pending the implementation of the latest iteration of TSO-C13.
A-90-61: "Open--Unacceptable Response," pending inclusion in TSO-C13 (latest iteration) of a cutoff date after which all life preservers manufactured for passenger-carrying aircraft would be required to meet the specifications of the TSO.
The FAA's March 9, 1992, response to Safety Recommendation A-90-59 included the final AD addressing this issue. The AD does meet the intent of the recommendation, which is now classified as "Closed--Acceptable Action."
Also as a result of this accident, on May 4, 1990, the Safety Board reiterated the following recommendations to the FAA:
A-85-35
Amend 14 CFR 121 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; ensure that 14 CFR 25 is consistent with the amendments to Part 121.

A-85-36
Amend 14 CFR 125 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; amend Part 125 to require approved flotation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR 25 is consistent with the amendments of Part 125.
A-85-37
Amend 14 CFR 135 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; Amend Part 135 to require approved floatation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR SFAR No. 23 is consistent with the amendments to Part 135.

In a November 28, 1988, letter to the FAA, the Safety Board recommended that a cutoff date January 1, 1989, be reestablished. Based on this accident, the Safety Board's again urges the FAA to establish a cutoff date by which life preservers meeting TSO-C13e would be introduced into the fleets within a reasonable time (A-85-36). The Safety Board recognizes that the FAA has complied with the part of this recommendation pertaining to the flotation-type seat cushions.

Safety Recommendations A-85-35 and -37 are being held in an "Open--Acceptable Action" status pending the publication of the final rule. Safety Recommendation A-85-36 is being held in an "Open--Unacceptable Action" status because Part 125 operations were not included in the FAA rulemaking action.

As a result of its investigation, on May 4, 1990, the Safety Board also recommended that the State of Hawaii, Department of

Transportation, Airports Division:
Develop, in cooperation with the Department of Defense, procedures for direct radio communication between aircraft rescue and fire fighting vehicles operated by the State of Hawaii and Hickam Air Force Base that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-62)
Additionally, as a result of its investigation, on May 4, 1990, the Safety Board recommended that the Department of Defense:
Develop, in cooperation with the State of Hawaii Department of Transportation, procedures for direct radio communication between aircraft rescue and firefighting vehicles operated by Hickam Air Force Base and the State of Hawaii that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-63)
Comply with Federal Regulation 14 CFR 139.319(f)(2) and the guidance contained in Federal Aviation Administration Advisory Circular 150/5220-14 by using high visibility color for aircraft rescue and firefighting vehicles that operate at Honolulu International Airport. (Class II, Priority Action) (A-90-64)
The Department of Defense responded to Safety Recommendations A-90-63 and -64 on August 17, 1990, citing the establishment of emergency radio communication ability between ARFF vehicles operated by Hickam Air Force Base and the State of Hawaii at Honolulu International Airport. Based on this action, Safety Recommendation A-90-63 was classified as "Closed--Acceptable Action" on December 12, 1990. With the establishment of the communications system as recommended, the Safety Board now classifies Safety Recommendation A-90-62 as "Closed--Acceptable Action."
Also, with regard to Safety Recommendation A-90-64, the Department of Defense pointed out that the Air Force has initiated a program to rep™ aint the vehicles over a 3-year period

to spread out funding concerns. This safety recommendation is being held as "Open--Acceptable Response," pending the completion of the repainting program in 1993.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

SUSAN COUGHLIN
Acting Chairman

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Member

JAMES L. KOLSTAD
Member

March 18, 1992

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Washington Headquarters of the National Transportation Safety Board was notified of the United Airlines accident within a short time after the occurrence. A full investigation team departed Washington, D.C. at 1400 eastern daylight time on the same day and arrived in Honolulu at 0030 Hawaiian standard time the next day.

The team was composed of the following investigation groups: Operations, Structures/Systems, Maintenance Records, Metallurgy, and Survival Factors. In addition, specialist reports were prepared relevant to the CVR, FDR and radar plots.

Parties to the field investigation were United Airlines, the FAA, the Boeing Commercial Airplane Company, the Air Line Pilots Association, the International Association of Machinists, and the Association of Flight Attendants.

2. Public Hearing

A 3-day public hearing was held in Seattle, Washington, beginning on April 25, 1989. Parties represented at the hearing were the FAA, United Airlines, the Boeing Commercial Airplanes Company, the Air Line Pilots Association, and the International Association of Machinists.

APPENDIX B

PERSONNEL INFORMATION

Captain David Cronin

Captain David Cronin, 59, was hired by UAL on December 10, 1954. The captain holds Airline Transport Pilot (ATP) Certificate No. 1268493 with airplane multiengine land ratings and commercial privileges in airplane single-engine land, sea and gliders. The captain is type rated in the B747, DC10, DC8, B727, Convair (CV) 440, CV340, CV240 and the learjet. The captain was issued a first class medical certificate on November 1, 1988, with no limitations.

The captain's initial operating experience (IOE) check out in the B747 occurred in December, 1985. The captain's latest line and proficiency checks in the B747 were completed in August and December, 1988, respectively. Training in ditching and evacuation was included with the proficiency check. The captain had flown a total of about 28,000 hours, 1,600 to 1,700 hours of which were in the B747. During the 24-hour, 72-hour and 30-day periods, prior to the accident, the captain had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 76 hours, 18 minutes, respectively.

First Officer Gregory Slader

First Officer Gregory Slader, 48, was hired by UAL on June 15, 1964. The first officer holds ATP Certificate No. 1528630 with airplane multiengine land ratings and commercial privileges in airplane single-engine land. The first officer is type rated in B747, DC10, B727, and B737. The first officer was issued a first class medical certificate on February 14, 1989, with no limitations.

The first officer's initial operating experience (IOE) check out in the B747 occurred in August, 1987. The first officer's latest proficiency check in the B747 was completed in October, 1988. Training on ditching and evacuation was included with the proficiency check. The first officer had flown a total of about 14,500 hours, 300 hours of which were in the B747. During the 24-hours, 72-hour and 30-day periods prior to the accident, the first officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Second Officer Randal Thomas

Second Officer Randal Thomas, 46, was hired by UAL on May 22, 1969. The second officer holds Flight Engineer Certificate No. 1947041 for turbo jet powered airplanes, issued July 18, 1969. The second officer holds commercial pilot certificate No. 1585899 with ratings and limitations of airplane single and multiengine land with instrument privileges. The second officer was issued a first class medical certificate on December 6, 1988, with no limitations. The second officer's IOE check out in the B747 occurred in March, 1987. The second officer's latest proficiency check in the B747 was completed in October, 1988. Training in ditching and evacuation was included with the proficiency check. He had flown a total of about 20,000 hours, about 1,200 hours of which were as second officer on the B747. During his 24-hour, 72-hour and 30 day-periods, prior to the accident, the second officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Flight Attendant and Chief Purser Laura Brentlinger

Flight attendant Laura Brentlinger, 38, was employed by UAL in May 1982; and had completed B747 recurrent training on September 19, 1988.

Flight Attendant and AFT Purser Sarah Shanahan

Flight attendant Sarah Shanahan, 42, was employed by UAL in August 1967; and had completed B747 recurrent training on

October 10, 1988.

Flight Attendant Richard Lam

Flight attendant Richard Lam, 41, was employed by UAL on April 1970; and had completed B747 recurrent training on September 16, 1988.

Flight Attendant John Horita

Flight attendant John Horita, 44, was employed by UAL in June 1970; and had completed B747 recurrent training on November 1, 1988.

Flight Attendant Curtis Christensen

Flight attendant Curtis Christensen, 34, was initially employed by PAA in May 1978. He was subsequently employed by UAL in February 1986 when UAL purchased PAA Pacific Division. Flight attendant Chrisensen had completed B747 recurrent training on December 12, 1988.

Flight Attendant Tina Blundy

Flight attendant Tina Blundy, 36, was employed by UAL in May 1973; and had completed B747 recurrent training on October 28, 1988.

Flight Attendant Jean Nakayama

Flight attendant Jane Nakayama, 37, was employed by UAL in August 1973; and had completed B747 recurrent training on December 6, 1988.

Flight Attendant Mae Sapolu

Flight attendant Mae Sapolu, 38, was initially employed by Pan American Airlines (PAA) in March 1973. She was subsequently employed by UAL in February 1986; when UAL purchased PAA Pacific Division. Flight attendant Sapolu completed B747 recurrent training on October 13, 1988.

Flight Attendant Robyn Nakamoto

Flight attendant Robyn Nakamoto, 26, was employed by UAL in April, 1986, and transferred to the Inflight Service Division in May, 1988. She was initially trained on the B747 in May 1988; and had not attended recurrent training.

Flight Attendant Edward Lythgoe

Flight attendant Edward Lythgoe, 37, was employed by UAL in December 1978; and had completed B747 recurrent training on October 21, 1988.

Flight Attendant Sharol Preston

Flight attendant Sharol Preston, 39, was employed by UAL in July 1970; and had completed B747 recurrent training on July 29, 1988.

Flight Attendant Ricky Umehira

Flight attendant Ricky Umehira, 35, was employed by UAL in November 1983; and had completed B747 recurrent training on November 15, 1988.

Flight Attendant Darrell Blankenship

Flight attendant Darrell Blankenship, 28, was employed by UAL in February 1984; and had completed B747 recurrent training on February 10, 1988.

Flight Attendant Linda Shirley

Flight attendant Linda Shirley, 30, was employed by UAL in March 1979; and had completed B747 recurrent training on November 3, 1989.

Flight Attendant Ilona Benoit

Flight attendant Ilona Benoit, 48, was initially employed by PAA in November 1969. She was subsequently employed by UAL in February 1986; and had completed B747 recurrent training on November 17, 1988.

Lead Ramp Serviceman Paul Engalla

Lead ramp serviceman Paul Engalla was employed by UAL in 1959. Because of his extensive ramp service experience, Mr. Engalla was selected as a ramp service trainer in 1986.

Ramp Serviceman Daniel Sato

Ramp serviceman Daniel Sato was employed by UAL in May 1987. Company records indicate that his proficiency in the opening and closing of B747 cargo doors and the operation of

container loads was attained in September 1988.
Ramp Serviceman Brian Kitaoka
Ramp serviceman Brian Kitaoka was employed by UAL in November 1986. Company records indicate that his proficiency in the operation of container loaders was attained in November 1987. His proficiency in the opening and closing of B747 cargo doors was attained in October 1988.
Dispatch Mechanic Steve Hajanos
Dispatch mechanic Steve Hajanos was employed as an airplane mechanic by UAL on October 30, 1986. He holds FAA Airplane and Powerplants Certificate No. 362583850, issued November 14, 1981. He was formerly employed by Aloha Airlines as a maintenance supervisor and by World Airways as a mechanic and maintenance supervisor. He began his aviation career as an airplane mechanic in the United States Air Force.
APPENDIX C
AIRPLANE INFORMATION

Type of Date of Maximum Inspection Inspection Cycles Interval Service No. 1 Current 02/23/89 58,814:24 15,027 Note 1 Previous 02/23/89 58,809:02 15,026 Service No. 2 Current 02/22/89 58,802:35 15,024 65 Hours Previous 02/18/89 58,747:12 15,016 Note 2 A Check Current 02/14/89 58,710:14 15,009 350 Hours Previous 01/16/89 58,368:57 14,947 B Check Current 11/28/88 57,751:44 14,839 131 Days Previous 07/28/88 56,635:36 14,632 C Check Current 11/28/88 57,751:44 14,839 393 Days Previous 11/19/87 53,789:00 14,146 MPV Check Current 04/30/84 43,731:0 11,857 5 Years Previous 01/30/80 30,906:0
D Check Current 04/30/84 43,731 19,237 9 Years Previous 09/09/76 19,237 Note 1: Service No. 1 to be accomplished on through flights or at trip termination whenever time is less than 12 hours per Maintenance Manual Procedures BX 12-0-1-1.
Note 2: Aircraft with layover of 12 hours or more will receive a

Service No. 2 not to exceed 65 flight hours between checks.

APPENDIX D

INJURY INFORMATION

Flight Crewmember.--The second officer sustained minor superficial brush burns to both elbows and forearms, during the evacuation.

Cabin Crewmembers.--The cabin crewmembers sustained the following injuries during the evacuation:

Flight attendant No. 1 sustained a strained left shoulder;

Flight attendant No. 2 sustained acute thoracic and lumbosacral strain;

Flight attendant No. 3 sustained a mild right bicep strain;

Flight attendant No. 4 sustained a left elbow contusion, left shoulder dislocation, and mild lumbosacral strain;

Flight attendant No. 5 sustained a left calf contusion;

Flight attendant No. 6 sustained a mild left elbow bruise;

Flight attendant No. 7 sustained mild left arm and lower back strain;

Flight attendant No. 8 sustained a soft tissue injury to the back;

Flight attendant No. 9 sustained abrasions to both palms and the left knee;

Flight attendant No. 10 sustained a fracture of the left tenth rib;

Flight attendant No. 11 sustained a minimal injury to the right middle finger PIP joint and left first MP joint;

Flight attendant No. 12 sustained a pulled muscle on the left side of the neck;

Flight attendant No. 13 sustained a comminuted fracture of the right ulna and radius;

Flight attendant No. 14 sustained a mild thoracic back strain;

Flight attendant No. 15 sustained a non-displaced fracture of C-6, a cerebral concussion, a fracture of the proximal right humerus, and multiple lacerations;

A flight attendant, flying as a passenger, sustained mild lumbosacral strain, a laceration of the right little finger, and a left elbow abrasion.

Passengers.--Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH, and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally injured in the accident.

Passengers seated in the indicated seats sustained the following injuries:

Seat

7C - Barotrauma to both ears

9C - Half-inch laceration to the upper left arm, superficial abrasions to left arm and hand, barotrauma to both ears

9E - Superficial abrasions and contusions to the left hand, mild barotrauma to both ears

10B - Superficial abrasions to the left elbow and left middle finger

10E - Superficial abrasions to the torso and left forearm, bruising of the left hand and fingers

11E - Laceration on the right ankle tendon, multiple bruises

11F - Slight contusion of the right shoulder

13D - Barotrauma to both ears

13E - Bleeding in both ears

13H - Contusion to the left periorbital area

14A - Laceration in the parietal occipital area, barotrauma to both ears

15J - Comminuted fracture of the lateral epicondyle of the left distal humerus (about 5mm separation)

16B - Superficial abrasions to the right arm

16J - Barotrauma to both ears

16K - Right temporal abrasions

26A - Barotrauma to both ears

26B - barotrauma to both ears

26H - Barotitis to both ears, low back pain, irritation to the

right eye due to foreign bodies
27A - Barotrauma to the right ear
28J - Superficial abrasions and a contusion to the left hand, mild barotrauma to both ears

1The flap track canoe fairings are numbered 1 through 8, from left outboard to right outboard.

2For ease in reference, the following numbering was used to relate forward cargo door frames to fuselage body stations (BS): frame 1--BS 567.10, frame 2--BS 580.95, frame 3--BS 596.75, frame 4--BS 608.15, frame 5--BS 623.96, frame 6--BS 636.02, frame 7--BS 651.50, frame 8--BS 662.90.

3 The "used" switch is the switch through which electricity passes; the "unused" switch does not have electricity pass through it.

4NFPA 414 - Aircraft Rescue and Fire Fighting Vehicles, National Fire Protection Association, 1984, Batterymarch Park, Quincy, MA 02269.

5Airport Fire and Rescue Vehicle Specification Guide, AC 150/5220-14, March 15, 1979, Federal Aviation Administration, Washington, D.C. 20591.

6 Air Carrier Overwater Emergency Equipment and Procedures" (NTSB/SS-85/02)

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:49 PM PDT
To: Jaswindersingh <jaswinderp@hotmail.com>
Subject: **AI 182 AAR and URL for TWA 800**

http://www.ntsb.gov/Publictn/2000/aar0003.htm

Abstract: On July 17, 1996, about 2031 eastern daylight time, Trans World Airlines, Inc. (TWA) flight 800, a Boeing 747-131, N93119, crashed in the Atlantic Ocean near East Moriches, New York. TWA flight 800 was operating under the provisions of 14 Code of Federal Regulations Part 121 as a scheduled international passenger flight from John F. Kennedy International Airport (JFK), New York, New York, to Charles DeGaulle International Airport, Paris, France. The flight departed JFK about 2019, with 2 pilots, 2 flight engineers, 14 flight attendants, and 212 passengers on board. All 230 people on board were killed, and the airplane was destroyed. Visual meteorological conditions prevailed for the flight, which operated on an instrument flight rules flight plan.

The National Transportation Safety Board determines that the probable cause of the TWA flight 800 accident was an explosion of the center wing fuel tank (CWT), resulting from ignition of the flammable fuel/air mixture in the tank. The source of ignition energy for the explosion could not be determined with certainty, but, of the sources evaluated by the investigation, the most likely was a short circuit outside of the CWT that allowed excessive voltage to enter it through electrical wiring associated with the fuel quantity indication system.

Contributing factors to the accident were the design and certification concept that fuel tank explosions could be prevented solely by precluding all ignition sources and the design and certification of the Boeing 747 with heat sources located beneath the CWT with no means to reduce the heat transferred into the CWT or to render the fuel vapor in the tank nonflammable.

The safety issues in this report focus on fuel tank flammability, fuel tank ignition sources, design and certification standards, and the maintenance and aging of aircraft systems. Safety recommendations concerning these issues are addressed to the Federal Aviation Administration.

Canadian Aviation Bureau canadien Safety Board de la sécurité aérienne AVIATION OCCURRENCE AIR INDIA BOEING 747-237B VT-EFO CORK, IRELAND 110 MILES WEST 23 JUNE 1985 1.0 INTRODUCTION

Air India Flight 182, a Boeing 747-237B, registration VT-EFO, was on a flight from Mirabel to London when it disappeared from the radar scope at a position of latitude 51°O'N and longitude 12°50'W at 0714 Greenwich Mean Time (GMT), 23 June 1985, and crashed into the ocean about 110 miles west of Cork, Ireland. There were no survivors among the 329 passengers and crew members. The depth of the water at the crash site is about 6,700 feet.

At 0541 GMT, 23 June 1985, CP Air Flight 003 arrived at Narita Airport, Tokyo, Japan, from Vancouver. At 0619 GMT a bag from this flight exploded on a baggage cart in the transit area of the airport within an hour of the Air India occurence. Two persons were killed and four were injured. From the day of the occurrences, there have been questions about a possible linkage between the events.

This Submission examines the information available to the Canadian Aviation Safety Board (CASB) with respect to the circumstances surrounding the AI 182 accident. The sources of information include: information made public to the Indian Inquiry as a result of the RCMP investigation; the flight data recorder (FDR), cockpit voice recorder (CVR) and Shannon ATC tape recording analyses by Canadian, United Kingdom, and Indian authorities; the medical evidence obtained from Dr. Hill of the Accident Investigations Branch of the United Kingdom; and the evidence obtained by examination of the wreckage recovered, the wreckage distribution pattern, photographs, and videotapes of the wreckage on the ocean bottom.

2.0 EXAMINATION

2.1 Vancouver

On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight East Indian accent.* He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vancouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

On the same date at approximately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to

Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

On 20 June 1985 at about 1210 PDT (1910 GMT), a male appearing to be of East Indian origin purchased the tickets with cash from a CP Air ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to M. Singh. The telephone contact number was also changed. The final itinerary was as follows:

a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22 June 1985

*See Appendix A for chronology of events.

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22 June 1985

b) L. Singh - CP 003 Vancouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 (local time in Tokyo), 23 June 1985

On 22 June 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy East Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that he was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

On Saturday morning, 22 June 1985, a CP Air passenger agent worked check-in position number 26 at the CP Air ticket counter, Vancouver International Airport, and recalls dealing with a passenger booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto he could not interline his baggage. The passenger insisted and, as the line-ups were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that M. Singh checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage. The flight manifest for CP 003 shows that on the same day the person using the name of L. Singh with a ticket to Bangkok also checked in through the same counter, was assigned seat 38H, and checked one piece of baggage.

A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as M. and L. Singh did not board these respective flights.

2.2 Toronto

Air India Flight 181 from Frankfurt arrived at Toronto on 22 June 1985 at 1430 EDT (1830 GMT) and was parked at gate 107 of Terminal 2. All passengers and baggage were removed from the aircraft and processed through Canada Customs. Passengers continuing on the flight to Montreal were given transit cards, and on this flight 68 cards were handed out. These transit passengers are required to claim their luggage and proceed through Canada Customs. Prior to entering the public area, there is a belt which is designated for interline or transit baggage. Transit passengers deposit their luggage on this belt which carries it to be reloaded on the aircraft. This baggage was not subjected to X-ray inspection as it was presumed to have been screened at the passengers' overseas departure point. When the transit passengers checked in to proceed to Montreal, their carry-on baggage was subjected to the normal security checks in place on this date. Passenger and baggage security checks were conducted by Burns International Security Services Ltd. and all passenger and baggage processing for both off-loading and on-loading was handled by Air Canada staff.

Air India Flight 181 was composed of the following:

- passengers continuing to Montreal (68)
- passengers from connecting flights

AC 102 (Saskatoon) 2

AC 106 (Edmonton) 4

AC 192 (Winnipeg) 1
AC 170 (Winnipeg) 4
AC 136 (Vancouver) 10
CP 060 (Vancouver) 1 Standby (M. Singh)

- passengers originating at Toronto
- diplomatic bags from the Vancouver India Consul General via AC 508
- produce cargo from India
- cargo in the form of 5th pod engine components loaded in the aft cargo compartment.

It should be noted that some passengers from India book flights to Montreal with their intended destination being Toronto. The reason is that the fare to Montreal is cheaper and therefore some passengers get off the flight in Toronto, claim their luggage and leave without reporting a cancellation of the trip to Montreal. It has been established that 65 of the 68 transit passengers reboarded the flight to Montreal.

Air India personnel were in charge for the overall operation at Toronto regarding the unloading and loading of both passengers and cargo. Although the actual work was performed by various companies under contract, Air India personnel oversaw the operation. The Air India station manager was away on vacation on 22 June 1985. The evidence does not clearly establish who had been assigned to replace the station manager and assume his duties.

Air Canada had stored in a hangar an engine that had failed on a previous Air India flight from Toronto on 8 June 1985. Air Canada received a message from Air India stating that the failed engine was to be mounted as a 5th pod on Flight 181/182 on 22 June 1985. The engine was prepared for loading and component parts were crated for loading into the aft cargo compartment. On 22 June, the component parts were taken from the hangar and placed outside to be delivered to the aircraft by MEGA International Air Cargo. The component parts were placed just inside the airport fence separating the restricted and unrestricted areas. The installation began immediately upon the arrival of Flight 181 and was completed at 1530 EDT (1930 GMT). The front engine cowling was crated but would not fit through the aft cargo door. The crating was rearranged, and the door stops on the cargo door were removed to permit the loading of the crate and the remaining engine parts were loaded on pallets. Due to problems with loading the 5th pod and component parts, the departure was delayed from 1835 EDT (2235 GMT) to 2015 EDT (0015 GMT, 23 June).

CP Air Flight 060 arrived in Toronto at 1610 EDT (2010 GMT) and docked at gate 44, Terminal 1. A number of passengers on this flight were interlined to other flights including passenger M. Singh wait-listed on Air India Flight 181/182. It has been established that this passenger did not board Flight CP 060 but did check baggage onto the flight. This baggage was to be interlined to the Air India flight departing from Terminal 2. In this case, CP Air employees would have off-loaded all baggage from CP 060 and deposited the baggage at Racetrack 6 on the ring road of Terminal 1 to be transported to the Air Canada sorting room at Terminal 2.

Consolidated Aviation Fuelling and Services (CAFAS) is a company which is contracted to pick up and deliver baggage from one terminal to the other. The CAFAS driver on duty at the time recalls picking up a bag from a CP Air flight originating in Vancouver and destined for Air India at Terminal 2. As this piece of luggage did not turn up as found luggage, it is deduced that normal practice was followed, and the luggage was interlined and loaded on AI 181/182.

MEGA International Air Cargo is a firm that handled air cargo and containers for Air India. Since the flight was carrying a 5th engine and component parts, no commercial cargo could be loaded at Toronto. MEGA delivered the engine component parts to be loaded in the cargo compartment by Air Canada employees. Later, MEGA received two diplomatic bags and delivered these to the aircraft. The bags were loaded into the valuable goods container (see Appendix B). These bags were not subjected to X-ray or any other security checks.

All checked-in baggage for AI 181/182 was to be screened by an X-ray machine which was located in Terminal 2 at the end of international belt number 4. This location would permit all baggage from the check-in counters and interline carts to be fed through the X-ray machine before being loaded. It has been established that this machine worked intermittently for a period of time and stopped working during the loading process at about 1700 EDT (2100 GMT). Rather than opening the bags and physically inspecting them, the Burns security personnel performing the X-ray screening were told by the Air India security officer to start using the hand-held PD-4 sniffer.

One Burns security officer checked the bags with the sniffer while another put stickers on the bags and forwarded them. The security officer forwarding the baggage recalls the sniffer making short beeping noises not long whistling ones. The security officer who used the sniffer claims it never went off, and the only time any sound was made was when it was turned on and off. At those times, it would emanate a short beep (refer to section 2.8 for further information regarding the PD-4 sniffer).

Burns International Security had a contract with Air India for the security of the aircraft while it was docked. The security arrangements contracted from Burns were as follows:

- security at the bridge door leading to the aircraft;
- security inside the aircraft from the time the passengers disembarked upon flight arrival until flight departure;
- security guards assigned the physical inspection of all carry-on baggage in the departure room; and
- security guards in the international baggage make-up room conducting screening of baggage using an X-ray machine and a hand-held PD-4 sniffer.

The statements taken from Burns security personnel in Toronto indicated that a significant number of personnel, including those handling passenger screening, had never had the Transport Canada passenger inspection training program or, if they had, had not undergone refresher training within 12 months of the previous training.

As a result of official requests made by Air India in early June 1985 for increased security for Air India flights, the RCMP provided additional security as follows:

- one member in a marked police motor vehicle patrolling the apron area;
- one member in a marked police motor vehicle parked under the right wing from time of arrival until push-back;
- one member on foot patrol at Air India check-in counter; and
- one member at the loading bridge during boarding.

In addition, all RCMP members working in that particular area of Terminal 2 were aware of the Air India flight and would check in with the assigned personnel during their patrols in the area of the aircraft and check-in/boarding lounges. Uniformed members are to patrol and monitor security within the airport premises as detailed in section 2.5 below.

Passenger check-in was handled for Air India by Air Canada under contract with Air India. The check-in included passengers originating in Toronto and interline passengers but did not include the transit passengers to Montreal. The check-in passengers were numbered using a security control sheet in accordance with instructions from Air India; however, the check-in and interline baggage was not numbered, and no attempt was made to correlate baggage with passengers. Hence, any unaccompanied interline baggage would not have been detected.

The flight and cabin crew had been in Toronto for the week prior to this flight and were to take the aircraft to London where they would be replaced by another crew. The crew members themselves and their carry-on baggage were not subjected to any security checks; however, their checked-in baggage was screened in the same manner as other baggage.

2.3 Montreal

Air India Flight 181 from Toronto arrived at Mirabel International Airport at about 2100 EDT (0100 GMT, 23 June) and parked in supply area number 14 at 2106 EDT (0106 GMT). The 65 passengers destined for Montreal along with three Air India personnel deplaned and were transported by bus to the terminal building. The remaining passengers remained on board as transit passengers and were not permitted to disembark at Montreal. Air Canada baggage handlers off-loaded four containers of cargo, three containers of baggage and a valuables container. Two diplomatic pouches from the Indian High Commission in Ottawa were delivered to the aircraft by MEGA International Cargo. One pouch weighing one kilogram was hand-delivered to the flight purser for storage in a valuables locker within the cabin and the other pouch was loaded into the valuables container.

During the check of the aircraft at Montreal, the second officer pointed out to an Air Canada mechanic that a rear latch on the fan cowl for the 5th engine did not appear to be properly secured. The mechanic examined the latch and found it well secured, but the handle was not flush and was hanging about five degrees. The mechanic applied high-speed tape to the latch handle for aerodynamic smoothness. This repair was examined by the second officer who was satisfied with the work. No records were completed by Air Canada in connection with this temporary repair.

At about 1730 EDT (2130 GMT), Air Canada, which is Air India's contracted agent, opened its check-in counter to passengers who would be flying on Air India Flight 182. Burns security personnel were also assigned at this time to screen the checked baggage. Passenger tickets were checked, issued a number, and copies of the tickets were removed and retained by Air Canada. Boarding passes were then issued and affixed to the numbered tickets. Also attached to the ticket booklets were numbered tickets which corresponded to each piece of checked baggage. The numbered checked baggage was sent to the baggage area by Air Canada personnel to be security-checked by Burns security personnel. The passengers for AI 182 after checking in were free to enter the departure area. At the entrance to the departure area, Burns security staff used X-ray units and metal detectors to screen passengers and carry-on baggage. At about 2100 EDT (0100 GMT), the passengers proceeded to gate 80 where they gave their boarding passes and numbered tickets to an Air Canada agent. The agent kept the numbered flight tickets and checked the numbers against the passenger list. Also, at gate 80, a secondary security check was done on passengers by a Burns security officer using a metal detector. Hand-carried baggage was subjected to

further physical and visual checks. A total of 105 passengers boarded the flight at Mirabel Airport; there were no interline passengers.
Between 1900 (2300 GMT) and 1930 EDT (2330 GMT), Burns security personnel identified a suspect suitcase using the X-ray machine. The suitcase was placed on the floor next to the machine. The Burns security supervisor told Air India personnel that a suspect suitcase had been located and was advised within 15 to 20 minutes to wait for the Air India security officer who would be arriving on the flight from Toronto. Subsequently, a second suspect suitcase was identified and a little later a third. The three suitcases were placed next to the X-ray machine.
Between 1930 (2330 GMT) and 1945 (2345 GMT), all the Burns security personnel at the X-ray machine were assigned to other duties and the three suspect suitcases remained in the baggage area without supervision. At about 2140 (0140 GMT), the Air India security officer went to the baggage room and inspected the three suitcases with the X-ray machine and a sniffer that was in the possession of the security officer. The Air India security officer decided to keep the three suitcases and, if further examination proved negative, send them on a later flight.
At approximately 2155 (0155 GMT), the Air Canada Operations Centre supervisor contacted the airport RCMP detachment regarding the suspect suitcases. At about 2205 (0205 GMT), an RCMP member located the suitcases in the baggage room and requested that an Air India representative be sent to the baggage room. About five minutes later, the Air India security officer contacted the baggage room by telephone and advised that he could not come to the room immediately. The Air India security officer arrived in the baggage room at about 2235 (0235 GMT) and, when asked to determine the owners of the suitcases, informed the RCMP member that the flight had already departed [2218 (0218 GMT)]. The three suspect suitcases were later examined with negative results.
The remainder of the checked baggage which cleared the security check was identified by a green sticker. The baggage was then forwarded to Air Canada personnel who loaded the baggage in containers to be placed on board the aircraft. A later check with Canada Customs and Air Canada at Mirabel revealed no unclaimed baggage associated with AI

181/182. A similar check at Dorval Airport was conducted with negative results.

No record was kept as to the location and number of individual pieces of checked-in luggage. Records were kept as to the location of the containers according to destination, where loaded and the number of pieces of luggage in each container (see Appendix B).

The Mirabel Detachment of the RCMP provided the following security at the airport on 22 June 1985:

- one member in a police vehicle for airside security;
- one member on patrol in the arrival and departure areas;
- one member on general foot patrol throughout the terminal; and
- one member as a telecommunications operator in the detachment office.

In addition, due to the increased threat to Air India flights, the RCMP provided the following supplementary coverage to Air India Flight 181/182 on 22 June 1985:

- one member in a police vehicle escorted the aircraft to and from the runway and the terminal building and remained with the aircraft while it was stationary;
- one member in a police vehicle remained at the entrance to the ramp;
- two members patrolled the area of the ticket counter and access corridors, and one of these members also served in a liaison capacity with the airline representatives.

2.4 International Standards and Recommended Practices

International security standards and recommendations to safeguard international civil aviation against acts of unlawful interference are listed in ICAO Annex 17 to the Convention on International Civil Aviation. Suggested security measures and procedures are amplified in the ICAO Security Manual for Safeguarding Civil Aviation Against Acts of Unlawful Interference.

Annex 17 requires contracting States of which Canada is one to "take the necessary measures to prevent weapons or any other dangerous devices, the carriage or bearing of which is not authorized, from being introduced by any means whatsoever, on board an aircraft engaged in the carriage of passengers."

In addition to other recommendations, Annex 17 recommends that contracting States should establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage, cargo, mail and stores to be carried on board aircraft.

The Security Manual specifies that,

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Recently, ICAO has proposed amendments to Annex 17. These proposals arise from a decision taken by the Council in its 115th Session on 10 July 1985. The Council instructed its Committee on Unlawful Interference, as a matter of urgency, to review the entirety of Annex 17 and to report on those provisions which might be immediately introduced, upgraded to Standards, strengthened or improved. Among the proposed amendments is the following upgrading in the Standards:

- Each contracting State ensure the implementation of measures at airports to protect cargo, baggage, mail stores and operator's supplies being moved within an airport to safeguard such aircraft against an act of unlawful interference.

2.5 Canadian Law

In terms of Canadian statutory requirements, the Civil Aviation Security Measures Regulations and the Foreign Aircraft Security Measures Regulations made pursuant to the Aeronautics Act require specified owners or operators of aircraft registered in Canada or specified owners or operators who land foreign aircraft in Canada to establish, maintain, and carry out security measures at airports consisting of:

- systems of surveillance of persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- systems of searching persons, personal belongings, baggage, goods and cargo by persons or by mechanical or electronic devices;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas that are inaccessible to any person other than a person who has been searched and the personnel of the owner or operator;

- a system that provides, at airports where facilities are available, for check-points at which persons intending to board the aircraft of an owner or operator can be searched;
- a system that provides, at airports where facilities are available, for locked, closed or restricted areas in which cargo, goods and baggage that have been checked for loading on aircraft are inaccessible to persons other than those persons authorized by the owner or operator to have access to those areas;
- a system of identification that prevents baggage, goods and cargo from being placed on board the aircraft if it is not authorized to be placed on board by the owner or operator; and
- a system of identification of surveillance and search personnel and the personnel of the owner or operator.

Specified carriers including Air Canada, CP Air, and Air India were required to provide a description of their security measures to the Canadian Minister of Transport.

An Order-in-Council on 29 September 1960 established that the RCMP was responsible for the direction and administration of police functions at major airports operated by Transport Canada. The duties of the Police and Security Detail at these designated airports include the following:

- carry out policing and security duties to guard against unauthorized entry, sabotage, theft, fire or damage;
- enforce federal legislation;
- respond to violations of the Criminal Code of Canada, Federal, Provincial, and Territorial statutes, and perform a holding action pending arrival of the police department having primary criminal jurisdiction;
- man guard posts; and
- provide a police response in those areas of airports where pre-board screening takes place.

Section 5.1(9) of the Aeronautics Act states that "The Minister may designate as security officers for the purposes of this section any persons or classes of persons who, in his opinion, are qualified to be so designated." Pursuant to this section Transport Canada has established criteria for persons or classes of persons that are designated as security officers in a Schedule registered on 11 April 1984. The criteria also specify that a security guard company and its employees will meet Transport Canada requirements provided that the company:

- is under contract with a carrier to conduct passenger screening under the Aeronautics Act and Regulations;
- is licensed in the province or territory;
- complies with the security guard criteria as follows in that the guard must:
  - be 18 years or older,
  - be in good general health without physical defects or abnormalities which would interfere with the performance of duties,
  - be licensed as a security guard and in possession of the licence while on duty, and
  - meet the training standards of Transport Canada consisting of successfully completing the Transport Canada passenger inspection training program, attaining an average mark of 70 per cent, and undergoing refresher training within 12 months from previous training;
- uses a comprehensive training program which has been approved by Transport Canada and is capable of being monitored and evaluated;
- keeps records showing the date each employee received initial training and/or refresher training and the mark attained; and
- provides supervision to ensure that their employees maintain competency and act responsibly in the conduct of searching passengers and carry-on baggage being carried aboard aircraft.

2.6 Canadian Security Procedures

In accordance with the Canadian Aeronautics Act and pursuant regulations, air carriers are assigned the responsibility for security. Transport Canada provides the following security services for the air carriers using major Canadian airports, including the international airports in Vancouver, Toronto and Montreal:

- security and policing staff including RCMP airport detachments;
- specific airport security plans and procedures;
- secure facilities (e.g., secure areas, pass identification systems, etc.); and

- security equipment and facilities (e.g., X-ray detection units, walk-through metal detectors, hand-held metal detectors, explosive detection dogs).

As of 22 June 1985, the following general security measures were in place at Canadian airports:

- metal detection screening of passengers; and
- X-raying of carry-on baggage.

Checked baggage was not normally subject to any security screening. A few air carriers such as Air India had extra security measures in place because of an assessed higher threat level (see section 2.7 below).

On 23 June 1985, Transport Canada required additional security measures to be implemented by all Canadian and foreign air carriers for all international flights from Canada except those to the continental United States. These measures required:

- the physical inspection or X-ray inspection of all checked baggage;
- the full screening of all passengers and carry-on baggage; and
- a 24-hour hold on cargo except perishables received from a known shipper unless a physical search or X-ray inspection is completed.

Further, on 29 June 1985, Transport Canada directed that all baggage or cargo being interlined within Canada to an Air India flight was to be physically inspected or X-rayed at the point of first departure and that matching of passengers to tickets was to be verified prior to departure.

2.7 Air India Security Program in Canada

In accordance with the Foreign Aircraft Security Measures Regulations, Air India had provided the Minister of Transport with a copy of its security program. It included measures to:

- establish sterile areas;
- physically inspect all carry-on baggage by means of hand-held devices or X-ray equipment;
- control boarding passes;
- maintain aircraft security;
- ensure baggage and cargo security; and
- off-load baggage of passengers who fail to board flights.

Under these procedures established by Air India, passengers, carry-on baggage, and checked baggage destined for AI 181/182 on 22 June 1985 were subjected to extra security checks. A security officer from the Air India New York office arrived in Toronto on 22 June 1985 to oversee the security operation at Toronto and Montreal.

On 17 May 1985, the High Commission of India presented a diplomatic note to the Department of External Affairs regarding the threat to Indian diplomatic missions or Air India aircraft by extremist elements. Subsequently, in early June, Air India forwarded a request for "full and strict security coverage and any other appropriate security measures" to Transport Canada offices in Ottawa, Montreal and Toronto, and RCMP offices in Montreal and Toronto.

2.8 PD-4 Sniffer

On 18 January 1985, prior to the inaugural Air India flight out of Toronto on 19 January, a meeting on security for Air India flights (Toronto) was held with representatives from Transport Canada, RCMP and Air India. At this meeting, a PD-4 sniffer belonging to Air India was produced. It was explained that it would be used to screen checked baggage as the X-ray machine had not yet arrived. At that time, an RCMP member tested its effectiveness. The test revealed that it could not detect a small container of gunpowder until the head of the sniffer was moved to less than an inch from the gunpowder. Also, the next day the sniffer was tried on a piece of C4 plastic explosives and it did not function even when it came directly in contact with the explosive substance. It is not known if this was the same sniffer used on 22 June 1985.

2.9 Medical Evidence

Medical examination was conducted on the 131 bodies recovered after the accident. This comprises about 40 per cent of the 329 persons on board. It should be noted that assigned seating is based on preliminary information. Also, the exact position of passengers is not certain because it is not known if passengers changed their seats after lift-off. On the information available, the passengers were seated as follows:

Passengers:*

Seats Bodies

	Available	Occupied	Identified
Zone A	16	1	0
Zone B	22	0	0
Upper Deck	18	7	0
Zone C	112	104 + 2	29
Zone D	86	84 + 1	38
Zone E	123	105 + 3	50
SUB-TOTAL	377	301 (+6 infants)	117
Crew:			
Flight Deck	3	3	0
Cabin	19	19	5
TOTAL	399	329	122

There were 30 children recovered and they showed less overall injury. The average severity of injury increases from Zone C to E and is significantly less in C than in Zones D and E.

Flail pattern injuries were exhibited by eight bodies. Five of these were in Zone E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in Zone E.

There were 25 bodies showing signs of decompression, including 7 children. They were evenly

*See Appendix C for interior seating arrangement.

distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 in Zone D, 11 in Zone E, 2 crew and 1 unknown), and 16 had little or no clothing.

Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

There is a general absence of signs indicating the wearing of lap belts. Pathological examination failed to reveal any injuries indicative of a fire or explosion.

2.10 Flight Recorders and Shannon Air Traffic Control (ATC) Tape Analyses

VT-EFO was equipped with a Fairchild A100 Cockpit Voice Recorder (CVR) and a Lockheed 209E Digital Flight Data Recorder (DFDR). These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the aft pressure bulkhead. The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor.

The Shannon Air Traffic Control Centre was in contact with VT-EFO and recorded radio communications with the aircraft. At the time of the accident, 5.4 seconds of noise was recorded, and the transponder signal seen on the radar scope was lost from the aircraft. This signal which displays aircraft altitude showed no deviation before disappearing from the radar scope.

2.10.1 Analysis by National Research Council, Canada

From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder. The initial waveform of the cockpit area microphone signal is not consistent with the sharp pressure rise expected with detonation of an explosive device close to the flight deck, but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, the possibility that it originated from such a device elsewhere in the aircraft cannot be excluded.

By correlating the oscillograph records of the CVR and the Shannon ATC VHF recording, it was estimated that the unusual sounds recorded on the ATC tape started 1.4 ± 0.5 seconds after the start of the sudden sound detected by the cockpit area microphone and lasted intermittently for 5.4 seconds. It was felt the closeness in time of the two noises indicated the 5.4 seconds recorded on the ATC tapes originated from AI 182. The ATC recording that followed the cockpit area microphone sounds appeared at first to contain a series of short intermittent sounds. Listening to the sounds, it also appeared that a human cry occurred near the end of the recording. Spectral analysis of these sounds and comparison with voice imitations revealed that the recorded sounds do not contain all the pitch harmonic frequencies normally associated with voice sounds. The origin of these sounds has not been determined.

An examination of the DFDR showed no abnormal variations before the accident. With the spare engine, this aircraft was restricted to altitudes below 35,200 feet and indicated airspeeds less than 290 knots. During the last 27 minutes of the flight, the computed airspeed did gradually increase to nine knots above this limit in the first part of this period and the power was readjusted several times. The speed fell below the 290 knot limit at about 07h:09m GMT as recorded by the DFDR; power was increased again at about 07h:10m causing the aircraft to accelerate to six knots above the limit by the time the accident occurred at 07h:13m:59s. The observed excursions outside the specified limits are not considered significant.

The aircraft was flown with 1.5-degree left-wing-down with 4.2 degrees clockwise control wheel as compared to the aircraft without the 5th engine installation. Also, 9.4 per cent of right rudder pedal was applied giving a 1.1-degree right deflection of the upper and lower rudders. Considering the carriage of the 5th engine on the left side, these figures are not considered abnormal.

When synchronized with the other recordings, it was determined, within the accuracy that the procedure permitted, that the DFDR stopped recording simultaneously with the CVR.

Irregular signals were observed over the last 0.27 inches of the DFDR tape. Laboratory tests indicated that the irregular signals most likely occurred as a result of the recorder being subjected to sharp angular accelerations about the lateral axis of the recorder, causing rapid changes in tape speed over the record head. This equates to an angular acceleration on the recorder about the aircraft's longitudinal axis in a left-wing-down sense. Therefore, these tests indicate that the digital recorder was subjected to a sharp jolt separate from any violent motion of the aircraft.

The other possibility for the irregular signals is that the Flight Data Acquisition Unit which generated the serial digital data signal and which is located in the electronics bay under the cabin floor forward of the cargo compartment could have suffered some damage or had an intermittent power supply that caused it to generate the irregular signals.

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom

The AIB analysis was restricted to the CVR and the Shannon ATC tape. The correlation of the CVR and ATC tapes showed that the ATC recording started after the CVR had stopped recording and 1.1 ± 0.4 seconds from the start of the sudden sound. The total duration of the signal on the ATC tape was 5.4 seconds.

An analysis of the CVR audio found no significant very low frequency content which would be expected from the sound created by the detonation of a high explosive device. Evidence of the presence of audio warning signals buried amongst the noise was investigated with negative results. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR.

The analysis of the ATC tape audio determined three or four words could be heard at the beginning of the transmission, but extensive filtering did not allow the sounds to be transcribed. Two bursts of tone occurred during the first second. The spectrum of the tone does not coincide with any B747 audio warning. The transmission is chopped until at about 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5 seconds later by a sound which increases in volume. This sound is similar to that heard in other accidents where there has been a rapid increase in airspeed. Toward the end of the transmission a crying sound was heard; however, a study of the noise indicates a human cry would contain more harmonics. The origin of this sound was not determined. Knocking sounds were also heard during the transmission. These were initially thought to be due to hand-held microphone vibration, but this was discounted because of the frequency of the sounds. Almost identical sounds were heard on the DC-10 CVR after the explosive decompression had occurred. Their source was not identified. On the DC-10, the pressurization audio warning sounded 2.2 seconds after the decompression. No such warning was identified on the ATC tape.

*Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization. A loud noise is associated with this event but not necessarily an explosion.

Every aircraft provides a different signature when the press-to-transmit button is released. These signatures were compared with transients which occurred during the open microphone transmission. There is a close match with the previous AI 182 signatures. Therefore, it is almost certain that the ATC tape recording originated from AI 182.

The AIB report concluded that the analysis of the CVR and ATC recordings showed no evidence of a high-explosive device having been detonated on AI 182. It further states there is strong evidence to suggest a sudden explosive decompression of undetermined origin occurred. Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. However, the AIB report is of the opinion that the device would have to be small not to be detected as it is considered that a large high-explosive device could not fail to be detected on the CVR.

2.10.3 Analysis by Bhabha Atomic Research Centre (BARC), India

The BARC analysis was restricted to the CVR and the Shannon ATC tape.

Channel 3 of the recording which corresponded to the cockpit area microphone showed the first indication of a rising audio signal. The signal level rises from the ambient level in the cockpit by about 18.5 decibels in approximately 45 milliseconds. The signal starts falling and stabilizes at a level about 10 decibels higher than ambient for about 375 milliseconds. The total duration of the signal is about 460 milliseconds. The timings of the CVR and the Shannon ATC tape were correlated, and it was determined that the explosive sound on the CVR coincided with the beginning of the series of audio bursts on the ATC tape. The report concluded that the sounds recorded on the ATC tape emanated from AI 182 at the time of the occurrence.

The noise on the CVR was compared with an explosion which caused the crash of an Indian Airlines B737. In this occurrence, the explosive sound recorded on the cockpit area microphone showed a rise time of about 8 milliseconds. It was also determined that the explosion occurred 8 feet from the microphone. The report concluded that the rise time is a measure of the distance from the cockpit area microphone to the source of an explosion. Hence, the exact location in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the cockpit judging from the rise time of 45 milliseconds.

The report concluded that the series of audio bursts on the ATC tape were most probably generated by the break-up of AI 182 in mid-air.

2.11 Aircraft Structures Examination

The examination of aircraft structures consisted of the following areas: floating wreckage, wreckage mapping and surveying, wreckage distribution, photographic and video interpretation of wreckage, wreckage recovery and initial examination, and examination of recovered wreckage.

2.11.1 Floating Wreckage

During the search, aircraft wreckage was sited and recovered by several search vessels. The wreckage was transported to Cork, Ireland, where preliminary examination was conducted. This examination took place in June and July, 1985.

The wreckage consisted mainly of various leading edge skin panels of the left and right wings, left wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canoe fairing pieces, landing gear wheel well doors, pieces of elevator and aileron, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggage, suitcases, personal effects and a number of internal fittings. The floating wreckage constitutes about three to five percent of the aircraft structure.

The wreckage was then transported from Ireland to Bombay, India where it underwent further examination by the Floating Wreckage Structures Group which then produced a report which was submitted to the Indian Inquiry. The report concluded:

- There was no evidence of fire damage.
- There was no evidence of lightning strike damage.
- The cabin floor panels from the forward and rear sections of the aircraft separated from the support structure in an upward direction (floor to ceiling) pulling free from the attaching screws and, in some cases, breaking the vertical web of the seat track/floor beams.
- The position of the leading edge flap rotary actuator and the damage to the flap structure indicated that the leading edge flaps were in the retracted position.
- The six spoiler actuators found were in the retracted position. The lower surface of all the spoiler panels showed signs of spanwise skin splits with the edges curled into the core of the honeycomb. The report concluded that this was possibly due to the loading of the spoilers by being deployed in flight at high speed, resulting in compression on the lower surfaces. This, in turn, caused splitting of the lower skin into the honeycomb.
- The right wing root leading edge, number 3 engine inboard fan cowling, the right inboard midflap inboard leading edge, and the right stabilizer root leading edge all exhibited damage possibly due to objects striking the right wing and stabilizer before water impact.

In addition to the above conclusions, the following significant information regarding the floating wreckage is noted in the report:

- The aircraft was carrying a -7Q engine at the 5th pod and a -7J 5th pod kit in the aft cargo compartment. In all there were 14 engine fan cowls (four in the aft cargo compartment). Out of these 14 fan cowls, nine, including six from the working engines and three from the aft cargo compartment, and two additional pieces of fan cowls were found. Five of the fan cowls from the working engines showed folding damage lines at about the three and nine o'clock positions. The number 3 engine inboard fan cowl had severe impact damage on its leading edge and had small outward puncture holes but no penetration through the outer skin in the lower centre region. The two fan cowls of the -7J 5th pod kit stowed in the aft cargo compartment showed severe damage. One piece was cut at one corner in an arc of about 20 inches diameter and its external skin was peeled back.
- The cockpit entry door and the side bulkhead panel were found relatively intact but had come out of their attachments.
- Twelve toilet doors out of 16 were found and were relatively intact but had come out of their attachments.
- Cabin interior panels and overhead bins of the main and upper decks which were recovered exhibited only minor damage.
- The wooden boxes which contained the fan blades of the 5th pod engine were loaded in container 24L in the forward cargo compartment and were found broken apart exhibiting no burn marks.
- One passenger oxygen bottle and one portable oxygen bottle were recovered and showed no sign of damage.

Mr. V.J. Clancy, an aviation explosives expert representing Boeing Aircraft Corporation, prepared a preliminary report based on his examinations of certain items of recovered and floating wreckage. Mr. Clancy's report notes the following with respect to floating wreckage:

- A foam-backed floor panel which showed a small number of perforations was recovered. Mr. Clancy recommended that it should be X-rayed and a detailed examination completed.
- One of the lavatory doors had, into its inner surface, a number of

fragments of glass mirror - presumably from breakage of a mirror normally fitted into the lavatory. Most of the fragments, buried edgeways, were oriented parallel to each other. The remainder were approximately at right angles to the others. Mr. Clancy concluded that it would be improbable that any reliance could be placed on the penetration by mirror fragments as being indicative of an explosion.

- Three steel oxygen cylinders which were stowed in the forward cargo compartment were recovered. One had been dented apparently by the impact of an object measuring about one to two centimetres. The depression had a maximum depth of about four millimetres.
- A few suitcases recovered among the floating wreckage were examined. Mr. Clancy felt that one might provide useful information. It was of red plastic material with a blue lining. Mr. Clancy reported that plastic material has been found to retain identifiable traces of explosive after long immersion in the sea. Also, the lining which was severely tattered resembled that of one found after an explosion in an aircraft in Angola.
- A wooden spares box was found on the foreshore of Wales. It was of the kind used on the aircraft. It was charred on one side and partially on the bottom. The depth of charring suggested that the burn time was three to four minutes. This box was normally stowed in the aft cargo compartment; however, on this flight it may have been stowed in the forward compartment.
- Two pieces of the cover of an overhead locker originating above either door 2R or 4R were also found on the foreshore. They were partially damaged and blackened by fire. Mr. Clancy concluded that this indicated the presence of fire.
- Two pieces of U-section alloy channel partially filled with plastic foam were found on the foreshore. The alloy was of a kind not used in aircraft structure; however, it could have been from some fitting supplied by a sub-contractor. Also, since the pieces were found near an area where practice firings at targets are carried out off the west coast of the United Kingdom, it could have come from some other source. One piece of the alloy bore marks ("mooncraters") typical of an attack by

very high velocity fragments such as produced by an explosion. X-rays showed the presence of a few small particles buried in the foam which Mr. Clancy recommended should be extracted and examined. He also felt that this provided the strongest single indication of an explosion and that it was essential to determine if these pieces came from the aircraft or any of the equipment or cargo aboard the aircraft.

The CASB in its examination of the floating wreckage noted the following:

- The fan cowls of the number 4 engine had a series of five marks in a vertical line across the centre of the Air India logo on the inboard facing side of the fan cowl. These marks had the characteristic airfoil shape of a turbine blade tip. It is possible that a portion of the turbine parted from the number 3 engine and struck the cowl of the number 4 engine.
- The upper deck storage cabinet which was located on the left side had unusual damage to its bottom. A large rounded dent in the bottom inboard edge of this stiff cabinet structure revealed smooth stretching without breakthrough. The damage did not seem to be achievable by inertia or impact forces as the cabinet except for the bottom was undamaged. The damage was considered by a CASB investigator to be compatible with the spherical front of an explosive shock wave generated below the cabin floor and inboard from the cabinet; however, it is not known if this damage could be caused by some other means.
- The right wing root fillet which faired the leading edge of the wing to the fuselage ahead of the front spar had a vertical dent similar to that which would have resulted had the fillet run into a soft cylindrical object with significant relative velocity. The paint on the inboard chord appeared to be scorched brown in the centre areas of three honeycomb panels. It has been determined that sudden heat can turn these panels brown, but it is not known if other reasons for the discolouration exist. The fillet abutted the fuselage side at the aft end of the forward cargo compartment.
- There was blackened erosion damage to the bottoms of some seat cushions. The damage had an appearance similar to that which would have been caused by an explosive device. It is not known if marine life

feeding on the cushions or some other cause could have produced the same effect.

- The charred wooden spares box contained some sand and small shellfish. The flesh from the shellfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

An electronic device was found among some floating wreckage and was forwarded to the Bhabha Atomic Research Centre for analysis. There was some concern that it could have been used to detonate an explosive device. The device was forwarded to the RCMP who in conjunction with the CASB determined it to be an item manufactured for use in radiosondes (weather balloons) and was not modified as a detonating device.

2.11.2 Wreckage Mapping and Surveying

The Canadian Coast Guard Ship (CCGS) John Cabot was given the task of mapping the wreckage on the ocean floor. On 19 July 1985, the Cabot with a SCARAB deep submersible on board departed Cork. On arrival at the site, and based on surface wreckage distribution and bottom side scan sonar plots, four transmitters were placed on the sea bed. These transmitters provided signals for the ALLNAV navigation system used to accurately plot the sea bed wreckage.

Based on all the data available, the SCARAB was launched on 24 July 1985 to begin the bottom search in position 51°01.9'N 12°41.0'W. During the mapping, stage areas were designated for search and each progressive area was determined based on the information gained during the search. The search was conducted using sonar and video. Wreckage found was recorded on video tape and on 35mm positive film.

The first object plotted on the sea bed was a torn suitcase located at lat 51°02.63'N, long 12°53.15'W and was the most westerly object located. This suitcase has not been recovered, nor has it been positively identified as having come from the accident aircraft.

As the search progressed eastward, the first positive identification of aircraft wreckage was made at lat 51°02.9'N, long 12°49.93'W. Slowly, over a period of about 90 days, a detailed bottom wreckage plot was developed.

While mapping was in progress, some of the wreckage was revisited to obtain additional data. During the transit through areas already searched, wreckage not previously plotted was found, and, in some areas, the density of wreckage physically precluded 100 per cent coverage. Components and major structural items were identified from all sections of the aircraft and when the mapping of the sea bed ended, most of the aircraft had been found and photographed. Although positive identification of each piece of wreckage could not be made, it was decided in late October 1985 that the search phase was essentially completed and wreckage recovery could begin. A bottom wreckage distribution plot is contained separately in an envelope as Appendix F.

2.11.3 Wreckage Distribution

The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling on the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled.

Although badly damaged, sections 41, 42 and 44*, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been plotted or photographed.

Sections 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the westernmost identified aircraft component located at lat 51°02.90'N and long 12°50.1'W. The wreckage extended in a line about 110 degrees True to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern.

A?? third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southeast orientation. One of the operating engines was displaced 0.5 nautical miles to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

*See Appendix D for location of aircraft sections and aircraft body stations (BS).

2.11.4 Photographic and Video Interpretation of Wreckage

2.11.4.1 Photographic Interpretation

All wreckage sighted was recorded on video tape and all major items were recorded on 35mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage patterns. For example, the sine wave bending of target 7* appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into account.

2.11.4.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

2.11.4.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gear were in the 'up' position at the time of impact.

2.11.4.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

*See Appendix E for location of targets on aircraft.

2.11.4.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

2.11.4.6 Section 42

Portions of section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers.

All cargo doors were found intact and attached to the fuselage structure except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different than that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back onto the sea bed. An attempt to relocate the door was unsuccessful.

2.11.4.7 Section 44

Section 44, containing the aircraft structure between body station (BS) 1000 and BS 1480 including that area where the fuselage and wings were mated was located in the same general area as the forward sections of the aircraft. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one-third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gear were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

2.11.4.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northernmost area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

2.11.4.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of BS 1480 and, for purposes of this Submission, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

The aft cargo and bulk cargo doors were found in place and intact, and

5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were identified (targets 35, 37, 73 and 296), and one portion of the bulkhead was never located. Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognizable as having come from a specific area of the aircraft.

Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from BS 1600 to BS 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

The tail cone and the auxiliary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure of air or water.

The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabilizer was missing and the auxiliary spar was exposed. There was localized damage to the right-hand root of the leading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

2.11.4.10 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from sections 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42, and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat-belts were not fastened.

2.11.5 Wreckage Recovery and Initial Examination

During the wreckage mapping, some small items were recovered, and an unsuccessful attempt was made to recover a portion of the forward cargo door. On completion of the sea bed survey, an offshore supply ship, Kreuztrum, chartered by the National Transportation Safety Board (NTSB), joined John Cabot for a wreckage recovery operation. Prior to the commencement of the wreckage recovery, the structures group met at the Boeing facility in Seattle, USA and reviewed the video tapes and photographs of the wreckage. Based on their findings, a list of items was identified as being most desirable for recovery. The priority list was prepared by a group in Cork, Ireland, headed by Dr. V. Ramachandran. On 8 October 1985, the John Cabot sailed, and on 9 October 1985, the Kreuztrum sailed for the accident site. The following target numbers and items were recovered during the mapping and wreckage recovery stages of the investigation: 7, 8, 35, 47, 117, 193, 223, 245, 287, 296, 299, 362/396, and 399 (as the location on the aircraft of some of the targets was not known when Appendix E was created, some are not shown in the appendix). The first officer's seat, some suitcases and small debris were also recovered using a metal frame basket. Initial examination of the wreckage was carried out in Cork and then it was transported to Bombay for detailed examination.

2.11.6 Examination of Recovered Wreckage

Although all the recovered wreckage was examined, only those items exhibiting characteristics which provided some evidence as to what may have happened to the aircraft during its final moments of flight are discussed. CASB engineering personnel and other participants examined the recovered wreckage at Cork and Bombay. The observations made during their examinations are discussed below.

2.11.6.1 Target 7 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from BS 1480 to 1860 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear, and the torn edge was buckled in waves, like the trace of a sine wave. On the right side, between the one-quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at BS 1480. The skin tear located at about BS 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distorted and elongated.

The left and right trunnion vertical support fittings located at BS 1480 were examined optically using the stereomicroscope. Both trunnions were fractured through the three bolt holes. The right fracture characteristics were consistent with an overload mode of failure. Although most of the left fracture surface was also characterized by overload features, there were heavily corroded areas where the fracture mode could not be confirmed through optical examination. One lug fracture was sectioned from the left trunnion and prepared for scanning electron microscope (SEM) examination. After the corroded area was cleaned, the examination revealed some ductile characteristics on the fracture surface. There was no evidence of intergranular fracture observed to suggest a stress corrosion cracking mode of failure, nor was there any evidence of progressive failure observed. The corrosion appeared to have developed after the accident.

2.11.6.2 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from BS 1860 to 1960 and from stringer 46L to 46R. A small section from the aft end along the belly skin splice at stringer 46L was removed for examination. SEM examination revealed that the fracture was characterized by slightly elongated ductile dimples along its length, including areas adjacent to the edges of the rivet holes. On the aft edge of each rivet hole examined, a distinctive shear lip was observed. These features are consistent with an overload mode of failure along the skin splice with an apparent direction of failure from aft to forward.

2.11.6.3 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 o'clock position. The piece from 12 to 1 o'clock had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 o'clock position, the outer edge showed sinusoidal buckling, and the edge sector at 9 o'clock was partially collapsed and its edge was turned under. Samples taken for optical stereomicroscope and SEM examination revealed that the fracture characteristics were consistent with an overload mode of failure. The examination suggested a general direction of failure from the aft to the forward edge of the rear pressure bulkhead panel.

2.11.6.4 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occupied the 7 to 9 o'clock position. Optical and SEM examination were undertaken on this item.

The fracture along the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation. Representative fracture samples were cut from the left-hand and right-hand edges of the fracture surfaces. Optical and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

2.11.6.5 Target 47 - Aft Cargo Compartment

This portion of the aft cargo compartment roller floor was located between BS 1600 and BS 1760. Based on the direction of cleat rotation on the skin panel (target 7) and the crossbeam displacement on this structure, target 47 moved aft in relation to the lower skin panel when it was detached from the lower skin. No other significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

2.11.6.6 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between BS 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

2.11.6.7 Target 399 - Left-Hand Side Triple Seat with Tray Arms

It would appear that this section was from row 18, seats A, B and C, the first set of triple seats aft of door 2L. The notable damage to this unit was as follows: front leg aisle side buckled and crushed in place; front leg window side buckled and crushed in place; forward edge tube to seat broken and bent downwards at joint with fore and aft tube between window and centre seats; and fore and aft tube between centre and aisle seat broken at start of T-connection to rear edge of seat tube. The damage suggests that the failures resulted from vertical loading. All the life-jackets were in place.

2.11.6.8 Target 399 - Fuselage Side and 2R Entry Door

The fuselage segment was located between BS 780 and 940. This piece was badly damaged and buckled inwards along a line through the lower door hinge. There were 12 holes or damaged areas on the skin generally with petals bending outwards. The curl on a flap around a hole had one full turn. This curl was in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal. When this target was recovered from the sea, along with it came a few hundred tiny fragments and medium-sized pieces. One of the medium-sized pieces recovered with this target was a floor stantion about 35 inches long. It was confirmed that this stantion belonged to the right side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the curl being in the outboard direction and up into the centre of the stantion.

Scientists from the Bhabha Atomic Research Centre, the National Aeronautical Laboratory and the Explosives Research and Development Laboratory in India conducted a metallurgical examination of certain items of wreckage. Their report on target 399 concluded that:

- the curling of the metal on the floor channel was indicative of a shock wave effect;
- the large number of tiny fragments from the disintegration of nonbrittle aluminum was a characteristic indication of explosive forces; and
- the indications of punctures, outward petalling around holes, curling of metal lips, reverse slant fracture, formation of spikes at fracture edges and certain microstructural changes all were indicative of an explosion.

2.11.6.9 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segment was located between BS 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

2.11.6.10 Target 362/396 - Lower Skin Panel - Forward Cargo Area

This section of skin panel was located between BS 720 and 860 and is just below target 399. The skin was badly crumpled and torn and had several punctures. It was pulled free from a large mass of debris which included some mangled cargo floor beams and roller trays. Some of the punctures had a feathered or spiked profile, with spikes angled at approximately 45 degrees to the edge. Other puncture holes gave clear indication of being formed by underlying stiffeners at impact. Two of these holes contained pieces of web stiffener. Most of the punctures were the result of penetrations from inside.

In the preliminary report of Mr. V.J. Clancy, representing Boeing, the following observations regarding target 362/396 were made:

- There were about 20 holes in the lower skin panel clearly resulting from penetration from inside.
- In addition to the fact that perforation was from inside, there were certain features which suggested that they were made by high velocity fragments such as those produced by an explosion. Mr. Clancy's report describes these features as follows:

- the presence of toothed or spiked edges at some parts of the metal which has petalled out from the perforations;

(Tardif and Sterling, Canadian Aeronautics and Space Journal, 1969, 15, 1, 19-27, obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.)

- the presence of marked curling (in some cases of more than 360 degrees) of some of the petals;

(Tardif and Sterling stated that such curling was a feature of explosively produced fragments.)

- the virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal;
- the virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object, thereby suggesting that the production of at least many of the perforations were separate independent events; and
- the presence of one perforation (identified as number 14) resembling a "bullet hole" that was clearly punched out - a type of hole

usually associated with a high velocity missile.
- There was evidence that the forward part of the skin panel had been folded back inward along the line of station 760 and then bent back again along a line slightly forward of this station.
- Such folding, perhaps violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces, thus producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.
- One hole (identified as number 13) was almost certainly caused by a slipping wire rope used as a sling.
- Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken of this area for further examination for evidence of fire or explosives.
- A large number (several hundred) of small fragments were recovered. These varied in size from an inch or less to a few inches. They included fragments broken out of sheet metal, and these were reported to be from the same area as T362.
- The production of a large number of small fragments is generally regarded as an indication of an explosion.
- One piece, which was isolated, was about an inch square of sheet alloy with characteristic spikes on one edge similar to those described by Tardif and Sterling.

The following is an excerpt from the report by Mr. V.J. Clancy wherein he gives his opinion and conclusions regarding target 362.

"Opinion

The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

A more detailed study, metallurgical and fractographic, is required.
The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.
The single "bullet hole," No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.
If the forward part of this item was forcefully and rapidly folded back to impact on the other part, it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility.
The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.
The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."
Mr. Clancy concluded that:
"there is strong circumstantial evidence that an explosion occurred but neither individually nor collectively do the several pointers give the degree of confidence necessary for a firm and final conclusion, at this time."
With respect to target 362/396, in his report Mr. Clancy recommended:
"that firing trials be carried out projecting various size missiles at targets similar to the material of T362 to obtain reference samples for laboratory comparison with the perforations in T362."
The Indian report, in addition to the observations made by Mr. Clancy, noted the following with respect to the metallurgical examination:
- The microstructure in the various areas examined on target 362/396 confirmed explosive loading in this part of the aircraft.

- The holes and other features observed in targets 362/396 and 399 must have been due to shock waves and penetration by fragments resulting from an explosion inside the forward cargo hold.
- The chemical nature of the explosive material was not identified. No part of an explosive device, its detonator or timing mechanism was recovered.

2.11.6.11 Examination of Wreckage in India with CASB Participation

The examination of the targets recovered did not reveal any pre-existing defect, premature cracking or pre-impact corrosion damage associated with any of the failures.

3.0 DISCUSSION

3.1 Initial Event

From the correlation of the recordings of the DFDR, CVR and Shannon ATC tape, the unusual sounds heard on the ATC tape started shortly after the flight recorders stopped recording. The conversations in the cockpit were normal, and there was no indication of an emergency situation prior to the loud noise heard on the CVR a fraction of a second before it stopped recording. The DFDR showed no abnormal variations in parameters recorded before it stopped functioning. The only unusual observation was the irregular signals recorded over the last 0.27 inches of the DFDR tape. Laboratory tests indicated the possibility that these signals resulted from the recorder being subjected to a sharp disturbance at the time it stopped recording. The other possibility for the irregular signals on the DFDR is that they were caused by a disturbance to the Flight Data Acquisition Unit in the main electronics bay. Since there was an almost simultaneous loss of the transponder signal, this indicates the possibility of an abrupt aircraft electrical failure. The medical evidence showed a general absence of signs indicating that seat-belts were fastened. From the video and photographic examination of the wreckage on the bottom, it was ascertained that the majority of seats located did not have the seat-belts fastened. The above evidence indicates that the initial occurrence was sudden and without warning. The abrupt cessation of the data recorder could be caused by airframe structural failure or the detonation of an explosive device as the initial event. The millisecond noise on a CVR as observed in this case is usually, as described in the available literature, the result of the shock wave from detonation of an explosive device. However, in this case, certain characteristics of the noise indicate the possibility that the noise was the result of an explosive decompression. There is some disagreement regarding the cause and location of the source of the noise heard on the CVR, that is, whether the noise resulted from an explosive device or an explosive decompression and whether the noise originated from the rear or closer to the front of the aircraft.

3.2 Passenger/Flight Deck Area

From the examination of the wreckage recovered and wreckage on the bottom, there is no indication that a fire or explosion emanated from the cabin or flight deck areas. The medical examination of the bodies also showed no fire or explosion type injuries. However, pieces of an overhead locker coming from above door 2R or 4R had been blackened by fire. There was blackened erosion damage to the bottoms of some seat cushions, showing damage possibly from an explosive device, and the upper deck storage cabinet had a large rounded dent in the bottom inboard edge which might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet. It should be noted that the pieces of the overhead locker were found on the Welsh shore some time after the accident, and it is not known if the pieces were subjected to a fire after the accident. Also, it is not known if the damage to the seat cushions and the upper deck storage cabinet could have been caused by other means. Nevertheless, the above evidence suggests that some areas of the passenger cabin may have been subjected to minor fire and explosive damage possibly emanating from below the cabin floor.

3.3 Aircraft Break-up Sequence

The medical evidence showed a proportion of the passengers with indications of hypoxia, decompression, flail injuries and loss of clothing. The incidence of hypoxia and decompression indicates that the aircraft experienced a decompression at a high altitude. The flail injuries and loss of clothing indicate a proportion of the passengers were ejected from the aircraft before water impact. The severity of injuries increased from Zones C to E and was significantly less in Zone C than in Zones D and E.

The wreckage of the forward portion of the aircraft up to and including the aircraft body wheel well area and the wings was lying about 0.8 miles north of the vertical and horizontal stabilizers. Hence, it is likely that the aft portion of the aircraft separated from the forward portion before striking the water. In addition, the wreckage found west of longitude 12°48' consisted of suitcases and aft cargo compartment lower skin panels. There was also a wide scatter of sections 46 and 48 in an east-west direction, whereas the wreckage of the forward portion was mainly localized within a relatively small area.

The higher severity of injuries in the aft end of the passenger cabin appears to coincide with the break-up of the aft end, sections 46 and 48 of the aircraft. The fact that items from the aft cargo compartment were found further west than the tail section indicates that the aft cargo compartment ruptured first during the break-up sequence of the aft end. The forward portion of the aircraft was highly localized, which indicates that it struck the water in one large mass.

3.4 Aircraft Structural Integrity

As described earlier, the sudden nature of the occurrence indicates the possibility of a massive airframe structural failure or the detonation of an explosive device.

3.4.1 Aircraft Break-up

The examination of the floating wreckage indicates that the right wing root leading edge, the number 3 engine inboard fan cowling, the right inboard midflap leading edge, and the right horizontal stabilizer root leading edge all exhibit damage consistent with objects striking the right wing and stabilizer before water impact. In addition, the right wing root interior area appears to have been scorched briefly by a heat source. The fan cowls of the number 4 engine show evidence of being struck by a portion of the turbine from number 3 engine.

The number 3 engine nacelle strut was separated from the rest of the engine components and was located about one nautical mile to the west indicating that there was some break-up of the number 3 engine before water impact.

The forward cargo door which had some fuselage and cargo floor attached was located on the sea bed. The door was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force and the fracture surfaces of the door appeared to be badly frayed. This damage was different from that seen on other wreckage pieces. A failure of this door in flight would explain the impact damage to the right wing areas. The door failing as an initial event would cause an explosive decompression leading to a downward force on the cabin floor as a result of the difference in pressure between the upper and lower portions of the aircraft. However, examination showed that the cabin floor panels separated from the support structure in an upward direction. Also, passenger seats viewed and recovered exhibited that they had been subjected to an upward force from below. They showed that the seats to the rear in sections 46 and 48 had their back legs buckled, and the seats toward the front had both front and back legs buckled. This indicates the vertical force was greater at the front than the rear of the aircraft. It is possible that this vertical force on the floor was caused by the force of the water during impact, but the rear of the aircraft broke up before impact and therefore any vertical loading on the floor in this area is unlikely to have occurred at impact. Twenty-three passengers also showed evidence of vertical impact injuries. These could have been caused from a force from below during flight or at water impact. Sixteen of these passengers had little or no clothing indicating that some may have been ejected before water impact. Therefore, there is some indication that the upward force on the floor may have occurred in flight and was more severe toward the front.

3.4.2 Aft Pressure Bulkhead

The localized impact mark found on the leading edge of the right horizontal root leading edge is indicative of an object striking the stabilizer in flight before water impact. This suggests that the loss of the tail plane was not the first event. The horizontal and vertical stabilizers were found separated and each was intact and in good condition. Items from the aft cargo compartment were found further to the west of the tail plane. The absence of the type of damage to the tail plane as was found in the Japan Airlines (JAL) Boeing 747 accident where the aft pressure bulkhead failed and which took place shortly after this occurrence, and the rupture of the aft cargo compartment before the loss of the tail indicate that there was not an in-flight failure of the aft pressure bulkhead. In addition, examination of the recovered portions of the bulkhead shows evidence of overload failures from the rear to front only and no evidence of any pre-existing defect, premature cracking or pre-impact corrosion damage.

3.4.3 Target 7 - Lower Fuselage Skin Panel

Target 7 which extends from BS 1480 to 1860 shows a break at the joint at BS 1480. The forward keel joint splice plate is bent and the keel joint holes are distorted and elongated. Some of the fracture surface was heavily corroded. An in-flight failure in this area would cause a massive failure of the aircraft's structural integrity. Further examination showed the fractures to be overload, and there was no evidence of an intergranular type fracture to suggest a stress corrosion cracking mode of failure. The corrosion was concluded to be post-impact and, therefore, there is no evidence to suggest an in-flight failure in this area as the initial event.

3.4.4 Structural Failure

The examination of the floating and recovered wreckage and the analysis of the photos and videos of the wreckage on the bottom failed to indicate any evidence of a failure of the primary or secondary structure as a result of a pre-existing defect. The initial event has been established as sudden and without warning. The abrupt cessation of the flight recorders indicates the possibility of a massive and sudden failure of primary structure; however, there is evidence to suggest that there were ruptures in the forward and aft cargo compartments prior to any failure of the primary structure in flight. Therefore, available evidence tends to rule out a massive structural failure as the initial event.

3.4.5 Explosive Device

A violent explosion occurring within an aircraft in flight usually leads to a complicated break-up mode and sequence of failure. Fractures of metal caused by an explosion are normally different in character to those caused by overstressing or crash impact forces. Shattering of metal into very small and numerous fragments and minute deep penetration of a metal surface are not usually found in aircraft accident wreckage. The size and characteristics of these particles often accompanied by rolled edges, surface spalling, pitting or evidence of heat are indicative of an explosion.

Of the floating wreckage, there is little to indicate the possibility of an explosion:

- the lining in one suitcase was severely tattered;
- although the wooden spares box was burned, this could have happened after the occurrence;
- although pieces of an overhead locker were damaged by fire, it is not known if the burning happened at the time of the occurrence;
- although the pieces of U-section alloy clearly indicated evidence of an explosion, it is quite possible that these pieces were not associated with the aircraft;
- the bottoms of some seat cushions show indications of a possible explosion;
- the inside of the right wing root fillet appears to have been scorched; and
- the deformation of the floor of the upper deck storage cabinet might have been caused by an explosive shock wave generated below the cabin floor and inboard from the cabinet.

It is not known if the suitcase came from the aft or forward cargo compartment, and the location of the seats from which the cushions came is also unknown.

The scorching of the right wing root fillet and the damage to the upper deck cabinet suggest, if there was an explosion, it emanated from the forward cargo compartment.

From the examination of the recovered wreckage, the following deductions can be made:

- Target 47, which is a portion of the aft cargo compartment roller floor, shows no indications characteristic of an explosion emanating from the aft cargo compartment.
- Target 362/396, which is a lower skin panel from the forward cargo compartment is badly crumpled and torn and has about 20 punctures resulting from penetration from inside. It appears that some folding occurred on water impact which brought stringers or stiffeners from the aircraft structure into forceful contact with the internal surface of the panel producing most of the penetrations. However, there are certain punctures which indicate no evidence of impact marks on the inside surface and show evidence of being produced by high velocity fragments. Part of the inner surface of the skin panel appeared to have been blackened by soot from a fire.
- Target 399, consisting of a piece of the skin and stringers on the right side in the area of the forward cargo compartment contained holes and several hundred metal fragments. The damage to the floor stantion and the presence of the fragments are consistent with an explosion.

The examination of the recovered wreckage contains no evidence of an explosion except for targets 362/396 and 399 which contain some evidence that an explosion emanated from the forward cargo compartment.

An explosion in the forward cargo compartment would explain the loss of the DFDR, CVR and transponder signal as the electronics bay is immediately ahead of the cargo compartment.

3.5 Security Aspects

There is a considerable amount of circumstantial and other evidence that an explosive device caused the occurrence. Therefore, it is reasonable to examine the security measures in place on 22 June 1985. The evidence indicates that if there was an explosion, it most likely occurred in the forward cargo hold, not the passenger and flight deck areas or exterior to the fuselage. Although an explosive device could have been placed in a cargo hold in a number of ways, the available evidence points to the events involving the checked baggage of M. and L. Singh in Vancouver. The investigation determined that a suitcase was interlined unaccompanied from Vancouver via CP Air Flight 060 to Toronto. In Toronto, there is nothing to suggest that the suitcase was not transferred to Terminal 2 and placed on board Air India Flight 181/182 in accordance with normal practice. The aircraft departed Toronto for Mirabel and London with the suitcase unaccompanied. Similarly, a suitcase was interlined unaccompanied on CP Air Flight 003 from Vancouver to Tokyo to be placed on Air India Flight 301 to Bangkok. The explosion of a bag from CP 003 at Narita Airport, Tokyo, took place 55 minutes before the AI 182 accident. Therefore, the nature of the link between the two occurrences raises the possibility that the suitcase which was unaccompanied on AI 182 contained an explosive device.

3.5.1 Canadian Security Situation

Canadian security arrangements in place prior to 23 June 1985 met or exceeded the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand luggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

In Canada, the Department of Transport (Transport Canada) is responsible for establishing overall security standards for airports and airlines, and for the provision of certain security equipment and facilities at airports. By regulation, air carriers are responsible for applying security standards for passengers, for baggage and cargo and for ensuring security within individual aircraft. The RCMP provides airport physical security and responds to criminal incidents.

Air carriers contract for or otherwise provide the personnel who operate the security check-points through which passengers and their carry-on baggage enter the secure area of the airport terminal. These personnel also operate security equipment for the screening of cargo, passengers and checked baggage. Usually, air carriers use the service of private security firms. Transport Canada has established certain standards required for licensed security guards, such as the successful completion of the Transport Canada passenger inspection training program and annual refresher training. As stated earlier, a significant number of the security guards did not meet the criteria with respect to the completion of the training program and refresher training. In addition, the criteria do not require training for the screening of cargo and checked baggage.

ICAO Annex 17 recommends that contracting States establish the necessary procedures to prevent the unauthorized introduction of explosives or incendiary devices in baggage or cargo intended to be carried on board aircraft. For all Canadian airlines, Canadian regulations before 23 June 1985 required a system of identification that prevented baggage, goods and cargo from being placed on board an aircraft if it was not authorized to be placed on board by the airline operator. However, if someone were to purchase a ticket, check in baggage and not board the aircraft, the baggage would in all likelihood have been authorized by the airline to be placed on board the aircraft. Therefore, it was possible to interline baggage unaccompanied and this explains how a suitcase was interlined to AI 181/182 from CP 060. It is not the normal practice of airlines to interline baggage if there is not a confirmed reservation to the destination. In this case, the ticket agent allowed the suitcase to proceed; however, if there had been a confirmed reservation, the suitcase would have been interlined unaccompanied without question.

3.5.2 Air India Security

Air India, as required by Canadian regulation, had a security program. Because of the threat level assessed against the airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and received extra security from Transport Canada and the RCMP for the month of June 1985. For Air India Flight 181/182, Air India provided a security officer from its New York office to oversee the security arrangements at Toronto and Mirabel. The security program at each airport was under the overall supervision of the respective Air India station managers. In Toronto, it was not clear who, if anyone, was undertaking this function.

It is not known if the suitcase interlined from CP 060 was screened before or after the X-ray machine broke down in Toronto. Although baggage not examined by X-ray was screened by a PD-4 sniffer, there are indications that the sniffer could have been ineffective in detecting explosives, especially plastics. Rather than using the sniffer, it would have been more effective to open all bags and physically inspect them. Even though a number of security personnel were not adequately trained in the screening of passengers and baggage, it is not known whether more training would have prevented an explosive device from being placed on board.

Although airline procedures required baggage to be accompanied, the agents checking in passengers in Toronto used a passenger security numbering system but did not number checked-in baggage, and baggage was not correlated with passengers. Therefore, the interlined unaccompanied suitcase from CP 060 was not detected. At Mirabel, checked-in passengers and baggage were numbered so that the number of passengers checking in baggage could be correlated with the number of passengers boarding the aircraft. Had a passenger-baggage correlation been carried out in Toronto, the suitcase from CP 060 would have been detected. The airline procedures would have prevented the placement of the suitcase on the aircraft.

Once loaded on the aircraft, the suitcase would have been placed in container 11L and 12L (see Appendix B) if in the forward cargo compartment, in container 44L or 44R if in the aft cargo compartment, or in position 52 if in the bulk cargo compartment. It could not be determined in which cargo compartment the suitcase was loaded. Therefore, although the procedures were in place to prevent an explosive device from being placed on board the aircraft in checked-in baggage, there was a breakdown in the X-ray machine used to screen baggage, and there are indications that the PD-4 sniffer was inadequate. Also, the security numbering system used in Toronto was ineffective in preventing unaccompanied interlined baggage from being placed on board the aircraft.

4.0 CONCLUSIONS

The Canadian Aviation Safety Board respectfully submits as follows:

4.1 Cause-Related Findings

1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.

2. The forward and aft cargo compartments ruptured before water impact.

3. The section aft of the wings of the aircraft separated from the forward portion before water impact.

4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.

5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion.

4.2 Other Findings

Even though they may not be causal or related to the accident, the following additional conclusions can be drawn from the investigation with respect to certain security arrangements and their application pertaining to this flight:

1. In compliance with the International Civil Aviation Organization Annex 17 to the Convention on International Civil Aviation, the Department of Transport of Canada has made regulations requiring foreign aircraft operators who land in Canada to establish, maintain, and carry out certain security measures at airports.

2. In accordance with these regulations, Air India submitted a security program to the Minister of Transport which included security measures with respect to aircraft, cargo, baggage, and passengers.

3. On 22 June 1985, an unaccompanied suitcase was interlined from Vancouver to Toronto on CAP Flight 060 for transfer in Toronto to Air India Flight 181/182.

4. The baggage loaded in Toronto was screened through an X-ray machine process but, during the course of this procedure, the X-ray machine broke down.

5. After the X-ray machine breakdown, an explosives detector was

used to screen the baggage; the baggage was not opened and physically examined.

6. The effectiveness of the explosives detector is in doubt.

7. It is not known whether the unaccompanied suitcase interlined from Vancouver was screened before or after the X-ray machine broke down.

8. The security numbering system used in Toronto did not prevent unaccompanied interlined baggage from being placed on board the aircraft.

9. The normal procedures for interlining baggage in Toronto indicate that the unaccompanied suitcase was loaded on Air India Flight 181/182.

Appendix A

PAGE

REPORT OF THE COURT INVESTIGATING ACCIDENT TO AIR INDIA BOEING 747 AIRCRAFT VT-EFO, "KANISHKA" ON 23RD JUNE 1985

HON'BLE MR. JUSTICE B. N. KIRPAL JUDGE, HIGH COURT OF DELHI

ASSESSORS

DR. V. RAMACHANDRAN MR. J. S. GHARIA

CAPT. J. S. DHILLON MR. J. K. MEHRA

CAPT. B. K. BHASIN

SECRETARY

MR. S. N. SHARMA

FEBRUARY 26, 1986

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Cockpit Voice Recorder Tape Transcript

INTRODUCTION

1.1.1 On the morning of 23rd June, 1985 Air India's Boeing 747 aircraft VT-EFO (Kanishka) was on a scheduled passager flight (AI-182) from Montreal and was proceeding to London enroute to Delhi and Bombay. It was being monitored at Shannon on the Radar Scope. At about 0714 GMT it suddenly disappeared from the Radar Scope and the aircraft, which has been flying at an altitude of approximately 31,000 feet, plunged into the Atlantic Ocean off the south-west coast of Ireland at position latitude 51° 3.6'N and Longitude 12° 49'W. This was one of the worst air disasters wherein all the 307 passengers plus 22 crew members perished.

1.1.2 The fact that emergency had arisen was first noticed by Shannon Upper Area Control (UAC) after the aircraft had disappeared from the Radar Scope. The control gave a number of calls to the aircraft but there was obviously no response. Thereafter various messages were transmitted and that is how the rest of the world came to know of the accident.

1.1.3 Shannon Control at 0730 hours advised the Marine Rescue Coordination Centre (MRCC) about the situation which appeared to have arisen. MRCC, in turn, explained the situation to Valencia Coast Station and requested for a Pan Broadcast. Thereafter ships started converging on the scene of the accident and they commenced search and rescue operations.

1.1.4 The aircraft in question - Kanishka, was named after the most powerful and famous king of the Kushanas who perhaps ruled in India from AD 78 to AD 103. Besides being a great conqueror, he was an ardent supporter and follower of Budhism - a religion which preaches non-violence. Emperor Kanishka, however, met a violent end. After 25 years of reign he was killed by some of his own subjects. His life was thus brought to an abrupt end.

1.1.5 It is indeed ironical that the Jumbo Jet which bore the name 'Kanishka' also met with a violent and a sudden end on that fateful morning of 23rd June, 1985.

INITIAL ACTION TAKEN BY THE GOVERNMENT OF INDIA

1.2.1 Initial intimation of the accident was received by Air India who, in turn, communicated the same to Mr. H.S. Khola, Director of Air Safety, Civil Aviation Department, New Delhi. The Accident Investigation Branch of United Kingdom also sent information to the Director General of Civil Aviation, New Delhi to the effect that the accident had taken place on international waters and as such it was India which was the authority to investigate the accident in accordance with the provisions of ICAO Annex 13.

1.2.2 Thereupon Order No. AV.15013/8/85-AS dated 23rd June, 1985 was issued by the Director General of Civil Aviation whereby Mr. H.S.Khola was appointed Inspector of Accidents for the purpose of carrying out the investigation into the aforesaid air accident. This appointment was made under Rule 71 of the Aircraft Rules, 1937.

1.2.3 While search and rescue operations were underway at the site of the accident, a team of officials headed by Dr.S.S. Sidhu, Secretary, Ministry of Tourism & Civil Aviation rushed from India to Cork. The said team was joined by Mr. Kiran Doshi, the Indian Ambassador to Ireland, and also by two officers of the Indian Navy who were attached to the Indian High Commission at London. Subsequently two Medical Experts from India also joined the said Team.

1.2.4 The Indian Team arrived at Cork, Ireland on 24th June, 1985. Representatives of the Governments of United States of America, Canada and United Kingdom also reached there that day. They were met by the representatives of the Government of Ireland.

1.2.5 The members of the Team saw the rescue and salvage operations being conducted. They also visited the Cork Regional Hospital and had discussions with Irish and other Authorities with a view to release the bodies of the victims which were being brought to Cork.

1.2.6 For facilitating the process of investigation the Inspector of Accidents after consulting the representatives of the aforesaid Governments formed the following groups:

a. Structures, Power Plant and Systems Group.

b. Operations Weather & ATS Group.

c. Medical and Human Factor Group.
d. Search & Rescue Group.

The aforesaid groups were required to collect evidence and to submit their respective reports to the Inspector of Accidents.

1.2.7 The bodies which were being recovered were brought to the Cork Regional Hospital for identification and post-mortem. At that time it was considered proper that apart from the two medical experts from India, Wing Commandor Dr.I.R. Hill, who is an expert in aviation pathology should also be called from United Kingdom.

1.2.8 It was also being speculated that the accident may have occurred due to an explosion on board the aircraft. In order to see whether there was any evidence of an explosion which could be gathered from the floating wreckage which was being salvaged, the Government of India requisitioned the services of Mr. Eric Newton, a Specialist in the detection of explosives sabotage in aircraft wreckage.

1.2.9 In order to coordinate and guide the operations of the various ships working at the crash site, a control centre was set up at Cork Airport on 30th June, 1985.

1.2.10 The control centre was manned by representatives of the Governments of Ireland, Canada and United States. The Indian Naval Officers from the High Commission at London were overall in-charge of this centre. After the flight recorders had been recovered the centre continued to function, but the representatives of the United States departed.

1.2.11 For retrieving the Cockpit Voice Recorder (CVR) and Digital Flight Data Recorder (DFDR), a cable ship named Leon Thevenin was engaged which had on board Submersible Robot (Scarab) which was fitted with a Sonar receiver and TV Cameras. The aforesaid ship was engaged and after an intensive search CVR and the DFDR (more popularly known as 'the black boxes') were located and retrieved on 10th July and 11th July, 1985 respectively.

1.2.12 The Government of India, in exercise of the powers conferred by Rule 75 of the Aircraft Rules, 1937 vide Notification No. AV. 15013/10/85-A, dated 13th July, 1985, directed that a formal investigation of the accident be carried out. Mr Justice B.N. Kirpal, Judge of the Delhi High Court, was appointed as the Court to hold the said investiation. The Central Government also appointed Dr. V. Ramachandran of National Aeronautical Laboratory, Bangalore; Mr. J.S. Gharia of Explosive Research and Development Laboratory, Pune; Captian J.S. Dhillon, retired Director of Operations, Air India, Bombay; Mr. J.K. Mehra, retired Manager (Technical Training), Indian Airlines, Hyderabad and Captain B.K. Bhasin, Deputy Managing Director of Indian Airlines, New Delhi to act as Assessors of the said Investigation. The Court was required to make its report to the Central Government by 31st December, 1985, which date was later extended to 28th February, 1986.

1.2.13 Mr. S.N. Sharma, Director of Airworthiness, Civil Aviation Department, was appointed as Secretary to the Court vide Ministry of Tourism & Civil Aviation letter No. AV/15013/10/85-A, dated 22nd August, 1985. The appointment was to take effect from 13th July, 1985.

ACTION TAKEN BY IRELAND, INCLUDING THE CORK REGIONAL HOSPITAL

1.3.1 The accident had occurred on the Atlantic Ocean approximately 100 miles south-west of the coast of Ireland. It is the Air Traffic Control at Shannon, Ireland who first became aware of the tragic event.

1.3.2 On coming to know of the accident, various authorities in Ireland took immediate action. The Shannon ATC asked the Marine and Rescue Coordinating Centre there to take emergency action. Thereupon MRCC, Shannon asked Valantia Coast Radio Station (CRS) for a PAN broadcast requiring all the vessels in areas 51N/1250W to keep a look out for the wreckage of an aircraft. The PAN broadcast was repeated and all ships were directed to proceed to the site of accident which was determined as 5101.9N/1242.5 W.

1.3.3 Irish authorities also took great pains in rendering every possible assistance to the Indian and other authorities. Some of the wreckage which had floated in to the west coast of ireland was transported to Cork where a boat house had been hired by the Government of India. The wreckage which was placed in the said boat house was protected from any outside interference by the local Gardai (police).

1.3.4 Irish ships proceeded to the scene of accident and helped in search and rescue operations. The ATC at Shannon gave details about the accident, in so far as they were aware of it, and copies of the ATC tapes were supplied. Aer Lingus, national airline of Ireland, provided assistance by making available its local engineering facilities to the coordinating centre at Cork and also to the other authorities.

1.3.5 Cork is a city having a population of approximately 1,34,000. One of the hospitals which was opened in 1978 is the Cork Regional Hospital which had been set up to meet the needs of the people. This 600-bed hospital was designated for the purposes of the Major Accident Plan of the Southern Health Board and thus became the appropriate centre for the reception of the casualities of the Air India disaster. Since the hospital first opened, it had dealt with a number of major accidents involving road, rail and marine incidents. The Major Accident Plan of the Southern Health Board sets out formally, the strategy and procedure which the hopital is required to follow while deailing with major accidents.

1.3.6 On the morning of 23rd June, 1985 at approximately 11.20 A.M. the hospital was put on alert following the disappearance of the Air India Flight 182 off the south-west coast of Ireland. The first message which was communicated to the hospital indicated that it was unlikely that there would be any survivors. The key hospital personnel were alerted and a meeting was arranged in the hospital for the purposes of discussing and making arrangements for the receipt of the bodies on the basis of the information which was available at that time.

1.3.7 On being informed that there were no survivors in the accident and that the hospital should be prepared to receive a large number of bodies, then, in accordance with the Major Accident Plan, mortuary facilities were improvised by appropriating the gymnasium attached to the Deparatment of Rheumatology. Subsequently it became evident that additional mortuary and postmortem facilities would be needed. In order to decide where the second mortuary was to be located, the hospital had to take into cosideration the following factors:-

(a) The number and the condition of the bodies;
(b) The period during which the bodies would be retained;
(c) The hospital would be required to provide an on-going service for in-patients, out-patients and serious accident and emergency cases;
(d) To avoid unnecessary internal transport problems, the bodies should be near the Post-Mortem and Pathology Departments; and
(e) To facilitate traffic flow in the hospital curtilage and to to aviod unduc public access.

The hospital authorities accordingly located the second mortuary in a recreational room adjoining the gymnasium.

1.3.8 Two rooms were put at the disposal of the Garda (Police) authorities for use as Garda Control Rooms in the hospital. Telecommunications lines were set up immediately for their assistance as the Gardai was responsible for the forensic and identification procedures in regard to the bodies brought to the hospital.

1.3.9 A small Co-ordinating Group was set up consisting of the Chief Executive Officer of the Southern Health Board, Medical Co-ordinating Officer, Press Liaison Officer, a Senior Registrar who knew about Indian customs and traditions and a Hospital Administrator. This small Co-ordinating Group, whose membership never changed, worked together and were capable of assessing situations, making decisions, liaising with other agencies and services and undertaking with other agencies and services and undertaking responsibility for hospital press releases. Apart from individual contact between members, the Group had a standing arrangement to meet every morning and afternoon. In the late evening, the Group, met the Garda, Hospital Pathologists and key staff members for a general review of progress and to decide the tasks and objectives for the following day.

1.3.10 Within a few hours, the Co-ordinating Group realised that the hospital was a world focal point of the international media, and was required to:

a. Accommodate 131 bodies;
b. Provide pathological and Radiological services for each body;
c. Co-operate with the Garda in their forensic work;

d. Cater for relatives of the victims;
e. eet representatives of foreign Governments; and
f. Keep press agencies informed.

Thus began an operation which demanded a quick and dedicated response from all staff working in close cooperation with the Gardai. At the same time, the hospital was required to continue functioning in the delivery of normal in-patient and out-patient services. The Major Accident Plan, apart from alerting staff, provided the framework and basis for many
decisions taken as events evolved. An additional advantage in the practical implementation of the Plan was the fact that the hospital had staff experienced in dealing with previous emergency situations and could marshal the extensive manpower resources available.

1.3.11 The hospital authorities also made the following arrangements:-

a. They briefed Government Ministers and Officials and other dignitaries who visited the hospital. They were taken round the hospital and were explained the arrangements which had been made.

b. Some of the services which were being provided at the hospital were either discontinued or postponed.

c. Bodies were received at the hospital and arrangements were made on their arrival to numerically label and certify as dead all the 131 bodies which were initially received. All the bodies, at that stage, had been individually placed in special purpose body bags. Initially, bodies were placed on tables, but, it was subsequently decided that it would be much easier for all concerned to place the wrapped bodies on polythene covered floors.

d. Arrangements were made for carrying out of the post-mortem examinations. Three Pathologists from other city Hospitals were recruited to augment the existing staff. Dr. Harbison, State Pathologist, was in charge of this aspect of the operation. All the post mortem were completed by 27th June, 1985.

e. For the preservation of the bodies five refrigerated containers with a capacity to hold 140 bodies were hired. These containers were fitted with timber shelving.

f. Government Information Service was located in the Matron's Office.

g. The Army provided troops for the unloading of the bodies from the helicoplers at Cork Airport. They also supplied and erected two large tents for storing bodies after post mortem and embalming. Under Garda escort transport of all the bodies which were recovered was undertaken by the

Army and these arrangements were co-ordinated by Chief Ambulance Officer.

h. Embalming was carried out in the hospital and bodies were then coffined and the coffins with appropriate number plaques were subsequently laid out in the numerical order on the floor when all the post mortems had been completed.

I. All the embalmed bodies were x-rayed (whole body). The examination was completed on 28th June, 1985.

j. A provision was made for a 24 hour extended catering service to meet the needs of staff, Gardai, Army and other personnel involved including visiting relatives.

k. A simple plan was devised for dealing with the relatives. This was a sensitive task bearing in mind the varying religious beliefs, customs and cultures generally of the visiting relatives. Their main function was to provide moral and emotional support to the relatives.

l. As identification progressed, special arrangements were made to assist the relatives. They were met by teams of councellors from the Hospital as soon as they disembarked at Cork Airport and subsequently at the Hospital. The relatives had the same Counsellor and Garda Officer throughout the identification procedure. An interesting development noted was that each family group of relatives, their Counsellor and Garda officers formed a single family unit transcending cultural barriers. On subsequent visits, families appeared lost if their own Counsellor was not immediately available to them. Usually, the Counsellor and the Garda officers accompanied the relatives, at their own request, for visual identification.

m. When plans were being formulated to receive the relatives, it had been hoped to discourage them from coming to the Hospital until such time as progress had been reported on the identification process. Practical experience subsequently proved this strategy to be inappropriate for a number of reasons. Apart from facilitating the collection from relatives

of salient information on the victims, the most fundamental reason was the underestimation of the abiding wish of the relatives to be physically and psychologically as close as possible to their deceased dear ones. Moreover, it was the express wish of almost all relatives on arriving at Cork Airport to proceed directly to Cork Regional Hospital; there, they were given an informal talk by Air India and Garda representatives on the progress of the investigation and the methods of identification. Many of the relatives visited the hospital daily and remained there throughout each day.

n. Coach trips were arranged to Bantry Bay for the relatives; Bantry Bay is the nearest landmark from the site of the crash. Relatives visited the seaside to pay their last respects to the departed souls. These were solemn occasions when each relative prayed in his/her own way. Rose petals and wreaths were immersed in the sea in keeping with Indian traditions. The visit gave them mental satisfaction and in the early days following the crash, helped in diverting their attention while the investigative procedures were being completed.

o. A small number of visiting relatives had personal medical problems and they were treated at out-patient and in-patient levels at the Hospital.

p. Cork/Kerry Tourism Organisation helped to co-ordinate the accommodation of relatives between a number of hotels. Approximately seven hotels were used within a radius of twenty miles of the city for this purpose.

g. A number of press conferences were held. The Chief Executive Officer, directed that press photography and television filming be not allowed within the hospital in deference to the privacy of patients and in respect for the relatives wishes.

r. Responsibility for the identification of bodies rested with the Garda

Authorities and the conditions under which bodies were released are summarised as follows :-

(I) Satisfactory identification

(ii) Consent of the Coroner

(iii) Proper authentification of the person claiming each body

All bodies arriving at Cork Regional Hospital had already been numerically labelled by the Garda Authorities. To prevent confusion, the bodies were then given identical numbers under the hospital major accident labelling system and this proved to be very helpful later during identification, investigations and recordings. A routine was established for examining and recording information about each body. Teams consisting of a doctor, nurse, clerical officer and Garda made the necessary examination, labelling and recording each body and such details as :-

a. Sex

b. Adult or child

c. Clothing

d. Jewellery and personal effects

e. Injuries

f. Obvious scars

Death was confimed in all cases. Each body was fingerprinted and photographed by Garda Technical Bureau Staff. Each body was subjected to autopsy, forensic and dental examination. All bodies were embalmed and following embalming, were photographed and x-rayed. This procedure was completed in respect of all the bodies by the evening of the fifth day of the crash. The data from these investigations was collated on an Interpol form (pink) for each body. Similar ante-mortem information was obtained from the relatives about each victim on a separate Interpol form (yellow). When the information on the pink and yellow forms matched beyond doubt, a positive identification was made. It might be noted that the photographs originally taken by the Garda Technical Bureau Officers of each body were matched with photographs of the 131 embalmed bodies. When a positive identification was made, the relatives were shown photographs of the deceased. These photographs were available for inspection by Saturday, 29th June. As positive identification progressed, personal effects were added to the identification process and finally, visual identification took place. For obvious forensic reasons, positive identification was necessarily slow and meticulous and, in fact, was made more difficult by reason of the fact that only 131 bodies out of the 329 passengers and crew were recovered. All 131 bodies were identified, the first positive identification was made on 27th June and the last on the 6th August. Each coffin had affixed to it a metal plaque clearly indicating the number assigned in the first instance to the body it contained. The bodies when identified were released by the Garda Authorities through the undertaker. The Coroner directed that a reasonable time would have to elapse before unidentified bodies could be disposed off an this was to be by way of burial. The final date for this purpose was fixed for 3rd August, 1985, but, this date was subsequently extended to 6th August, 1985, to coincide with the date of the Civic Commemoration Ceremony.

(s) Bodies of victims for identification were brought individually to separate viewing rooms, suitably decordated with flowers and with incense burning. Visual identification was performed in private by the relatives and moreover, it allowed them to pay their last respects in their own religious beliefs. An adjoining room was also made available where they could grieve in private. Subsequently, it was learnt that these arrangements were much appreciated by the relatives who articulated this appreciation by commenting that the arrangements provided were as near as possible to the funeral rites observed in their domestic communities. The relatives were of the opinion that the special arrangements made conveyed a deep personal and individual response to the dignity of each victim which might otherwise be lost with such a large number of bodies.

(t) Procedures were laid down which were required to be followed and observed for the purposes of preventing infection.

(u) On 6th August, 1985 an interdenominational service was held in the morning. In the evening on that day a Civic Commemoration Ceremony was held which was attended by a large number of persons.

(v) A formal inquest was held by the Coroner in the Courthouse, Cork, which commenced on 17th September, 1985 and ended on 23rd September, 1985. The Coroner's Jury returned a verdict in accordance withmedical and pathological evidence.

ACTION TAKEN BY THE COURT

1.4.1 Despite the fact that Mr. H.S. Khola had been appointed as the Inspector of Accidents under Rule 71 of the Aircraft Rules, the Government thought it proper to appoint Mr.Justice B.N. Kirpal as the Court to investigate into the circumstances of the accident.

1.4.2 The appointment of the Court was made under Rule 75 of the Aircraft Rules, which is as follows :-

"75. Formal Investigation - Where it appears to the Central Government that it is expedient to hold a formal investigation of an accident it may, whether or not an investigation or an inquiry has been made under rule 71 or 74, by order direct a formal investigation to be held and with respect to any such formal investigation the following provisions shall apply namely

(1) The Central Government shall appoint a competent person (hereinafter referred to as "the Court"), to hold the investigation, and may appoint one or more persons possessing legel, aeronautical, engineering, or other special knowledge to act as assessors, it may also direct that the Court and the assessors shall receive such remuneration as it may determine.

(2) The Court shall hold the investigation in open court in such manner and under such conditions as the Court may think fit most effectual for ascertining the causes and circumstances of the accident and for enabling the Court to make the report hereinafter mentioned.

(3) (i) The Court shall have, for the purpose of the investigation, all the powers of a Civil Court under the Code of Civil Procedure, 1908 and without prejudice to those powers the Court may :-

(a) enter and inspect, or authorise any person to enter and inspect, any place or building, the entry or inspection whereof appears to the court reguisite for the purpose of the investigation; and

(b) enforce the attendance of witness and compel the production of documents and material objects; and every person required by the Court to furnish any information shall be deemed to be legally bound to do so within the meaning of section 176 of the Indian Penal Code.

(ii) The assessors shall have the same powers of entry and inspection as the Court.

(4) The investigation shall be conducted in such manner that, if a charge is made or likely to be made against any person, that person shall have an opportunity of being present and of making any statement or giving any evidence and producing witness on his behalf.

(5)Every person attending as a witness before the Court shall be allowed such expenses as the Court may consider reasonable: Provided that, in the case of the owner or hirer of any aircraft concerned in the accident and of any person in his employment or of any other person concerned in the accident, any such expenses may be disallowed if the Court, in its discretion, so directs.

(6)The court shall make a report to the Central Government stating its findings as to the causes of the accident and the circumstances thereof and adding any observations and recommendations which the Court thinks fit to make with a view to the preservation of life and avoidance of similar accidents in future, including, a recommendation for the cancellation, suspension or endorsement of any licence or certificate issued under the rules.

(7)The assessors (if any) shall either sign the report, with or without reservations, or state in writing their dissent therefrom and their reasons for such dissent, and such reservations or dissent and reasons (if any) shall be forwarded to the Central Government with the report. The Central Government may cause any such report and reservation or dissent and reason (if any) to be made public, wholly or in part, in such manner as it thinks fit."

1.4.3 The Court, which is appointed under Rule 75, does not act as a 'Commission of Inquiry' which is usually appointed under the Commissions of Inquiry Act to inquire into any definite matters of public importance. The role of the Court, on its appointment under Rule

75 of the Aircraft Rules, is essentially that of an Investigator. It is for this reason that no procedure has been prescribed in the Rules which the Court is required to follow. While carrying out its functions, the Court is not only required to comply with the provisions of the Aircraft Act, and the Rules framed thereunder, but it must necessarily also keep in view the provisions of ICAO Annex. 13.

1.4.4. As an Investigator, investigating into an accident, the Court had to perform multi-farious duties and functions. Before referring to them, it would be pertinent to point out that whereas an Inspector of Accidents, who is appointed under Rule 71, would normally be belonging to the Civil Aviation Department and would have all the machinery available to him for conducting the investigation, the Court, when it is appointed to hold an investigation under Rule 75, lacks the basic infrastructure to conduct the investigation of such a magnitude. Assessors are appointed to assist the Court but the actual investigation work cannot be carried out by them. Despite these handicaps, the investigation continued smoothly primarily due to the fact that whenever directions were issued by the Court to any of the participants before it or to the Civil Aviation Department or any other Organisations, the directions of the Court were readily complied with. On a few occasions it also became necessary to require the Assessors to conduct the investigation, which they did with the help of other organisations.

1.4.5 As an Investigator, the first task which was undertaken was to see that the tapes from the Cockpit Voice Recorder, which had been salvaged, were recoverd from the recorders and subsequently analysed. Requisite directions were issued and the tapes were removed from their respective recorders on 16th July, 1985. This operation was carried out at the Air India workshop at Santacruz in the presence of the accredited representatives of Lockheed (manufactures of DFDR), Fairchild (manufacturers of CVR), Boeing Airplane Co., Canadian Air Safety Board (CASB), National Transportation Safety Board, USA (N.T.S.B), Air India and Government of India. The tapes so recovered were subsequently played and analysed.

1.4.6 On an appointment being made under Rule 75 the Court would become incharge of overall investigation of the accident. In that capacity, and in order to effectively discharge its functions, it became necessary for the Court to undertake the following tasks :-

(a) For getting first hand information, the Court had to personally inspect the wreckage which had been recovered and was housed in a boat yard in Cork. While in Cork opportunity was also taken to go to the Cork Regional Hospital and to have discussions with and be briefed by the hospital staff. A trip was also made to Shannon with a view to see and understand the working of the Secondary Radar System which was in use there. On this visit the original ATC tape, which contained communication betwen Kanishka and the ATC, was also heard.

As it was suspected that there may be a link between the blast which had taken place at Narita Airport on 23rd June, 1985 and the accident to Air India's flight 182, it was felt necessary to inspect the site of the bomb blast at Narita Airport.

On the aforesaid visit to Tokyo, the site where the blast had taken place was inspected which gave some, though very vague, idea of the detonating power of the blast. While in Tokyo meetings and discussions were also held with the police and Aviation Authorities. The Court also had the advantage of being able to meet members of the team investigating into the Japan Airlines Flight JL 123 accident which had occurred near Tokyo on 12th August, 1985. Similarities and dissimilarities between the two accidents were, to some extent, noticed and some information was exchanged.

Information was received, that some floating wreckage had been picked on the coast of England and it was possible that some of the places, which were so received, should be subjected to further detailed chemical and metallurgical examination. In order to decide this, it became necessary to visit RADRE, Kent, U.K. As a result of the inspection and the discussions there, it was decided by the Court that the pieces so recovered should be sent to BARC at Bombay for further analysis.

(b) Directions had to be given, from time to time, with regard to the mapping and salvaging of the wreckage which was being effected. It had to be decided as to how, and in what areas, the Scarab should continue to map the wreckage and take video films and still photographs. Based on the information received therefrom and after discussions with the experts, both Indian and foreign, a list was drawn up indicating the items which had to be salvaged. As the weather was likely to be unpredictable, with a possibility of its deteriorating rapidly, a priority list of items to be salvaged had also to be prepared, and this was done. In view of the fact that the Canadian ship John Cabot and the Scarab had a limited capacity, with regard to the size and weight of pieces which could be lifted from the bottom of the ocean, decision had also to be taken with regard to the deployment of another ship. As a consequence thereof a ship 'Kreuzturm' was also engaged in salvage operations.

(c) Directions had also to be given assigning work and duties to different teams of persons. As an Investigator, the Court was incharge of the entire work of investigation which was being carried out in different parts of the world. It not being possible for the Court itself to undertake all the tasks, decisions had to be taken as to how the investigating work was to progress and who would carry out the directions issued from time to time. For example, immediately after reaching Cork on 25th July, 1985 it was felt necessary that a team should be immediately sent to Canada in an effort to get relevant information from there in connection with the flight AI 182. Accordingly, a team of 3 persons headed by Mr. H.S. Khola was directed to proceed to Canada immediately. As a result of the efforts put in by this team, and with the considerable amount of cooperation, help and assistance rendered by the Canadian Authorities valuable information was received by the Court having direct bearing on the investigation. Yet another example in this regard was of requiring Dr. V. Ramachandran, one of the Assessors and an expert in Metallurgy, to be stationed on board the salvage ships during the recovery operations. The procedure which had to be followed by him was also determined. Information about the progress of the salvage operations was communicated on telephone to the Court at all times of day and night. On receipt of such information further instructions, when ever necessary, used to be issued.

(d) Discussions were held with the Indian experts in order to understand some of the complicated questions which had arisen during the investigation.

In an effort to be able to fully appreciate the effect of decompression, the Court visited the Institute of Aviation Medicine at Bangalore where explsoive decompression was simulated for the Court's benefit. Discussions were also held with other experts of aviation medicine who were also given copies of the post-mortem reports for their opinion. National Aeronautics Laboratory was also visited in Bangalore where meeting was held with experts in aerodynamics, structure and metallurgy. Visits to Bombay where more frequent and necessary so that the Court could get first hand information with regard to the work which was being done at BARC.

The investigation involved looking into matters concerning aviation, electronics, medicine etc. Not being familiar with these branches, the discussions which were held, were of immense help and assistance to the Court who had to understand all the evidence and information which it was gathering.

(e) The accident had attracted world wide attention. Right from the start of the investigation by the Court when the recorders were first opened in Bombay on 16th July, 1985 till the conclusion of the hearing, the Press and the TV were eager for information. It was felt that rather than the media resorting to speculation of getting wrong information, the Court itself or its representative should, as and when necessary, brief the media. In this connection interviews were given, both in India and abroad, which were broadcast over the television and printed in the Press. As a result of this, correct information was disseminated with regard to the progress of the investigation without disclosing the Court's opinion on the evidence which had been received.

(f) Finally, the Court had to conduct the formal investigation in Court. For this purpose it laid down the procedure which would be followed. Rule 75 of the Aircraft Rules required that the investigation would be in open court. It was, however, felt that in this particular case it would be advisable that some evidence should be obtained in Camera.

The Court, accordingly, recommended that necessary amendment should be made in Rule 75 so that the Court was given the power to hold certain proceedings in camera when the circumstances so warranted. The suggestion of the Court was accepted and that resulted in Rule 75(2) being amended and, as a result thereof, the Court was given the power to hold proceedings in camera if the stipulated conditions existed.

COMMENCEMENT OF FORMAL INVESTIGATION

1.5.1 The object of setting up a court to investigate into an accident is primarily to find out the causes and circumstances of the accident and thereafter to make recommendations. Such an investigation is not in the nature of an adversary litigation between the participants before the Court. As such it should be the endeavour of all the participants to assist the Court in arriving at a correct conclusion.

1.5.2 Under Rule 75 of the Aircraft Rules, the procedure which has to be followed in the investigation of an accident is to be determined by the Court itself. While laying down the procedure which is required to be followed, the endeavour of the Court has necessarily to be to adopt such procedure which would help the court in being able to complete its task satisfactorily, and in the shortest possible time. Whenever an accident takes place, it is of utmost importance that the cause of the accident must be ascertained at the earliest so that if any remedial measures are to be taken then those steps should be taken without any undue delay.

1.5.3 In the present case, there were a number of factors which had to be kept in view while determining the procedure whichshould be followed. The accident had occurred over international waters and approximately at a distance of about 5000 miles from the place where the investigation was to be conducted, namely, New Delhi. The ill fated flight itself had commenced from Canada, and this meant that most of the evidence would only be available there. Matters were not simplified by the fact that the debris itself was lying at the bottom of the ocean, 2 miles under water. It became apparent, at the very beginning, that to recover the entire debris would be a superhuman task and it will not be possible to do so within the limited time span which was available.

1.5.4 It was thought that it would be of assistance if all the participants got together so as to determine what procedure should be followed. The procedure had to be such which would give an effective opportunity of hearing to all the participants, without in any way unduly prolonging the investigation.

1.5.5 The Court decided that, in order to obtain the views, it would be necessary and advisable to have a Pre-hearing Conference.

1.5.6 The first decision which had to be taken was as to who were to be given a participants status. Keeping inview the provisions of Annex 13, participants status was given to Governments of Ireland, Canada, USA and India. Similar status was also given to Boeing Airplane Co. and Air India. As there might have been some similarities or dissimilarities between the present accident and the accident of the Japan Airlines Boeing 747-SR and also because there may have been a possibility of the present accident being linked with the explosion which had taken, place at Narita Airport, Tokyo on 23rd June, 1985, an Observer's status was given to the Government of Japan.

1.5.7 Notices for holding of the Pre-hearing Conference on 16th September, 1985 were accordingly issued on 29th August, 1985. The agenda for the Conference was to be as follows :-

a. To make suggestions to the Court for its consideration, regarding the procedure to be followed in the conduct of the formal proceedings in the Court.

b. To draw up a tentative list of witness.

c. To draw up a tentative list of exhibits.

d. To determine the areas to be inquired into

e. To fix a date for the commencement of the public hearing.

f. Any other matter with the permission of the Court.

1.5.8 Except for the Government of Japan, all the other participants were represented at the said Pre-hearing Conference. After discussions had been held between the Court and the Participants, some decisions were arrived at regarding different items of the agenda.

1.5.9 Firstly the following points were framed, indicating the areas to be inquired into by the Court:

a. Whether the accident was caused by a structural failure?
b. Whether the accident was caused by some human effort?
c. Whether the accident was caused by some criminal act?
d. Whether the accident was caused by an external non-criminal act?
e. Based on the evidence on record, what steps should or can be taken so as to ensure greater air safety.

1.5.10 It was further decided that, as suggested by all the participants, at least critical portions of the wreckage should be recovered.

1.5.11 With regard to the recording of the evidence it was decided that evidence will, in the first instance, be taken by filling affidavits or by filling statements alongwith affidavits. Copies of the same were to be supplied to the other participants for their consideration. These affidavits were to be filed on or before 18th October, 1985 and a second Pre-hearing Conference was to take place on 30th October, 1985 at New Delhi when it was to be decided as to which of the persons should be called for cross-examination. It was determined that it is only thereafter that hearing would commence in open court.

1.5.12 A tentative list of witnesses was also drawn up and it was decided that on the next date names of more witnesses may be added and, furthermore, the participants would be free to file any affidavits which they deem fit including affidavits in rebuttal.

1.5.13 Another important decision which was taken at the Pre-hearing Confence was that a Structural Group was formed consisting of (1) Mr. H.S. Khola or his nominee (2) Representative of the Canadian Government (3) Representative of NTSB, USA (4) Representative of Boeing Airplane Co., USA (5) Representative of Air India. This group was entrusted with the task of examining and analysing, initially in Seattle, USA, the video films and the still photographs of the wreckage. This group was also to indicate and decide the items of priorities of wreckage which had to be recovered. The report of this group was required to be submitted by 18th October, 1985. The report of the work done at Seattle was in fact submitted only on 25th October, 1985. This group was also given the liberty to associate any other experts or persons from Boeing or any other Authority. The group was also to inspect the floating wreckage which had already been salvaged and any further wreckage which would be salvaged.

1.5.14 Although the affidavits by way of evidence had to be filed by 18th October, 1985, it was only the Government of Ireland who filed an affidavit by at date. On behalf of the Government of India, an application was filed asking for more time. The reason stated was that the affidavit which had to be filed was to be of Mr. H.S. Khola but he was out of India as he was heading the structures group which was evaluating the video films and photographs at Seattle. The Court had no option but to grant further time to the Union of India to file its affidavits and this necessarily resulted in the adjournment of the Pre-hearing Conference which had been fixed for 30th October 1985.

1.5.15 As the salvage operations were reaching a critical point it became necessary for the Court to go to Cork on 27th October, 1985. Taking advantage of the presence of the Court in Cork, other participants also came there. Besides them, representatives of CP Air and Air Canada also arrived. At one of the informal meetings between the Court and the representatives of the participants, applications were filed by CP Air and the Air Canada, inter alia, praying that they should be permitted to participate in the investigation. It might be mentioned here that CP Air had interlined one of the passangers from Vancouver to AI-182, while Air Canada was the handling agents in Canada of Air India. After hearing the participants it was decided that participant status should also be given to these two viz., CP Air and Air Canada.

1.5.16 The participant had all filed their affidavits by way of submissions. The Court indicated that formal hearings would be held for the purpose of cross-examining some of the witnesses about three weeks after the receipt of all the reports of the various groups. While in Cork, in the first week of November, 1985 some of the salvaged pieces of the wreckage were brought there. After they were inspected by all the participants and their advisers, who were present in Cork, it was decided by the Court that further detailed metallurgical and other examination of those pieces would be done at BARC, Bombay. In order that there should be no undue delay the Court decided that a Group be constituted

consisting of expert representatives of all the participants and also the nominees
of the Court. This group was asked to carry out metallurgical and other examination of some of the critical pieces salvaged and give its report to the Court. The group consituted as a 'Committee of Experts' was as under :-

a. Mr. A.J.W. Melson, Canadian Aviation Safety Board, Canada.
b. Mr. R.K. Phillips, Canadian Pacific Air, Canada.
c. Mr. T. Swift, Federal Aviation, Administration, USA.
d. Mr. R.Q. Taylor, Boeing Commercial Airplane Co., USA.
e. Mr. J.P. Tryzl, Boeing Commercial Airplane Co., USA.
f. Mr. J.F. Wildey II, National Transportation Safety Board USA.
g. Mr. S.N. Seshadri, Bhabha Atomic Research Centre, India (Coordinator).

1.5.17 The parties were informed in Cork that the report of Mr. H.S. Khola, Inspector of Accidents, would be available by about 8th November, 1985. It was then decided that the statements of the first batch of witnesses should be recorded from 20th November, 1985. It was also agreed that if some of the reports of the experts were not received, further examination of the witness may have to postponed.

1.5.18 After receipt of the report from Mr. Khola. on the 8th November, 1985, a notice of the holding of the Public Hearing was issued to all the participants. This notice indicated that the hearing would commence on 20th November, 1985. In the meantime, a Public Notice was also published in the daily "Times of India" in Delhi and Bombay editions on 21st October, 1985 in which it was stated as follows :-

NOTICE AIR INDIA KANISHKA ACCIDFNT INVESTIGATION

The Government of India, vide Notification dated 13th July, 1985, appointed Hon'ble Mr. Justice B.N. Kirpal as a Court to investigate into the accident to Air India's Boeing 747 aircraft VT-EFO (KANISHKA) near the Irish Coast on 23rd June, 1985, when the aircraft was engaged on a scheduled passenger flight from Montreal to Bombay via London and New Delhi.

Any person having direct knowledge, who may desire to make representation concerning the circumstances or causes of the accident, may do so in writing in the form of an affidavit duly attested by an Oath Commissioner or a Notary Public and address the same to the undersigned so as to reach him within 15 days of the publication of this Notice.

S.N. SHARMA SECRETARY COURT OF INVESTIGATION COURT NO.10,DELHI HIGH COURT SHERSHAH ROAD NEW DELHI - 110 003

Pursuant to the aforesaid public notice no affidavit was received from any one.

1.5.19 The public hearing commenced on 20th November, 1985 and the first session concluded on 28th November, 1985. During this period statements of Mr. H.S. Khola, Wing Commander Dr. I.R. Hill and Sgt. Atkinson of R.C.M.P., Canada were recorded.

1.5.20 Till that date, report on the examination of the salvaged pieces had not been received. It was anticipated that the report would be available by mid December, 1985. In order to give the parties sufficient time to study the reports of all the experts it was decided that further evidence would be recorded from 22nd January, 1986.

1.5.21 After the reports were received from BARC; AIB; Farnborrough; NTSB; USA; and Mr. Bernard Caiger of CASB, Canada and the copies of the same had also been received by all the participants, recording of evidence commenced from 22nd January, 1986 and concluded on 30th January, 1986. In all statements of 13 witnesses were recorded.

1.5.22 At this stage it will be pertinent to make a few observations with regard to the procedure which was laid down for recording of evidence etc. As already indicated, most of the evidence was such which was not available in India. As a Court investigating the accident under the provisions of Aircraft Rules, it had no jurisdication to compel attendance of any witness from abroad. The Court also had no jurisdication, either under the Rules or under the provisions of Annex 13, to require any witness to be examined in a country other than the one in which the Court is holding the investigation. The Court was informed that, if called upon, some of the persons who were outside India may not be inclined to testify before the Court.

1.5.23 Faced with the aforesaid difficulty it became necessary, therefore, to evolve a procedure which would enable the Court to get the requisite information. As long as the Court was satisfied that the information which was being received was one which had been truthfully given by a person, it was immaterial as to the manner in which the information was received. It is for this reason that it was decided that evidence will, in the first instance, be given by way of affidavits. It was also provided that the statements could also be filed along with affidavits. This latter course was permitted so as to enable some of the statements, which had been recorded by members of the Royal Canadian Mounted Police, to be placed before the Court. These statements, of course, had to be accompanied, as they were, with the affidavits of the persons who had recorded the statements.

1.5.24 At one stage, by a formal application in writing, Air India had protested against this procedure being followed. By order dated 22nd November, 1985, an objection by Air India to the filing of the statements accompanied by affidavits, was dealt with by the Court in the following words :-

"With regard to the affidavits which have been filed by the Government of Canada, I would only like to observe in the Pre-hearing Conference on 16th September, 1985, it was decided that "Evidence will, in the first instance, 1985 be taken by filing affidavits or by filling of Statements along with affidavits." It was understood that if it is not possible to file affidavits of the persons who are in a position to give information then affidavits may be filed of other persons who may have recorded the statements of the persons who are in a position to give information. This is not an adversary litigation where one of the parties may lose because of lack of proof. One of the objects of setting up a Court to investigate into an accident is to find out the causes of the accident and to make recommendations. It is necessary for this purpose to get information which may be relevant. It is true that strictly speaking the statements which are annexed to the affidavits may not be admissible as evidence in a Court of Law when there is a litigation between the parties but considering limitations which we have, namely, where a Court like the present has no jurisdication to enforce the attendance of any witness who is outside this country and furthermore, the Court has no jurisdication to compel any one to give information, the procedure which was adopted was thought to be the most practical one for obtaining information in connection with the accident. Under the circumstances, the affidavits which have been filed along with the statements which have been annexed thereto which give information with regard to the accident, have to be taken on record."

1.5.25 Another advantage of following the aforesaid procedure was that the time which would have been taken in Court in examining of the witnesses was considerably reduced. After the participants had filed affidavits, the same were to be secrutinised and it was then to be decided as to which of the deponents or persons should be called for examination in Court. Effectiveness of this procedure which was adopted is apparent from the fact that though affidavits by way of evidence were filed in Court, ultimately only 13 witnesses had to be examined in Court and sitings were held in Court only on 14 days.

1.5.26 Written arguments were filed on the forenoon of the 4th February, 1986 and oral arguments were heard in the afternoon of that day. No written arguments or oral submissions were made by the Government of Ireland, CP Air or Boeing Company.

1.5.27 Mr. I.G. Whitehall, councel for the Government of Canada took exception to some of the submissions which were contained in the written submissions filed by Air India. Mr. Whitehall contended that the Court had opined that it will not go into the question of responsibility of the unfortunate accident and therefore, there was no; justification for Air India to include in its written submissions numberous passages which tended to fix responsibilities.

1.5.28 By the order dated 4th February, 1986, it was made clear that it was not the intention of the investigation to apportion blame if any lapse had been committed and, therefore, the Court would ignore any written submissions which tended to apportion blame or responsibility for any lapse of any participants. It might here be mentioned that such a question had earlier arisen while the statement of Sgt. Atkinson was being recorded. The Court had then held that it will not go into the question as to who was responsible for the accident. It was in view of this order that no evidence was led by any of the parties on the question as to who may have been responsible for any possible lapse which could have led to this accident.

2.1 Flight Preparation

2.1.1. Air India Boeing 747 aircraft VT-EFO 'Kanishka' was operating flight AI-181 (Bombay-Delhi-Frankfurt-Toronto-Montreal) on 22nd June, 1985. From Montreal it becomes AI-182 from Mirabel to Heathrow Airport, London enroute to Delhi and Bombay. The aircraft arrived at Toronto from Frankfurt at 1830 Z and was parked at gate No. 107 Terminal 2 at L.N. Pearson International Airport. In accordance with the Canadian regulations, all the passengers and their baggage were off loaded to complete the customs and immigration checks. Transit cards were handed out to 68 transit passengers destined to Montreal who disembarked at Toronto for customs and immigration checks.

2.1.2. The flight from Toronto to Montreal was made up of the following:-

(I) Passengers originating at Toronto and their baggage.

(ii) Transit passengers, and their baggage, continuing their flight to Montreal.

(iii) Two diplomatic bags from Indian Consulate General, Vancouver via Air Canada Cargo Flight, and some Air India Mail.

(iv) Fifth Pod engine and its associated parts.

(v) Interline passengers and their baggage from connecting flights as detailed below:-

a) Air Canada flight AC-102
from Sasktoon - 2 Passengers

b) Air Canada flight AC-106
from Edmonton - 4 Passengers

c) Air Canada flight AC-170
from Winnipeg - 1 Passenger

d) Air Canada flight AC-170
from Winnipeg - 4 Passengers

e) Air Canada flight AC-136
from Vancouver - 10 Passengers

2.1.3. One passenger by name 'M. Singh', checked in at Vancouver on Canadian Pacific flight CP-060 (Vancouver-Toronto) of 22nd June 1985, and got his one piece of baggage interlined to Air India flight AI-181 even though he had no confirmed reservation on AI-181. This passenger, however, did not board the flight CP-060 at Vancouver and also did not check-in for Air India flight AI-181/182 at Toronto.

2.1.4 The checking-in of passengers for Air India flight AI-181/182 at Toronto began at 1830 Z. The checking-in of the passengers was carried out by Air Canada personnel who are the handling agents for Air India, and was supervised by Air India personnel. The Air Canada personnel indicated the computer sequeritial numbers (security numbers) on the passenger boarding card stubs. At about 1930 Z announcement was made for the primary security check of passengers and their hand baggage. The passengers passed through the Door Frame Metal Detector and their hand baggage was checked through X-Ray machine. The passengers were also subjected to physical security check with the help of Hand Held Metal Detectors. The transit passengers to Montreal and their hand baggage were also subjected to these security checks, while their checked in baggage, after clearance by the Canadian Customers authorities was placed by the passengers themselves on the conveyor belt while they were still in sterile area. In this way there was personal identification by the passengers of all checked in baggage, except the baggage which had been interlined to this flight.

2.1.5 The flight was closed for check-in at about 2150 Z. There were 10 'NO SHOWS' and 4 'GO SHOWS'. The security checked passengers remained in the holding area gate No. 107 till boarding was announced at about 2210 Z. At the boarding gate secondary security check of the passengers and their hand baggages was carried out. The passengers were frisked with the help of Hand Held Metal Detectors and their hand baggages were opened and physically checked.

2.1.6 The security numbers on the stubs were circled on the pre-numbered Security Control Sheet to ensure that all the checked-in passengers have boarded the aircraft. Passenger boarding was completed by 2300 Z. Traffic/Sales representative of Air India verified the Security Control Sheet with the number of stubs collected and the number of passengers checked-in.

He found that all the 202 passengers, who had checked-in, had boarded the aircraft.

2.1.7 As stated earlier, 68 transit passengers had disembarked at Toronto for completing the customs and immigration checks. However, only 65 of these passengers re-boarded the aircraft as per transit cards collected at the boarding gate. It is in evidence that almost every flight of Air India to Canada, two or three transit passengers do not re-board the flight at Toronto. Some Toronto passengers travelling to India buy their tickets "Montreal-India-Montreal" instead of "Toronto-India-Toronto", for which the fare is higher, and they travel by bus to Montreal to catch the Air India flight to India. On their return journey, when they get down at Toronto for customs and immigration checks, they simply do not re-board the flight even though their reservations are upto Montrteal. These passengers sometimes inform Air India personnel at Toronto about their not re-boarding the aircraft. On 22nd June, 1985, however, no such passenger informed Air India personnel.

2.1.8 There was a crew change at Toronto. The flight and cabin crew members who took over the flight AI-181/182 had been laid over in Toronto for the week prior to the accident flight and were scheduled to take the flight upto London where they were to be relieved by another set of crew. Capt H.S.Narendra was the Commander of the flight, with Capt S.S.Bhinder as co-pilot and Mr.D.D.Dumasia as the Flight Engineer. In addition there were 19 cabin crew members. All the crew members reported together at the airport at 2130 Z. As per the practice existing at that time, the flight crew and cabin crew members were not subjected to frisking checks and their hand baggage were also not security checked. Their checked-in baggage was, howevewr, security

checked along with the other checked-in baggage of passengers.
2.1.9 The interline baggage was brought to the international baggage make-up area by the Air Canada staff but, as mentioned earlier, it was not personally identified and matched with the passengers.
2.1.10 The checked-in baggage of the originating passengetrs and crew members of AI-181/182 was sent on a conveyer belt to the baggage make-up area. All the checked-in baggage along with the interline baggage was required to be security checked on the X-ray machine which was located in the baggage make-up area at the end of international belt No.4.
2.1.11 It has been reported that the X-ray machine worked intermittently for some period and at about 2045Z it broke down and there was no picture on the screen. The Machine could not be repaired on that day as it was a week-end and no technician could be contacted. Air India's Security Officer then advised that the rest of the baggage be checked with a PD-4 explosive detector provided by him. He also demonstrated the use of the PD-4 detec- tor to the concerned personnel. It has been reported that about 60 to 70 baggages were checked and cleared by the PD-4 detector.
2.1.12 The security checked baggage was loaded in the containers by the Air Canada personnel. The loading of the baggage in containers was over by about 2230 Z. The ramp personnel of Air Canada carried the container and loaded them in the aircraft.
2.1.13 From March, 1985, after the introduction of Air India flight AI-181 through Toronto, diplomatic bags from Indian Consulate General at Vancouver were being sent to India by Air India flight from Toronto. Accordingly, two diplomatic bags, duly sealed and escorted, were delivered to Air Canada office at Vancouver on 21st June and they arrived at Toronto by Air Canada flight AC-580. One of the bags Sl.No. 49 contained 13 empty large diplomatic bags while the other bag Sl.No. 50 contained diplomatic mail. The total weight of the bags was 13.8 Kgs.
2.1.14 In addition to the above, a few envelopes containing some flight documents addressed to Accounts Office, Air India, Bombay, and

one envelope addressed to Commercial Headquarters, Air India, Bombay from Air India Town Office in Toronto, were collected by Messrs Mega International.

2.1.15 The aircraft was refueled by CAFAS with 14,602 litres of fuel.

2.1.16 On 8th June No. 1 engine of Air India Boeing 747 aircraft VT-EGC had failed during take off. The failed engine was to be ferried to Bombay on flight AI-181/182 of 22nd June.

2.1.17 The failed engine and the associated parts were placed in Air Canada Engineering Hangar at Toronto airport since June 8,when the aircraft was brought to the engineering hangar for engine replacement. Air India had requested Air Canada on 15th June for preparing the failed engine for installation as fifth pod mounting of the aircraft on 22nd June.

2.1.18 On 15th June Air India deputed one of their foremen to Toronto to bring back the failed engine. From 17th to 21st June, Air Canada technicians prepared the failed engine for installation as fifth pod. This preparation involved removal of cowlings, fan blades, locking of compressor rotors etc. Air Canada Engineering/Maintence personnel loaded the aircraft/engine parts on 4 pallets and one container. These pallets and container were then delivered at 0100 Z on 22nd June by Air Canada personnel to Messrs Mega International cargo warehouse at Toronto Airport within restricted airport area. (Messrs Mega International Cargo Warehouse at Toronto Airport within restricted airport area. (Messrs Mega International is the cargo handling agent of Air India at Toronto). The fifth pod engine was transported by Air Canada directly from their premises to the 'Kanishka' aircraft for mounting it on the fifth pod.

2.1.19 Installation of the engine on the fifth pod began immediately on arrival of flight AI-181 at Toronto on 22nd June and the work was completed by 1930 Z. One of the mechanics of Air Canada installed the Mach Air Speed Warning Switch in the Main Equipment Centre as part of the fifth pod engine installation.

2.1.20 The pre-loaded four pallets and one container were brought to the aircraft by M/s Mega International personnel from their warehouse in the afternoon of 22nd June for loading them into the aircraft cargo compartment at positions assigned by the Air Canada load agent. Difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fitting from the aft cargo compartment door cut-out. After removal of the fittings, the cowl could be loaded. All the removed fittings were then reinstalled.

2.1.21. On account of the delay in loading the cowls, departure of the flight was delayed by one hour and twentyfive minutes.

2.1.22 Maintenance Manager of Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft and no snag was observed by him. The commander duly accepted the aircraft.

2.1.23 Senior Flight Despatcher, Air India, Toronto did the flight despatch of AI-181/182 for sectors Toronto-Montreal-London. He briefed the flight crew members about flight plan, weather, Air Traffic Control and fuel requirements. The flight plans for the sectors Toronto-Montreal-London were duly accepted and signed by the Commander.

2.2 Progress of the Flight

2.2.1. The Aircraft took off from Toronto Runway 24L at 0016 Z on 23rd June, 1985. The Maintenance Manager, Security Officer and Passenger Service Supervisor of Air India travelled on board the aircraft for their duties at Montreal. In all there were 270 passengers on board in addition to 22 crew members.

2.2.2. The route from Toironto to Montreal was V-98/JHL-594/MSS/ V 203/FRANX at flight level 290. The flight was uneventful and the aircraft landed at Montreal at 0110 Z. No snag was reported by the flight crew. The aircraft was parked at Cluster 1 Bay No.114.

2.2.3 Sixtyfive passengers destined to Montreal along with the three Air India personnel mentioned above deplaned at Montreal. The remaining 202 passengers, who had joined the flight at Toronto, remained on board the aircraft as transit passengers were not allowed to disembark at Montreal.

2.2.4 Baggage handlers off loaded three containers of baggage, one valuable container and four cargo containers from the aircraft.

2.2.5 Transit Check 'C' of the aircraft was carried out at Montreal. The Flight Engineer also carried out his pre-flight inspection and found that rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to an Air Canada Technician who flaired the handle and applied the high speed tape. There was no other snag observed during the inspection. The personnel of CAFAS refueled the aircraft with 96,000 litres of fuel. Total fuel on board at the time of take off from Montreal was 104,000 Kgs. which was adequate for 8 hours 40 minutes of flying. The commander accepted the aircraft and signed the 'Certificate of Acceptance' of the aircraft.

2.2.6 At approximately 2130 Z Air Canada personnel opened the passenger check-in counter for flight AI-182 (The flight AI-181 terminates at Montreal and the flight from Montreal to London-Delhi-Bombay is designated as AI-182). The checked-in baggage was sent to the baggage make-up area. Between 2300-2350 Z, a suspect suitcase was identified as the X-Ray showed what appeared to be some wires next to the suitcase opening. The suitcase was placed on the floor next to the X-Ray machine. Subsequently two more suspect suitcases were located. These suitcases were also placed next to the X-Ray machine to await the arrival of the Air India Security Officer who was to arrive on Air India flight AI-181 from Toronto. The remainder of the checked-in baggage, which cleared the security check, was loaded in containers by Air Canada personnel for loading on board the aircraft.

2.2.7 Two diplomatic pouches from the Indian High Commission, Ottawa were brought to Mirabel. After the flight arrived, one of the pouches of Category 'A' weighing 1 Kg. was given to the Flight Purser. The other Category 'B' pouch weighing 9 Kgs. was placed in an valuable container 14R.

2.2.8 No other cargo was accepted for this flight except a small package (weighing less than 1 Kg) containing medicines for cancer treatment of a patient in New Delhi. This parcel was received at 1530 Z on 21st June and was loaded in container 14R by Messrs Mega International on 22nd June, more than 24 hours after its receipt.

2.2.9 Five baggage containers, one valuables container and two empty containers were loaded in the aircraft.

2.2.10 The checked-in passengers with their hand baggage went to the departure sterile area. At the entrance to the departure sterile area security staff used X-Ray units and metal detectors to check passengers and their hand baggages.

2.2.11. At approximately 0100 Z, 23rd June, after the primary security check was completed, the passengers proceeded to boarding gate No.80. At this lcoation the secondary security check was done on passengers using hand held metal detectors. Hand baggages were also subjected to further physical and visual check by them.

2.2.12. A total of 105 passengers boarded the flight AI-182 at Mirabel Airport. It was determined that all the passengers who had checked-in, boarded the aircraft. There was no interline passenger. At Montreal there were five 'NO SHOWS' and two 'GO SHOWS'. In all 307 passengers were on board the aircraft. The flight plan and the load and trim sheet, however, indicated 303 passengers as four of the 6 infants were not included in the passenger list.

2.2.13. The seating distribution of the passengers was as given below:-

Zone/Class	Total number of Seats	Occupied seats
Zone 'A' - First Class	16	1
Zone 'B'- Club Class	22	-
Upper deck - Club class	18	7
Zone 'C' - Economy Class	112	104+ 2
Zone 'D' - Economy Class	86	84+ 1
Zone 'E' - Economy Class	123	105+ 3
	377	301+ 6 (Infants)

2.2.14 The seating distribution of the 19 cabin crew members was as follows:-

Two at door L1 and two at door R1
Two at door L2 and two at door R2
Two at door L3 and one at door R3
Two at door L4 and one at door R4
One at door L5 and one at door R5
One in crew rest area, Zone 'A'

One in jump seat upper deck
One crew rest area upper deck.

2.2.15 The three suspected suit cases were not loaded on the aircraft and were detained in the baggage make-up room. After the names of the passengers to whom the suit cases had belonged had been identified the same were transferred to the decompression chamber of E1 A1 Airline where they were examined, with the aid of a Police Explosive Dog, with negative results. The suit cases were kept overnight in the said chamber and when they were opened it was found that they contained no explosive items.

2.2.16. No unclaimed baggage pertaining to the Air India flight was recovered either at Toronto or at Mirabel or Dorval Airport in Montreal.

2.2.17. The flight plan for the sector Montreal to London was filed on telephone by the Air India Flight despatch from Toronto to Dorval ATC Centre. He requested for route SHERBROOKE-COLOR-NAT XRAYBUNTY-MERLY-EXMOR-IBLEY-SAMTN-HAZEL-OCKHAM-LONDON at flight level 290 upto COLOR and flight level 330 thereafter. The reporting points on Track XRAY on that day were COLOR, 47N/50W, 49N/40W, 50N/30W, 51N/20W, 51N/15W, 51N/08W and BUNTY.

2.2.18 The aircraft took off from Montreal at 0218 Z. Its estimated time of arrival at London was 0833 Z. The CVR and the ATC tapes show that the flight was normal and quite uneventful. Suddenly at about 0714 Z, when the flight was being monitored by the Air Traffic Controller at Shannon, with the help of secondary surveillance radar, the aircraft disappeared from the radar scope. Subsequently, the ATC at Shannon got the know that the aircraft had met with an accident and its wreckage was sighted about 110 miles west south-west of Cork, Ireland.

PERSONNEL INFORMATION

2.3.1 Pilot-in-Command (Capt. H.S. Narendra)

2.3.1.1 Cap.t H.S. Narendra (age 561/2 years, date of birth 25th November, 1928) joined Air India on 1st October, 1956. He held ALTP Licence No. 247 valid upto 29th October, 1985 and FRTO No. 478 valid upto 23rd October, 1985. He was released as a Co-pilot on Boeing 707 aircraft on 21st July, 1960 and as a Commander on Boeing 707 aircraft on 17th September, 1964.

2.3.1.2 For conversion as Pilot-in-Command on Boeing 747 aircraft, Capt. Narendra had undergone ground training at Boeing Airplane Company, USA and simulator and aircraft flying training at Bombay in 1972. He completed his route checks for Pilot-in-Command endorsement between December, 72 and January, 73. He became a Commander on Boeing 747 aircraft on 14th February, 1973.

2.3.1.3 Details of Capt. Narendra's flying experience and licence renewal checks are as given below:

a. Total flying experience : 20, 379:15 hours

b. Flying experience on B-747 as

(i) Pilot-in-Command : 6,364.50 hours

(ii) Co-pilot : 123:45 hours

c. Day flying experience
on B-747 aircraft : 3,980:00 hours

d. Night flying experience
on B-747 aircraft : 2,508:35 hours

e. Flying experience during

(i) last 6 months : 301:45 hours

(ii) last 3 months : 159:40 hours

(iii) last 30 days : 68:45 hours

(iv) last 7 days : 9:00 hours

He had last flown as Pilot-in-Command on flight AI 181 (Frank- furt to Toronto) on 15th June, 1985.

f. Date of last licence
renewal and IR check : 8 May, 1985

g. Date of last route check : 24 March, 1985

h. Date of last medical
examination at CME,
Delhi : 29 April, 1985

i. Date of last simulator
refresher course : 19 December, 1984

j. Date of ground technical

refresher course : 6/7 May, 1985
k. Date of last flight
safety refresher course : 25 July, 1984
l. Rest period before
operating the accident
flight : 1 week

2.3.1.4 Records indicate that on 29th June, 1966, Captain Narendra was declared medically unfit for 2 months to reduce his weight by 10 Lbs. In February, 1973 he was advised to wear corrective by-focal glasses while flying. In May, 1975 he was again declared medically unfit for 3 months.

2.3.1.5 Capt. Narendra was earlier involved in the following two incidents:

(a) On 25th August, 1984, while operating flight AI-1100 from London to Delhi, there was a deviation of the aircraft by about 170 nautical miles from the track over Rahimyar Khan in Pakistan. He was given necessary INS refresher and Route checks with particular emphasis on cross checking procedure.

(b) On 6th December, 1984, while operating flight AI-124 Delhi-Bombay, the aircraft was observed approaching runway 32 at Bombay Airport when runway in use was 27. Captain Narendra was given simulator training for a series of approaches and landings and visual circuits from right hand and left hands seats for approaches and landings on runway 27 at Bombay Airport.

2.3.1.6 Captain Narendra was not involved in any accident previously.

2.3.2 Co-pilot (Capt. S.S. Bhinder)

2.3.2.1 Capt. S.S. Bhinder (age 411/2 years, date of birth 30th November, 1943) joined Air India on 12th October, 1977. He held ALTP Licence
No. 940 valid upto 25th July, 1985 and FRTO Licence No. 2290 valid upto 2nd February, 1986.

2.3.2.2 Capt. Bhinder was released as a Co-pilot on Boeing 707 aircraft on 18th November, 1978 and as a Co-pilot on Boeing 747 aircraft on

17th May, 1980.

2.3.2.3 Details of his flying experience and licence renewal checks are as given below:

a. Total flying experience : 7,489:00 hours

b. Experience on B-747 aircraft as Co-pilot : 2,469:30 hours

c. Day flying experience on B-747 aircraft : 1,426:15 hours

d. Night flying experience on B-747 aircraft : 1,043:15 hours

e. Flying experience during

(i) last 6 months : 157:45 hours

(ii) last 3 months : 65:00 hours

(iii) last 30 days : 20:15 hours

(iv) last 7 days : 9:00 hours

He had last flown as Co-pilot on flight AI-181 (Frankfurt to Toronto) on 15th June, 1985).

f. Date of last licence renewal check : 25th March, 1985

g. Date of last IR check : 23rd November, 1984

h. Date of last route check : 9 April, 1985

i. Date of last medical examination at CME Delhi : 14 January, 1985

j. Date of last simulator refresher course : 16 July, 1984

k. Date of last ground technical refresher course : 8/9 October, 1984

l. Date of last flight safety refresher course : 3 December, 1984

m. Rest period before operating the accident flight : 1 week.

2.3.2.4 Records indicate that Capt. Bhinder was not involved in any accident earlier.

2.3.3 Flight Engineer (Mr. D.D. Dumasia)

2.3.3.1 Flight Engineer Mr. D.D. Dumasia (age 57 1/2 years, date of birth 10th October, 1927) joined Air India on 27th December 1954. He held flight Engineer's Licence No. 37 valid upto 6th December, 1985. Mr. Dumasia was released as a Flight Engineer on Boeing 707 airecaft on 16th December, 1963 and on Boeing 747 aircraft on 6th February, 1974. He had a total flying experience of 14,885 hours out of which 5,512:35 hours were on Boeing 747 aircraft.

2.3.3.2 Last medical examination of Mr. Dumasia was completed on 1st October, 1984 at CME Delhi. He had completed simulator refresher course on 14th February, 1985, ground technical refresher course on 14/15th January, 1985 and flight safety refresher course on 13th August, 1984.

2.3.4 Cabin Crew

2.3.4.1 A total of 19 cabin crew members were on duty on Flight AI-181/182 on 23rd June, 1985. Their brief details are as given below:

Sl.No. Names Designation Flight Safety course completed on 1. Mr. S.L. Lazar Inflight Supervisor 1/2 April, 1985 2. Mr. K.M. Thakur Flight Purser 18 February, 1985 3. Mr. Inder Thakur Flight Purser 9/10 May, 1984 4. Mr. Shukla Flight Purser 23 January, 1985 5. Mr. S.P. Singh Flight Purser 15 January, 1985 6. Mr. N. Vaid Asst. Flight Purser 2/3 May, 1985 7. Mr. B.K. Sena Asst. Flight Purser 3 December, 1984 8. Mr. N. Kashipri Asst. Flight Purser 12/13 Sept., 1984 9. Mr. J.S. Dinshaw Asst. Flight Purser 17/18 Dec., 1984 10. Mr. K.K. Seth Asst. Flight Purser 11/12 February, 1985

11. Miss Raghavan Airhostess 13 July, 1984 12. Miss S. Ghatge Airhostess 10/11 April, 1985 13. Miss R. Bhasin Airhostess 11/12 February, 1985 14. Miss L. Kaj Airhostess 17/18 April, 1985 15. Miss P. Dinshaw Airhostess 17/18 Dec., 1984 16. Miss S. Lasarado Airhostess 15/16 April, 1985 17. Miss E.S. Rodricks Airhostess 10/11 June, 1985 18. Miss S. Gaonkar Airhostess 3/4 April, 1985 19. Miss R.R. Phansekar Airhostess 29/30 April, 1985 AIRCRAFT INFORMATION

2.4.1 General

2.4.1.1. Boeing 747-237B 'Kanishka' aircraft VT-EFO was manufactured by Messrs Boeing Company under Sl.No. 21473. The aircraft was acquired by Air India on 19th June, 1978. Initially, it came with the expert Certificate of Airworthiness No. E-161805. Subsequently, the Certificate of Airworthiness No. 1708 was issued by the Director General of Civil Aviation, India on 5th July, 1978. The C of A was renewed periodically and was valid upto 29th June, 1985. From the beginning of June, 1985, C of A renewal work of the aircraft was in progress. The aircraft had the Certificate of Registration No. 2179 issued by the DGCA on 5th May, 1978. The commercial flight of 'Kanishka' aircraft started on 7th July, 1978.

2.4.1.2 The aircraft was maintained by Air India following the approved maintenance schedules. It had logged 23634:49 hours and had completed 7525 cycles till the time of accident.

2.4.1.3 The aircraft was fitted with four P & W JT9D-7J engines having thrust rating of 48650 pounds. The hours and cycles logged by the engines since new till the time of accident are as given below:

Engine No.1 : P662927-7J - 29,663:26 Hrs (9422 cycles)
Engine No.2 : P695610-7J - 20,810:28 Hrs (6031 cycles)
Engine No.3 : P695602-7J - 21,992:31 Hrs (6564 cycles)
Engine No.4 : P662926-7J - 32,332:15 Hrs (11295 cycles)

2.4.1.4 All the DGCA mandatory modifications and inspections applicable to the subject aircraft had been compiled with. No major component installed on this aircraft and its engines had exceeded the stipulated life period.

2.4.1.5 The last quarter Periodic Check of the aircraft was carried out on 24th May, 1985, at 23274:53 hours and 7439 cycles. Subsequent to this check, two Check 'B' schedules were carried out. The last Check 'B' was carried out on 17th June, 1985, at 23564:14 hours and 7510 cycles and was valid for 200 flying hours.

2.4.1.6 The aircraft had flown 359:56 hours and 86 cycles since last quarter Periodic Check and 70:35 hours and 15 cycles since last Check 'B' till the time of accident.

2.4.1.7 The last Flight Release Certificate was issued on 24th May, 1985 on completion of quarter Periodic Check and was valid for 1100 hours or 150 days elapsed time whichever occurred first. After the last departure from Bombay on 21st June, 1985, the aircraft had flown for 22:34 hours till the time of crash.

2.4.1.8 Mr. Rajendra, Maintenanace Manager, Air India, Montreal carried out the Terminal Transit Check 'E' of the aircraft at Toronto on 22nd June, 1985 and no snag was observed by him. No snag was reported by the flight crew during the flight from Toronto to Montreal. Transit Check 'C' of the aircraft for the flight AI-182 was carried out at Montreal by Mr. Rajendra and three Air Canada technicians. The flight engineer also carried out his pre-flight inspection and found that the rear latch handle of the fifth pod engine fan cowl was loose. He informed the same to Mr. P. Bayle, Air Canada technician who faired the handle and applied high speed tape. No other snag was observed during the inspection.

2.4.2 Previous Incidents and Snags

2.4.2.1 A maintenance Group was formed with representatives from Air India and Airworthiness Directorate with Mr. R.K. Paul, Senior Air Safety Officer as the Group Leader to scrutinise the maintenance documents and various defects experienced on this aircraft. The report submitted by the Group (Attachment 'B') indicates that the aircraft was involved in six incidents since the last C of A renewal, details of which are given below

(I) On 13th July, 1984 at Dubai -- flight AI-868 The aircraft returned after aborting take off due to no rise in the EPR and N1 on No.1 engine (Sl.No. 695612). The engine front and rear were checked and found OK. Slight wetness was noticed in the bleed outlets. No external oil leak was noticed. Oil quantity was topped up. The chip detectors and oil filter were found OK. EVC Ph filter was found

OK. EVC linkage wes exercised. The engine was run up and its operation was found satisfactory. The snag was suspected to be due to lack of pressurising air at low N1.

(ii) On 18th July, 1984 at Delhi -- flight AI-105 The right hand side fuselage skin between stations 480 and 500 in line with lower portion of forward cargo door cut-out was damaged by high lift. The same was repaired at Delhi. Permanent repair was carried out at Bombay. The repairs were accomplished using guidelines given in the Boeing Structural Repair Manual.

(iii) On 12th August, 1984, at Rome -- flight AI-135 The aircraft landed with No. 2 engine (Sl.No. 662826) shut down in flight due to oil pressure and oil quantity droping. On motoring the engine, oil leak was observed from metal line between F C O C and L O P switch at the switch end. The line was found cracked which was welded and refitted. The line was subsequently replaced at Bombay.

(iv) On 24th October, 1984, at London -- flight AI-104 There was total loss of No.1 hydraulic system fluid. The fluid leak was traced to inlet pressure adapter of flap control module in the left hand body gear wheel well. Two of the four bolts holding the adaptor on the flap control module had sheared. The hydraulic pump, seal, back-up ring and case drain filter were replaced. The flap control module was replaced when the aircraft arrived at Bombay.

(v) On 14th February, 1985, at Delhi -- flight AI-164 On arrival the leading edge honey comb of the left hand aft trailing edge flap was found damaged about 18 inches in length due foreign object damage. Necessary repair was carried out at Delhi. The aft flap was replaced at Bombay.

(vi) On 28th May, 1985, at Dubai -- flight AI-103 On arrival, the left hand wing to fuselage botton fairing forward rubber seal with strip was found turn off. Temporary repair was carried out at Dubai. Permanent repair was carried out subsequently at Bombay.

2.4.2.2 The flight snags recorded in the flight report books of the aircraft during the 4 1/2 month period prior to the accident were scrutinised by the Maintenance Group and the only significant repetitive defect observed was "R2 door not going to manual". On ground checks by the aircraft maintenance engineers, the operation of the selector was, however, found normal.

2.4.2.3 Prior to operating the accident flight, the aircraft arrived at

Toronto from Frankfurt. Capt. R.K. Spencer was the commander of the flight. The flight crew had reported the following three snags:

(I) HF system No. 2 had a lot of distortion

(ii) E P R L indicator unserviceable in 'Go around' mode

(iii) Hydraulic system No.1 pressure indication unserviceable (This snag was carried forward from Delhi).

2.4.2.4 The Auxiliary Power Unit (APU) was unserviceable ex-Bombay and had been released under M E L.

2.4.2.5 For rectification of the above stated snag No.1, Shri Rajendra, Air India's Maintenance Engineer at Totonto checked the connections of the transreceiver and reracked the unit. No snag was reported on this system on Toronto-Montreal sector.

2.4.2.6 Snag No. 2 was carried forward.

2.4.2.7 Regarding the third snag, Mr. Rajendra has stated that the indicator showed 4000 P S I pressure even with no pump running. He therefore, interchanged No.1 and No.3 indicators. The snag, however, persisted. He then replaced transmitter No.1 with a spare transmitter from the aircraft SE box and the snag was rectified. No rectification work was however, recorded by the AME in the Flight Report Book. No snag was reported on this system on Toronto-Montreal sector.

2.4.3 Installation of 5th Pod Engine

2.4.3.1 On 8th June, 1985, No.1 engine of Air India Boeing 747 aircraft VT-EGC operating flight AI-181 failed during take off at Toronto. The aircraft returned and the engine was replaced by a loaned engine from Air Canada. The removed engine was a P & W JT9D-7Q type (Sl. No. P702353-7Q).

2.4.3.2 Air India had planned to bring back the failed engine of VT-EGC aircraft to Bombay, as fifth pod on their flight AI-181/182 of 22/23 June, 1985 and had sent an Engineer along with the necessary kit to Toronto on 15th June, 1985. The engine borrowed from Air Canada on 8th June, 1985, was flown back to Toronto as a fifth pod engine on flight AI-181 of 22nd June, to return it to Air Canada.

2.4.3.3 Shri C.D. Kolhe, Controller of Airworthiness, Bombay examined the aspects relating to installation of the 5th Pod engine, loading of its components and certification of the related work. Shri Kolhe's report indicates that the failed engine and the associated parts were kept in the Air Canada engineering hanger at Toronto airport since June 8 when the aircraft was brought to the hanger for engine replacement. Air India requested Air Canada on 15th June, 1985, for prepairing the failed engine for installation as fifth pod engine on 22nd June. Accordingly, Air Canada's technicians undertook the preparatory work of removing the cowlings, fan blades, panels, locking of compressor, turbine rotors etc. on 17th June, 1985, and completed the work on 21st June, 1985. The fan blades (46 in number) from the failed engine were placed in 12 wooden shipping boxes provided by Air India. These boxes were then loaded in a container. The other components of the failed engine were loaded on 4 pallets.

2.4.3.4 Installation of the fith pod engine was carried out by Air Canada technicians and the individual items on the task card were certified by the individuals who had carried out the work.

2.4.3.5 Some difficulty was experienced while loading one of the pallets having inlet cowl of the pod engine. To enable loading of the cowl, Air Canada engineering/maintenance personnel removed door stop fittings from the aft cargo compartment door cut-out. After removal of the fittings, the pallet could be loaded. All the removed fittings were then re-installed. Removal and installation of the fittings was certified by Mr. Rajendra.

2.4.3.6 A question arose whether removal of the door stop fittings could have caused some difficulty in flight. From the video films of the werckage it was found that the complete aft cargo door was intact and in its position except that it had come adrift slightly. The door was found latched at the bottom. The door was found lying along with the wreckage of the aft portion of the aircraft. This indicates that the door remained in position and did not cause any problem in flight. In the front cargo compartment, there were 16 containers out of which four were empty. Five containers had baggage of Delhi bound passengers. Container at Position 13L had baggage of the first class and London passengers and container at position 13R had crew baggage. The entire baggage of passengers ex-Montreal was loaded in containers at positions 12R, 21R, 22R, 23R and 24R in the front cargo compartment. Container at position 24L contained fan blades in wooden boxes and the other components of the pod engine. Valuable container was at position 14R.

2.4.3.7 In the aft cargo compartment, there were four pallets containing parts of the fifth pod engine and two containers at positions 44L and 44R containing baggage of Delhi bound passengers. The bulk cargo compartment contained passenger baggage bound for Delhi and Bombay. All the baggage and engine parts in the aft and bulk cargo compartments were loaded at Toronto.

2.4.3.8 The total weight of the fifth pod engine and its items was about 9000 kgs. As a result of carriage of the fifth pod engine, the payload of the flight was considerably reduced on London-Delhi sector.

2.4.3.9 At the time of take off from Montreal the aircraft had 104,000 kgs of fuel on board which was adequate for 08:40 hours of flying as against sector flying time of 06:15 hours. The flight plan fuel was calculated taking Paris as the alternate airport for London.

2.4.3.10 The load and trim sheet from the sector Montreal London was prepared and was duly counter-signed by the commander. The take off weight of the aircraft was 317,877 kgs which was within the maximum take off weight limit of 334,500 kgs. The estimated landing weight of the aircraft was 237,177 kgs which was also within the maximum landing weight limit of 256,279 kgs. The centre of gravity of the aircraft was at 21.3 percent

of MAC at take off and the estimated C G position at the time of landing at London was 25.8 percent of MAC which was within the limits.

2.4.3.11 The load and trim sheet and the flight plan of the aircraft indicated that there was 301+2 passengers on board the aircraft whereas there were actually 301+6 passengers on board. The error occured because four of the six infants were not taken into account.

2.4.4 Corrosion Control Measures

2.4.4.1 Boeing Company have recommended various measure to control corrosion on Boeing 747 aircraft through different documents such as Maintenance Planning Data Document, Corrosion Prevention Manual and Service Bulletins. Compliance of these measures on Air India fleet is accomplished as follows:

(I) Support structure under galleys and lavatories

Boeing Company have recommended repeat inspections of under galley/ toilet structure at intervals of 12000 hours. However, in order to detect corrosion at an early stage, these inspections are carried out by Air India at intervals not exceeding 9000 hours.

(ii) Fuselage Lower Bilge Area:

Boeing Company have recommended modifications to provide improved drainage systems by incorporation of various Service Bulletins. All the relevant modification have been completed by Air India on the affected aircraft. In addition to completion of these modifications, repeat inspection of lower bilge area is being carried out to meet the requirements of Boeing Service Bulletins.

(iii) Canted Pressure Deck:

In order to prevent water accomulation and consequent corrosion in the area, Boeing Company have issued SBs 51-2015, 51-2026 and 51-2032. Air India have incorporated Service Bulletins 51-2015, and 51-2032 on all their affected airplanes SB 51-2026 is being complied progressively.

(iv) Cargo Compartments:

Inspection of all the cargo compartment interior structures for corrosion and cracks is being accomplished periodically by Air India after removal of linings and insulation blankets.

(v) Aft Pressure Bulkhead:

During every equalised Periodic Check routine, the aft surface of aft pressure bulkhead is being visually inspected for corrosion condition and security of attachements. The forward surface of the pressure bulkhead, which is covered by aft toilets, is inspected after removal of toilets at intervals not exceeding 9000 hours although the recommended interval by Boeing Company is 12000 hours.

2.4.4.2 Air India has stated that in addition to the above specific measures, aircraft structure particularly the areas below toilets, galleys, cargo compartments, outflow valve area etc. which are prone to corrosion, are inspected for corrosion, cleaned and protected during every equalised Periodic Check. Air India have further stated that no serious corrosion problem has been experienced by them so far on their fleet.

2.4.5 Supplemental Structural Inspection Programme

2.4.5.1 In the case of airplanes which have completed 10,000 flight cycles as on June 30, 1983, Federal Aviation Administration (FAA) U S A and Boeing Company had recommended additional structural inspections known as Supplemental Structural Inspection Programme. In the Air India fleet, the first three 747 aircraft, namely, VT-EBE, VT-EBN and VT-EBO fell in this category and are known as 'Candidate Airplanes'. The subject aircraft (VT-EFO) had completed only 7525 flight cycles at the time of the accident on 23rd June, 1985, and therefore, the Supplemental Structural Inspection Programme was not applicable to this aircraft.

2.4.6 Special Corrosion Inspection of B-747 Aircraft Fleet of Air India

2.4.6.1 In order to examine whether corrosion to the aircraft structure of Kanishka aircraft could have contributed to the accident, a group was constituted by Mr. H.S. Khola, Inspector of Accidents to carry out special corrosion Inspection of all the Boeing 747 aircraft of Air India.

The group consisted of the following members:

(a) Senior Air Safety Officer of the D.G.C.A.

(b) Senior Airworthiness Officer of the D.G.C.A.

(c) Air India's Representative.

2.4.6.2 The inspection was carried out in the following areas:

(a) Below toilets and galleys

(b) Forward and aft cargo compartments belly areas - internally and externally

(c) The forward and aft pressure bulkheads

(d) Canted pressure web area from inside the passenger cabin.

(e) Area around outflow valves

(f) MEC area inside and outside.

2.4.6.3 The inspection reports submitted by the Group show that no corrosion was noticed on the significant primary structural members of the aircraft. Surface corrosion was, however, noticed on some of the members below the toilets and galleys. The corrosion observed during the inspection was of minor nature which is normally expected on such inspection schedule. The Kanishka aircraft was subjected to Periodic Check on 24th May, 1985 at 23,274.53 hours/7,439 cycles and no significant corrosion was observed. Among the Nine 747 aircraft inspected for corrosion, 5 aircraft had logged hours more than the Kanishka aircraft. Three of the aircraft had actually logged nearly double the flying hours. Taking into consideration that the corrosion prevention measures recommended by the Boeing Company were followed by Air India and that even the high life aircraft (45,000 hours approximately) subjected to corrosion inspection at the time when Periodic Check was due i.e. 1100 hours since previous check, had no significant corrosion, it is considered unlikely that Kanishka aircraft, which had logged only 23,275 hours since new and 360 hours since last Periodic Check, had corrosion which could have contributed to the accident.

METEOROLOGICAL INFORMATION

2.5.1 A report on the Meteorological conditions prevailing en-route near the location where the aircraft crashed was provided by the Meteorological Service, Department of Communications, Dublin, Ireland. This report covers a period of one to two hours before and after the time of accident (0714 Z).

2.5.2 From the report it is seen that the surface Synoptic Situation in the vicinity of 51°N, 12.50°W at 0715 Z on 23rd June was as given below:

Surface wind : 250/15 knots

Surface visibility : 10 Kms (occasionally 4 kms in drizzle)

Surface temperature : 13°C

Cloud conditions : Cloud cover in the area was estimated to have been layered upto about FL 100 with a base of 600 feet. There is no evidence of cumulonimbus or thunderstorm activity.

Freezing Level : 700 feet.

2.5.3 With regard to Upper Air situation the report indicates that a mainly West or West North West airflow covered the area of FL 310 The Jet stream was centred at about 48°N. The estimated wind and temperature at FL 310 were 270/65 knots and -47°C. As per the report, at FL 310, 51°N 12.50°W and at 0715 Z any significant clear air turbulence was not expected.

2.5.4 Sunlight condition was prevailing at the time of accident. There were no sigmets valid for the area at that time.

AIDS TO NAVIGATION

2.6.1 The aircraft was equipped with Inertial Navigation System (INS) and was cruising normally at its assigned flight level 310 on track X-ray over Atlantic. It was under the control of Shannon Upper Area Control and was being monitored on the Secondary Surveillance Radar (SSR) located at Mount Gabreal. Till the time of accident, the aircraft was beyond the range of Shannon primary radar.

2.6.2 The aircraft entered Shannon airspace at the correct position and level and remained on the assigned track and flight level till it disappeared from the radar screen.

2.6.3. There is no evidence to indicate that AI-182 experienced any navigational problem during the flight.

COMMUNICATIONS

2.7.1 Two-way communication between the ill-fated aircraft and the ATS units of Canada and Ireland was maintained during the flight from Montreal till the time of crash. The communications were recorded on the ATC tapes. Transcripts of the relevant tapes were provided by the Canadian Aviation Safety Board and the Director of Air Traffic Services, Ireland.

2.7.2 From the Transcript of the conversations, it is observed that two-way communication between AI-182 and the various ATS units was normal. The last R/T contact with the aircraft was at 0709:58 Z when AI-182 informed Shannon UAC that it was squawking 2005. The tape transcript also shows that the aircraft did not transmit any information regarding the emergency on frequency 131.15 MHz on which it was last working with Shannon UAC or on distress frequency 121.5 MHz. Indecipheiable noise was, however, found recorded on the Shannon ATC tape just at the time of crash i.e. 0714:01 Z. Thereafter, repeated calls were made by Shannon UAC to AI-182, but there was no response.

SEARCH AND RESCUE

2.8.1 The report of the Search and Rescue Group gives the details of the Search and Rescue operations. From the report it is seen that at 0730 Z, Shannon UAC informed Marine Rescue Co-ordination centre (MRCC) shannon that AI-182, a Boeing 747 aircraft enroute Montreal-London had disappeared from the Secondary Surveillance Radar (SSR) at 0713 Z in position 51N/120W. Shannon UAC requested MRCC Shannon to take emergency section. At 0740 Z MRCC Shannon telephonically explained the situation to Valantia Coast Radio Station (CRS) and requested a PAN Broadcast urgently and to ask any vessels in area to keep sharp lookout and report to Valantia Radio. At 0746 Z Valantia Radio transmitted to all stations PAN message and above advice to ships. The transmission was repeated.

2.8.2 At 0750 Z, an Irish Naval Vessel AISLING reported on R/T to Valantia Radio that it was 54 miles from site of accident and was proceeding to the site. Valantia Radio passed on this information by Telex to MRCC Shannon. Between 0740/ 0750 Z MRCC briefed the Irish Naval Service (INS) Haulbowline, MRCC Swansea, RCC Plymouth and Irish Army Air Corps (IAAC) on the situation. At 0754 Z MRCC relayed a distress message to Shannon Aeradio via the Aeronautical Fixed Telecommunication Network (AFTN)

2.8.3 At 0803 Z Valantia Radio again transmitted the PAN message and the advice to ships. At 0840 Z Cargo vessel M W Laurentian Forest/ HBWP (Registered in PANAMA and owned by Federal Commerce of Montreal, Canada) at position 51.09N/12.18W reported that it was 22 miles away from distress area and was proceeding there. Laurantian enquired if there were other ships in the area and was informed about position of Aisling. At 0813 Z Valantia Radio informed MRCC Shannon by telex about Laurentain Forest.

2.8.4 Between 0815/0820 Z, MRCC Shannon updated RCC plymouth and they advised that a Nimrod Rescue Aircraft would depart shortly for the area and that SEA KING helicopters were already enroute the Cork Airport initially. Edinburgh RCC advised MRCC Shannon that a Nimrod Rescue Aircraft was also being prepared at Kinloss. At 0820 Shannon Aeradio informed Valantia Radio that there was message from Shanwick Oceanic Control that aircraft were picking up ELT signal in position 51N/15W and 51N/08W and the actual position was beleived to be 51W/1250W. At 0833 Z, Valentia Radio sent message giving the above information and requesting ships in the area to report to Valentia Radio.

2.8.5 At 0842 Z, Ali Baba informed Valentia Radio that it was at position 5125.5N/0825.4W and was listening on 121.5 MHz. At 0850 Z Western Arctic informed Valentia Radio its position 5207N/1151W and that it would proceed in about 20 minutes after bringing in cable. At 0857 Z, High Seas Driller informed Valentia Radio that Vessel Kongstain could be released, ETA 51/2 to 6 hours and they would standby. At 0858 Z, Valentia Radio informed MRCC Shannon about reports from Ali Baba Western Arctic and High Seas Driller.

2.8.6 At 0905 Z, Laurentian forest reported to Valdentia Radio that it was 5 miles from SOS position 51N/12.5 W and it had not sighted anything. Between 0905/0908 Z, three more vessels viz. Atlantic Concern, MV Norman Amstel and MV Tasman reported their positions to Valentia Radio. At 0908 Z, Swansea advised MRCC Shannon that four Seaking helicopters and two Nimrod Aircraft were enroute.

2.8.7 At 0913 Z, Laurentin Forest reported to Valentia Radio that they had sighted what looked like 2 rafts about 2 miles away. At 0914 Valentia Radio informed MRCC Shannon about the report from Laurentian Forest.

2.8.8 At 0918 Z, Laurentian Forest reported to Valentia Radio that it had sighted wreckage in water at position 5101.9N/1242.5W and the liferafts were not inflated. Valentia Radio passed the message to MRCC Shannon at 0920 and also sent transmission about wreckage sighting. Lifeboats Valentia and Baltimore reported to Valentia Radio that they were proceeding to the position of wreckage.

2.8.9 At 0937 Z, Laurentian Forest reported that it had sighted 3 bodies in water. Valentia Radio informed the same to MRCC Shannon at 0940 Z. At 0945 Z, MRCC Shannon and MRCC Swansea decided that for security and operational reasons Cork Airport would be the primary operational base and ATC Cork were informed of this decision.

2.8.10 At 0953 Z, S MYROLI informed Valentia Radio that it was 80 miles north of position and had a group of 10 to 20 French vessesls and desired to know if they should proceed to site. After consulting Laurentian Forest, S MYROLI was advised that it was not necessary. Valentia Radio kept on giving Mayday relay frequently.

2.8.11 At 1045 Z, a prohibited flying area was established with a radius of 40 N Miles from the datum point from sea level to 5000 feet. Falmouth Coast Guard reqested Valentia Radio the position of all ships in the distress area and those proceeding so that each vessel could be designated to search a particular area.

2.8.12 At 1126 Z, Laurentian Forest reported Valentia Radio that it had located numerous bodies in water and Seaking helicopter was hovering there. Valantia Radio Transmitted this information to all stations.

2.8.13 At 1133 Z, Valentia Radio informed Coast Guard Falmouth the position and ETA of various ships and also of the Lifeabouts Valentia and Beltimore. At 1150 Z, RRC Plymouth requested MRCC Shannon that "Le Aisling" assume duty as "On Scene Commander Surface Unit". At 1204 Z, information was received by Valentia Radio that 8 Spannish Trawlers were proceeding to distress position of AI-182 and their ETAs were between 1630/2000 Z. At 1246 Z, Star Orion informed Valentia Radio that it would be able to refuel any vessel in medium or small quantities at the accident site. Valentia Radio informed MRCC Shannon and Falmouth about the Spanish Vessels and Star Orion.

2.8.14 Falmouth requested Valentia Radio at 1303 to advise Laurentian Forest to inform Aisling that 8 Spanish trawlers would arrive in search area between 1600 Z and 2000 Z and Aisling should deploy trawlers in conjunction with lifeboats to recover bodies as it would be easier to recover than from large vessels. Valentia Radio sent the above message.

2.8.15 Laurentian Forest informed Valentia Radio at 1307 Z that 10 bodies were on Aisling, 4 on Helo, and they had some alongside and had launched lifeboats to pick them up. Valentia Radio informed the same to MRCC Shannon and Falmouth. At 1338Z, MRCC Shannon requested Valentia Radio to include the following in their broadcast:
"Vessels within 100 N Miles of datum 5101.9N/1242.5W are requested to proceed to search area and contact Aisling/EIYP. Any vessels recovering bodies or wreckage are requested to retain them on board and inform MRCC Falmouth of total number of bodies recovered."
2.8.16 Valentia Radio transmitted the above message at 1340 Z to all stations and also informed MRCC Shannon. At 1503 Z Aisling informed Valentia Radio that they had recovered 56 bodies. MRCC Shannon requested Valentia Radio to advise Aisling that if they could locate "Black Box", they should drop buoy. Valentia Radio advised Aisling accordingly. At 1530 Z, on advice from MRCC Shannon, Valentia Radio asked Baltimore, Courtmaesherry and Ballycotton lifeboats to return to base. At 1633 Aisling requested Valentia Radio to inform Falmouth that they were unable to transfer bodies to Valentia Lifeboat as latter was returning to base owing to fuel shortage. At 1659, Laurentia Forest informed Valentia Radio that 66 bodies had been picked up by then. Aisling advised Valentia Radio that Valentia lifeboat was returning with four bodies.
2.8.17 At 1721 Z Falmouth requested Valentia Radio to relay following to all surface units at scene:
1. One mimrod remaining on scene overnight.
2. All other air units will be recalled at 2200 Z. One Helo remains at 15 minutes notice at Cork
3. Air Search recommences at 240400 Z.
4. All Civil surface units will be released by 2200 and may proceed on passage. Bodies should be landed at Irish Post for transfer to receiving station at Cork Airport.
5. Warship Challenger, Emer and Aisling acknowledge".
2.8.18 At 1723 Z Aisling informed Valentia Radio that they saw 3 Spanish vessels approaching and they were using Ch.16 which Aisling

was using for co-ordination with RESCUE 52 and requested that Spanish Vessels be asked to stay outside 5 miles radius. Spanish Agent was told about Aisling request.

2.8.19. Valentia lifeboat informed Valentia Radio that they were heading for home (Valientia) at reduced spead of 11 knots and they had five bodies on board. At 1822 Z, Aisling requested Valentia Radio information on 'Black Box' that might help its location. Aisling was advised of ELT signal on 121.5 MHz. At 1840 Z Cork ATC Advised MRCC Shannon that a total of 64 bodies were in Cork.

2.8.20 At 1920 Z, MRCC Shannon downgraded the 'MAYDAY' Broadcast to 'PAN' (Urgency) Broadcast, Aisling informed Valentia Radio that 79 bodies had been recovered. At 1958 Z Laurentian Forest informed Valentia Radio that they were proceeding to Dublin. Valentia Radio thanked them for assistance.

2.8.21 At 2000 Z, MRCC Swansea advised MRCC Shannon that main air search would cease at 2200 Z and would recommence at 240400 Z. The overnight search would continue with one Nimrod providing air cover for the surface search by three warships. Vessels transiting the area were requested to keep a sharp look out and to report to HMS Challenger.

2.8.22 By 0300 Z on 24th June, four Seaking helicopters had deported from Cork to resume the airborne search. At that time the search area covered a six nautical mile radius of position 5059.2 N/1225.3W and the vessels Le Emer and HMS Challenger were requested to search this area. HMS Challenger was the coordinator of the surface search and Nimrod Rescue 02 was on-Scene-Commander.

2.8.23 At 0450 Z Rescue 02 reported sighting of wreckage in position 5101 M/1245 W. Between 0505 and 0543, three USAF Chinook helicopters departed from Cork Airport to join the search. At 0556, MRCC

Swansea confirmed that there were 329 people on board the aircraft (Earlier reportes had idicated 325 people on board).

2.8.24 A continuous search was maintained throughtout the day (24th June) but only one further body and numerous pieces of wreckage were recovered. An extensive surface search was also maintained throughout the day and instructions were passed by MRCC Shannon to Valentia Radio requestiong all shipping to recover any wreckage or bodies sighted.

2.8.25 At 0900 Z, Capt. G Mc. Stay of Department of Communications advised MRCC Shannon that Aisling was bound for Cork, ETA 1300 Z and he (Capt. Mc Stay) was assuming responsibility for collection of wreckage. MRCC were also advised by Mr. Gregory of Britoil that their two vessels 'Constine' and 'Star Orion' were enroute to Foynes having picked up quantities of wreckage.

2.8.26 At 1740 Z, SRCC Plymouth advised Shannon that the Search will terminate at 242200 Z, at 1800 Z Falmouth MRCC advised MRCC Shannon to direct the Portisheal and Valentia Radios to concel Urgency Broadcast from 242000 and to release HMS Challenger and Le Aisling from the search at 242000 hours. All the aircraft were released at 24000. It was also decided that Le Emer would remain at the area. At 242003 Z, a message was transmitted to all stations on R/T and W/T that air and sea search was being terminated at 242000 Z and all the participant were thanked for their assistance.

INJURIES TO PERSONS

3.1.1 Post mortem examination was carried out by Irish Authorities at Cork. At that time Wing Commandor Dr. LR. Hill was also present. Subsequently Air Vice Marshall Kunzru also reached Cork. Both of them were members of the Medical Group which had been constituted by Mr. H.S. Khola.

3.1.2 By then 131 bodies had been recovered. None of the bodies of the flying crew were revocered. The bodies which were recovered represented 39.8 per cent of the victims. The exact seating position of passengers is not certain, because it is known if the passengers had changed their seats after the take off of the aircraft from Montreal. On the information which is available, the passengers were supposed to have been as follows:-

Passengers: Seats Occupied Bodies Available identified Zone A 16 1 0 Zone B 22 0 0 Upper Deck 18 7 0 Zone D 112 104 + 2 29

Zone D 86 84 + 1 38 Zone E 123 105 + 3 50 Sub-Total 377 301 +(6 infants) 117 Crew: Flight Deck 3 3 0 Cabin 19 19 5 Total 399 329 122

3.1.3 The Post-mortem reports were examined by Wing Commander Dr. Hill. He submitted two reports being Exhibits H-1 and H-2. He was also examined in Court as Witness No. 2. Dr. Hill who had developed a system which would indicate the severity of the accident and the injuries suffered. He used a scale from 0 to 4, with naught being no injury and 4 being a fatal lesion. Though there is some amount of subjectivity involved in the system, nevertheless categorising the injuries according to the sacle does give an overall picture of what had happened to the victims. After adding up all the injury scale for a particular body, Dr. Hill in his Report Exhibit H-1 divided the injuries as under:-

No. of victims Mild injury (0-49) total 34.4% 45% Moderate injury (50-99) 38.9% 51% Severe Injury (100-149) 25.2% 33% Catestrophic Injury (150 +) 1.5% 2 Total 100.1% 131 3.1.4 A further break up showing the overall injury score of the recovered victims is as follows:

Minor Moderate Severe Zone No. % % No. % % No. % % Total C 8 6.1 17.8 9 6.9 17.7 4 3.1 11.4 21 D 9 6.9 20 15 11.5 29.4 9 6.9 25.7 33 E 15 11.5 33.3 15 11.5 29.4 14 10.7 40 44 Unknown 13 9.9 28.9 12 9.2 23.5 8 6.1 22.9 33 Total 145 34.4 100 51 39.1 100% 35 26.8 100% 131 3.1.5 The reports submitted by Dr.Hill further indicted as follows

(a) There were 30 children recovered and they showed less overall injury. The average severity of injury increases from zone C to E and is significantly less in C than in Zones D and E.

(b) Flail pattern injuries were exhibited by eight bodies, five of these were in Zones E, one in Zone D, two in Zone C and one crew member. The significance of flail injuries is that it indicates that the victims came out of the aircraft at altitude before it hit the water.

(c) There were 26 bodies that showed signs of hypoxia (lack of oxygen), including 12 children, 9 in Zones C, 6 in Zone D and 11 in

Zone E. There were 25 bodies showing signs of decompression, including 7 children. They were evently distributed throughout the zones, but with a tendency to be seated at the sides, particularly the right side (12 bodies).

(d) Twenty-three bodies showed evidence of receiving injuries from a vertical force. They tended to be older, seated to the rear of the aircraft (4 in Zone C, 5 Zone D, 11 inZone E, 2 crew and 1 unknown), and 16 had little or no clothing.

(e) Twenty-one bodies were found with no clothing, including three children. They tended to be seated to the rear and to the right (3 in Zone C, 5 in Zone D, 11 in Zone E and 2 unknown).

(f) There were 49 cases showing signs of impact-type injuries, including 19 children (15 in Zone C, 15 in Zone D, 15 in Zone E, 1 crew member and 3 unknown).

(g) There is a general absence of signs indicating the wearing of lap belts.

(h) Pathological examination failed to reveal any injuries indicative of a fire or explosion.

3.1.6 In his testimony in Court, Wing Commander Dr. I.R. Hill further stated that the significance of flail injuries being suffered by some of the passengers was that it indicated that the aircraft had broken in mid-air at an altitude and that the victims had come out of the aeroplane at an altitude. He further explained that if an explosion had occurred in the cargo hold, it was possible that the bodies may not show any sign of explosion. It may here be mentioned that the forensic examination of the bodies do not disclose any evidence of an explosion. Furthermore, the seating pattern also shows that none of the bodies from Zone A or B was recovered, in fact as per the seating plan Zone B was supposed to have been unoccupied. This Zone is directly above the forward cargo compartment.

3.1.7 Dr. Hill further stated that the pattern of the accident as suggested by the injuries indicated that it was a complex affair and there were at least two phases of injuries, one in the air and the other at water impact. In answer to a specific question that if there was an explosive device in the cargo hold then could the passengers who were seated have suffered such injuries, the answer of Dr. Hill was that "it is possible". According to him, the pattern of injuries indicated that if there was an explosion in the aircraft it was more likely that the explosion had occurred in the rear cargo compartment than in the front cargo compartment. This conclusion was apparently based on the fact that, according to him, in zone E of the aircraft there were larger vertical load type injuries. Dr. Hill was also asked if he had to make any suggestions which would minimise injuries to passangers in the event of an accident. In answer, the witness made his suggestion in the following words

"There are very complicated things one would have to do such as rearward facing seats; having safety belts which incorporated restraint for the upper part of the body; increasing the space between aircraft seats; incorporating shocks absorbing system within the seat and using materials which do not break easily like plastic. We would also need fuel systems which would not immediately set on fire and furnishing which would be resistant to burining, and also passengers should not carry into the aeroplanes large amount of hand bags which only get in way in the event of evacuation, and I personally feel that the carriage of large amount of alchohol both in the passengers and in the aeroplane is a hazard to flight and safety. Finally the passengers should take heed of the flight safety instructions given to them by the crew of the aeroplane".

3.1.8 Air Vice Marshal Kunzru, witness No. 10 in his report dated 14th November, 1985, Ex.A-48, gave his comments not only on the post-mortem reports but also on the statement of Wing Commander Dr. I.R. Hill. With regard to the post-mortem examination, the comment of AVM Kunzru was as follows:

"All victims have been stated in the PM reports to have died of Multiple injuries. However two of the dead, one infant and one child, are reported to have dies of Asphyxia. There is no doubt about the asphyxial death of the infant. In the case of the other child (Body No. 93) there could be doubt because the findings could also be caused due to the child undergoing tumbling or spinning with the anchor point at the ankles.

Three other victims undoubtedly died of drowning. There was no evidence of significant Lap-belt injuries.
Considering rupture of the ear-drum, without injury to skull, as a criterion to indicate rapid decompression, two cases may be considered to fall in this category.
Histological examination has been carried out only in 57 bodies out of 131. Lung examination on almost all of them showed decelerative changes. Six bodies (Nos. 6,22,70,103,121 and 131) showed presence of Bone Marrow Embolism in Lung Sections. Though not of much significance in this accident, this finding does indicate survicval after a bony injury for an undefined period of time No evidence of fire burns or explosive material, other than Kerosene burns on some bodies, which I had myself seen at Cork, could be found. Kerosene burns in such acidents is a fairly common findings and is of no significance".
AVM Kunzru generally agreed with the crash injury analysis on the victims which had been furnished by Wing Commander Dr. Hill. He, however, gave the following comments with regard to hypoxia, decompression and decelerative changes:
"Hypoxia : The main Post Mortem findings in hypoxia is generalised congestion if the hypoxia is of the type described as "hypoxic hypoxia". In other causes of hypoxia of more severe degree such as "histotoxic hypoxia", "asphyxia" or "drowning" additional histological findings such as petechial haemorrhages and generalised congestion, and lung findings such as haemorrhage and extrusion of alvoolar phagocytos are seen.
Decompression : The term used by Dr. Hill is "Decompression". It is presumed that he means "Rapid/Explosive Decompression" which occurs within one Sec. and not "decompression sickness" which takes a minimum of 5 to 7 mnts to occur even at 31,000 ft. altitude and which in this case can positively be ruled out.
The Post-Mortem and histological signs of rapid Decompressions are :-
(a) Possibility of rupture of Ear drums without any injury to the skull.
*(b) Patchy Lung Haemorrhages
*(c) Emphysomatus changes

*(These occur more commonly in those cases where the individual was in the phase of breathing-in at the time of decompression.

3.1.9 If it is assumed that the aircraft suddenly broke up in Mid-Air at an altitude of 31,000 ft. the bodies will be at once exposed to hypoxia and rapid decompression and as a consequence will suffer body changes as mentioned above. As the aircraft/occupants start descending, they will be exposed to increasing amounts of Oxygen and as soon as ;they come down below 15,000 ft. and then below 10,000 ft. the effect of hypoxia rapidly diminishes. Finally, the aircraft/individuals come down and hit the ground/water with a very heavy impact, thus submitting the individuals to extremely severe G-loads of decelarative type.

Decelerative Changes : Decelerative impact brings about well established changes in the lungs besides many other associated injuries. It is relevant to note the decelerative lung changes which are :-

(a) Patchy haemorrhages in Lung.
(b) Marked Emphysomatus Changes.
(c) Extrusion of alvoolar Phagocytes
(d) Desqummation of bronchcolar epitherium.

"Comparative study of the PM/histological findings of hypoxia, Decompression and Decelerative Lung injuries reveal that they are more or less similar. Decelerative injury being the most severe of the three and last to occur tends to so modify the Post-Mortem and Histological findings that it becomes extremely difficult and some times impossible to isolate one from the other."

3.1.10 AVM Kunzru was, therefore, of the opinion that in this accident evidence of hypoxia/decompression (except in 2 cases) had not been confirmed or established.

3.1.11 The difference of opinion between Wing Commander Dr. hill and AVM Kunzru, with regard to evidence of hypoxia and decompression, is of no significance in the present case. What is important to note, however, is that they have agreed that the injury pattern does indicate break up of the aircraft in mid-air and that the occupants of Zone E had suffered the greatest amount of injuries as compared to the occupants of the other zones.

MAPPING, WRECKAGE DISTRIBUTION AND SALVAGE

3.2.1 Introduction

3.2.1.1 Oceanographic charts indicated that the depth of sea in the crash area was about 6700 feet and the site appeared to be a flat sea bed, without any valleys or hills. The immediate necessity after rescuing/ searching crash victims, was to locate and recover the digital flight data recorder (DFDR) and the cockpit voice recorder (CVR). The operation was unique of its kind and had never been undertaken earlier in the world at this depth of the sea. It required an equipment which could home on the transmitted signals from the underwater locater acoustic beacons fitted on DFDR/ CVR, identify the units, clear them from attachments/wreckages, grab them and bring them to the surface.

3.2.1.2 The pressure exerted by the water at 6700 feet below mean sea level is extremely high and the temperature is very low. No light penetrates to that depth and it is pitch dark. Scarab I fitted on French Ship "Leon Thevenin" which had undertaken the challenging job of locating DFDR and CVR, and recovering the same, was not designed to operate at 6700 feet depth. Its maximum design operating depth was only 6000 feet. However, it was decided to exceed the design operating depth for this emergency operation.

3.2.1.3 By using the preliminary information of probable area of location OF CVR and DFDR as indicated by ship 'Gardline Locator', the Scarab I was Lowered in the sea to locate and recover these units which it accomplished on 10.7.85 and 11.7.85 respectively.

3.2.1.4 Prior to recovery of DFDR/CVR by the ship 'Leon Thevenin', sufficient spade work was done by the ship 'Gardline Locator' (A ship provided by Accident Investigation Branch, U.K.) and 'Le Aoife' (an Irish Naval Ship). The survey of the crash area, carried out with the help of side-scan sonars fitted on these ships, had indicated a general distribution of the wreckage and a rough idea about the sizes of the parts. Each part of the wreckage was called a target. The method used for survey was triangulation with multiple passes through the crash site.

3.2.1.5 Next phase was the task of :

(a) Locating hundreds of pieces of wreckage by the combined use of sonar and video monitors.

(b) Video and still photography of the pieces of wreckage.

(c) Plotting the distribution of the wreckage.

All this was to be carried out under the directions of the Court.

3.2.2 Scarab

3.2.2.1 The means (vehicles/equipment) proposed to be used in the locating, mapping and video photography of the wreckage were the CCGS John Cabot and SCARAB II.

3.2.2.2 The John Cabot is an ice breaker of the Canadian Coast Guard. Since utilisation as an ice breaker is seasonal, the John Cabot is also equipped for submarine cable laying. In order to enlarge its capabilities in this regard, the John Cabot is equipped to have on its deck the Scarab and to operate it. Thus the John Cabot can be used for repair of submarine cables. The John Cabot has complete facilities for operation, maintenance and repair of the Scarab. This includes a Control Hut, a Test Room, Workshop, Stores etc. The John Cabot has considerable experience in work on deep sea bed.

3.2.2.3 The SCARAB II is a submersible craft assisting repair and burial of cables. As will be clear from the following details, the Scarab is not ipso facto a submarine. It is a total system for carrying out its complex functions.

3.2.2.4 The SCARAB II is a state-of-the-art system designed and built for tethered unmanned work at ocean depths of upto 6000 feet. Scarab's standard equipment are :

Two rugged manipulators.

A complete optical suite.

Six thrusters of 5 hp each.

CTFM Sonar.

Navigation System.

3.2.2.5 The manipulators have a choice of grippers/claws/cutters etc. of any required description and size. The Scarab has three TV cameras mounted on separate pan/tilt mechanism to allow real time observation and video tape documentation. A 35 mm still camera was also installed and used in the present work. There was a choice of quartz-iodide flood

lights to provide illumination.
3.2.2.6 The location and control of the Scarab is accomplished through a phased array navigation system.
3.2.2.7 The Scarab was equipped with a 360° high resolution Sonar with a range of 1000 meters. The Sonar was also capable of interrogating and detecting 37 KHz and 27 KHz pingers. It can function independently of the ship's facilities and is equipped with power generators and semiautomatic handling equipment.
3.2.2.8 The John Cabot can salvage items, but it is not a salvage ship as it does not have the specialised high capacity cranes, derricks etc. required for salvage of large objects. Further, it does not have deck space for keeping large salvaged items like the wings, fuselage or tail surfaces of an aircraft as large as a 747. The John Cabot was, therefore, adequate and fully satisfactory for the work envisaged in this phase of the programme, as salvage of large items was not planned in this phase. The task was, as mentioned earlier, locating, mapping and photography of the hundreds of pieces of wreckage. (The salvage work was part of the next phase of the programme).
3.2.3 Control and Monitoring of Operations
3.2.3.1 It was realised that the operation proposed would pose problems of control, monitoring and logistics.
3.2.3.2 Consider : A ship operating on the high seas in international waters on the task of locating, mapping and video photographing the hundreds of pieces of wreckage. The state of art system for Sonar location and photography (Scarab) used by the ship for handling this task. The group located on shore in charge of the operations. Finally, the Court in Delhi was in overall charge of the operatins.
3.2.3.3 It was realised that a proper line of control and communication was essential if the operations were to be smooth and successful.
3.2.3.4 Therefore it was decided that the following would be the chain of command :
Court Investigating the Accident
(Mr. Justice B.N. Kripal)

Control Centre at Cork
(Court's representative)
CCGS John Cabot
(Commanding Officer)
Scarab
(Project Manager)

3.2.3.5 Because of the multiplicity of agencies involved in the operations, the need was felt for a proper delineation of power at all levels. It was, therefore, decided that :

a. Overall responsibility for the operations would rest with the Indian authority viz. the Court. This would cover the identification and definition of assignment of the overall tasks, laying down of the priorities, overall control of the coverage of the operation and, finally, the time schedule for the operation.

b. Decisions taken at the Control Centre, flowing from the above, were to be taken solely by the Court's representative. The experts from CASB, NTSB and Boeing were free to give their views and recommendations, but the final decisions were to be left to the Court's representative. Examples of such matters are : Track of the survey, areas to be covered by John Cabot, assignment of priorities for specific tasks, amount of time to be devoted to any piece of wreckage, whether any item of wreckage is to be picked up, etc.

c. Operation Control of John Cabot would be in the hands of the Canadian Coast Guard Officer in the Control Centre, who would co-ordinate with the Commanding Officer of John Cabot. This would cover decision on feasibility or otherwise of operations under adverse weather conditions, manner of covering the area, method of retrieving any wreckage, etc.

d. Decisions relating to the Scarab (i.e. whether the weather was suitable for Scarab operations, whether the size, weight etc. of an item would permit its being picked up by Scarab, etc.) would be left to the Scarab Project Manager on Board John Cabot.

3.2.3.6 It might appear at first sight that in the above system excessive power was delegated at certain levels to the detriment of overall control. Any such impression would not be correct. In actual fact, because of proper delegation of responsibility and power at different levels, the operations were carried out with extraordinary efficiency, smoothness and coordination, In this connection, it is relevant to point out that the operations were not a uni-disciplinary one. The operation (aircraft accident investigation) was totally dependent on experts from other disciplines, like naval (coast guard) operations, deep sea photograph, salvage from sea bed etc. It was therefore, decided that for smooth and efficient operations, adequate power and responsibility should be delegated at all levels, particularly to specialists engaged in the different areas of work as above.

3.2.3.7 It was also considered that adequate communication was a sine qua non for smooth operation. Therefore, the following communication facilities were established :

Control Centre at Cork Airport

Telex

Telephones (2)

3.2.3.8 The ship John Cabot had both telex and telephone facility. These links were through satellite (IN MARSAT). The Control Centre was in continuous communication contact with John Cabot through telex and telephones. In order to establish a reliable and satisfactory line of communication it was decided that instructions or communication from Control Centre to the Indian experts on John Cabot would follow the path as under :

Control Centre

Court's representative --- Canadian Coast
Guard Officer

John Cabot

Indian experts --- Commanding Officer

3.2.3.9 It was felt that this would eliminate any possibility of inconsistent or contradictory orders/messages going to John Cabot.

3.2.3.10 With a view to have an ordered system of communications between the control centre and John Cabot (which is essential for proper control and monitoring of the operations), it was decided that John

Cabot would sent to the Control Centre daily Situation Reports (SITREPS) at specified times viz. 0800 hrs, 1200 hrs, 1600 hrs and 2000 hrs. This however did not preclude the despatch of telexes by both Control Centre and John Cabot at any other time.

3.2.3.11 In order to inform all agencies of the above system of Control and Communication a number of meetings were held. These were on 12.8.85 and 3.9.85 on board John Cabot and on a number of occasions at the Control Centre. The purpose of these meetings was not only to inform all concerned about the specific task, the programme and the line of control and communication but also to sort out differences and to understand the technical and operational difficulties faced by the personnel on the spot and to find a way out.

3.2.4 Daily Monitoring of Progress

3.2.4.1 It may be relevant to point out here that search, location and video photography work was to be carried out round the clock. Thus a considerable volume of data would be coming into Control Centre. This required regular, almost hourly, monitoring, study and analysis for (a) proper understanding of the data collected and (b) advising John Cabot of any changes in its programme, such as additional photography on an item etc. For this purpose (i) SITREPS were filed in the Control Centre (ii) all data (description, latitude and longitude) obtained on every target was tabulated and the cumulative list updated daily.

3.2.4.2 The location of the targets was plotted on charts every 4 hours. This was in addition to the plotting of targets carried out on John Cabot.

3.2.4.3 Every day (including holidays and week ends) all the officers posted at Control Centre assembled at about 0900 hrs. They studied the SITREPS received at 0800 hrs and any other telexes received from John Cabot in the night. The lists of targets were updated and the new targets plotted on the charts. John Cabot generally also sent brief remarks such as description, nature of failure/damage, dimensions etc. Discussions were held on the significance of the targets and their implications. Instructions if any to be telexed to John Cabot were also discussed. Similarly SITREPS received at 1200 hrs and 1600 hrs were studied.

3.2.5 Monitoring at Cork

3.2.5.1 The Scarab provided video tapes and still photographs. In the initial stages (upto 9.8.1985) the John Cabot was operating in peripheral areas and therefore few targets were found. Hence the output of videotapes was small. In fact upto 9.8.85, only about 10 targets were found and only 3 video tapes were used up. But later, when John Cabot came close to and into the crucial areas, video tapes were recorded at a fast rate. Further, still photography facility on the Scrab was activated at about this time. Therefore, arrangements were made periodically to obtain the video tapes and films from John Cabot. Video tapes and still photographs (these required to be processed) were transported from John Cabot to Cork Control Centre.

3.2.5.2 About 50 video tapes and nearly 3000 still photographs (positives and transparencies) provided the visual information on the targets.

Arrangements had to be made at Cork for such viewing and study of the video tapes and still photographs. Video equipment (TV monitor plus VCR) suitable for viewing the video tapes had to be arranged.

3.2.5.3 The still photography used special professional quality colour film (35 mm), each roll having 800 frames. The film was diapositive. These had to be developed and transparencies obtained from them. Thereafter negatives and prints had to be made. Special equipment for viewing the transparencies had to be provided for continuous work. The video tapes, transparencies and prints provided the principal means of monitoring of the results of the operation.

3.2.6 Operations

3.2.6.1 The Charts prepared by 'Gardline Locator' were on a different type of grid system, and had to be translated into LAT-LONG system, for use by John Cabot. For the convenience of search/mapping operation the search area was divided into 4 blocks viz. Block 1, Block 2, Block 3 and Block 4.

3.2.6.2 The navigation system used by John Cabot is PULSE-8 system. This system needs the transponders to be placed on the sea bed. These transponders help in getting the correct fix of a target and in obtaining relative positions of the targets on the sea bed which is highly useful for revisit for the purpose of rephotography or recovery. Initially 4 transponders were placed, and subsequently the number was increased as the search operation was continued. The strategic locations for placing the transponders was decided by considering :

(a) frequencies of relative transponders,

(b) distances required between relative transponders,

(c) wreckage distribution suggested by side scan sonar plots of Eithena and Garline Locator, and

(d) size of search area.

These transponders were calibrated to match the navigation system of the ship.

3.2.6.3 In order to obtain the maximum information from search, it was decided that the Scarab search paths should be as follows :

(a) Normally the search paths should be east to west, or west to east within the individual blocks.

(b) The pattern of search should be a parallel search method.

(c) Distances between the parallel paths to be 1,200 feet (i.e. 2 cable widths), for effective use of sonar fitted on the Scarab.

(d) If Scarab deviates from its planned path for photography or recovery, it should return to its planned path for further search.

(e) In each block, the search was to be made, at least 1/2 mile (North or South) beyond the last target sighted, so as to ensure no target is missed out from the given block.

3.2.6.4 However, when there was a need to modify the search pattern, due to wreckage distribution in particular areas, the following changes were made:

(a) Expanding box type search pattern was used in Block 1.

(b) Some North to South and South to North passes were made in Block 3.

(c) In Block 3 northern end, the distances between the search passes was reduced to 600 feet i.e. 1 cable width.

However, these deviations were made basically to improve the reliability of search in specific areas, as demanded by peculiar distribution of aircraft wreckage.

3.2.6.5 To facilitate identification of the wreckage located by Scarab it was necessary to position aircraft maintenance personnel on board the ship. As the aircraft structure was badly torn, mutilated and distorted, serious difficulty was anticipated in identification of small pieces of structure. It was therefore essential that these maintenance personnel were provided with aircraft photographs, manufacturing drawings, parts catalogue, wiring diagram manuals and maintenance manuals. Since carriage of such voluminous literature was not praticable, 3M micro film reader printer
machines with micro film cassettes of the above literature were produced and installed on the ship. In case of difficulty of locating any particular information, the engineers were advised to contact Cork Search Centre by telex or telephone who, in turn, could seek the desired information from the manufacturers.

3.2.7 Wreckage Distribution

3.2.7.1 The wreckage distribution as determined by the mapping of the sea bed provided some distinct distribution patterns. The depth of the wreckage varies between about 6000 and 7000 feet, and the effect of the ocean current, tides and the way objects may have descended to the sea bed was not determined, thus some distortion of an object's relationship from time of water entry to its location on the bottom cannot be discounted. In general, the items found east of long 12°43.00'W are small, lightweight and often made of a structure which traps air. These items may have taken considerable time to sink and may have moved horizontally in sea currents before settling at the bottom. Marks left on the sea bed beside some wreckage does indicate horizontal movement of the wreckage as it settled. Although badly damaged, sections 41, 42 and 44, and the wing structure were located in a relatively localized area centred about lat 51°03.30'N and long 12°47.80'W, and the wreckage scatter was oriented north/south. The wreckage scatter in this area was so dense that it is probable that some of the wreckage may not have been mapped or photographed. Section 46 and 48, including the vertical fin and horizontal stabilizer, extended in a west to east pattern with the western most identified aircraft component located at lat 51°02.90'N and long 12°50.1'N. The wreckage extended in a line about 110 degrees to an eastern position of lat 51°02.04'N and long 12°41.26'W, a distance of approximately 6.5 nautical miles. The aircraft structure had a random scatter pattern. That is, items such as the aft pressure bulkhead were broken into several pieces, and these pieces were located throughout the pattern. A third area which had some distinctive pattern was that of the engines, engine struts and components and was localized about lat 51°03.25'N and long 12°47.4'W in a northwest/southwest orientation. One of the operating engines was displaced 0.5 nautical mile to the north of this area, and it was also geographically separated from the wing structure. The number 3 engine nacelle strut was also separated from the rest of the engine components

and was located about one nautical mile to the west-southwest at lat 51°02.87'N, long 12°48.05'W. The reasons for the displacement of the number 3 engine nacelle strut and one of the operating engines from the other engines are not known.

3.2.7.2 Details of the various targets which were identified by the Structures Group is contained in Appendix 1 of this Report.

3.2.8 The Break up Pattern

3.2.8.1 The forward fuselage section of the aircraft was found inverted and badly broken into many pieces, the major pieces being :

(I) Section of fuselage right side below cockpit windows containing part of the name 'Kanishka' (in Hindi) and 3 passenger windows (Target No. 192)

(ii) Portion of upper skin between B S 360 and B S 520 below window belt right side, up and over crown. This portion includes the crew door and last letter of the "Air India" (in Hindi) logo (Target No. 192).

(iii) Section of fuselage between B S 510 to B S 700, including the passenger window belt right side, up and over crown to include upper deck windows left side (Target No. 218).

(iv) Section of fuselage between B S 720 to B S 840 including left side passenger window belt, up and over crown to right side passenger window belt. Forward and upper edges of L H No.2 door cutout can be seen (Target No. 193).

(v) Large section of fuselage between B S 1000 to B S 1460 including left side passenger window belt, up and over crown to right side passenger window belt. This section was found lying on its right side (Target No. 137).

(vi) The lower portion of the fuselage skin/frame between the nose and B S 1000 was damaged past recognition except for a small portion with the forwarded cargo door (Target No.204) and another portion containing the aft access door cutout at B S 810 (Target No. 362).

3.2.8.2 The aft fuselage was found in the following major pieces :

(I) Section of RH fuselage skin between B S 1640 and B S 1940 below the window belt up to the crown (Target No. 321).

(ii) The RH fuselage bottom skin between B S 1820 (forward edge of C2 door) and B S 2060 and between two stringers above the door cutout to just below stringer 46 lap joint (Target No. 40).

(iii) The lower fuselage skin with stringers between B S 1480 and B S 1846 about 100 inches wide approximately (Target No. 7).

(iv) The LH fuselage skin panel between B S 1740 and B S 1880 about 110 inches wide (Target No. 11).

(v) The LH fuselage skin between B S 1460 and B S 1800 width 80 inches including No. 4L door and passenger windows (Target No. 28).

(vi) The RH fuselage skin between B S 1660 and B S 1920, from below window belt up to the crown including the 4R door cutout (Target No. 321).

(vii) A fuselage lower skin panel (containing out flow valve) between B S 2120 and B S 2240 and 120 inches wide (Target No. 320).

(viii) A fuselage LH skin panel (containing 5 windows with "T -" part of registration) between B S 1980and B S 2080 between stringers 19L and 24L (Target No. 369 and 26).

(ix) A fuselage LH skin panel between B S 1460 and B S 1800 with 8 stringers below the bottom of the door and 3 stringers above the top of the door (Target No. 28).

3.2.8.3 The tail portion of the fuselage was found in the following pieces:

(I) The lower fuselage skin between B S 2412 and B S 2598 about 20 stringers wide (Target No. 371).

(ii) The vertical fin with rudders attached was lying on the ground by itself with a portion of B S 2517 frame. This includes a small portion of the aft pressure bulkhead (Target No.37).

(iii) The horizontal tail with elevators attached was lying on ocean floor with the jack screw and drive motor attached (Target No. 31).

(iv) The fuselage tail cone aft of B S 2669 was found basically intact and lying separately (Target No. 27).

3.2.9 Extent of Damage

Photographic and Video Interpretation of Wreckage

Photographic Interpretation

3.2.9.1 All wreckage sighted was recorded on video tapes and all major items were recorded on 35 mm positive film. During the course of the investigation, several members of the investigation team had the opportunity to view the tapes and photographs. Subsequently, when some items were recovered, it became apparent that the optical image presented on video and still film had some limitation with respect to identification of damage or damage pattern. For example, the sine wave bending of target 7 appeared in the video and photographs as a sine wave fracture, and some of the buckling on target 35 was not evident in either the video or photographs. The interpretation of damage through photographic/video evidence without the physical evidence might be misleading, and any interpretation should take this into acount.

3.2.9.2 Engines

The four operating engines were all extensively damaged. A view of the fan blades did not show signs of any rotational damage, and it could not be determined whether any pre-impact failures had occurred. The external damage to the engines varied, and at least one engine appeared to be attached to part of the nacelle strut. Except for the non-operational fifth engine, the engines could not be matched with their original positions on the aircraft.

3.2.9.3 Landing Gear

The nose, wing, and body landing gear were all located. Photographic examination indicated that all the gears were in the 'up' position at the time of impact.

3.2.9.4 Flaps and Spoilers

Positive identification of all the flap and spoiler surfaces was not made. All the flap jackscrews indicated that the flaps were retracted at impact. Of the spoilers identified, six had actuators attached. The actuators were in the fully retracted position.

3.2.9.5 Section 41

Section 41, consisting of the cockpit, first-class section, and electronics bay and identified as target 192, was found in a near-inverted attitude. This section was severely damaged. The electronics bay and cockpit areas could not be located within the wreckage. The first officer's seat was found on the sea bed near section 41 wreckage.

3.2.9.6 Section 42

Portions of Section 42, consisting of the forward cargo hold, main deck passenger area, and the upper deck passenger area, were located near section 41. This area was severely damaged and some of section 42 was attached to section 44. Some of the structure identified from section 42 was the crown skin, the upper passenger compartment deck, the belly skin, and some of the cargo floor including roller tracks. The right-hand, number two passenger door including some of the upper and aft frame and outer skin was located beside section 44. Scattered on the sea bed near this area were a large number of suitcases and baggage as well as several badly damaged containers. All cargo doors were found intact and attached to the fuselage structure, except for the forward cargo door which had some fuselage and cargo floor attached. This door, located on the forward right side of the aircraft, was broken horizontally about one-quarter of the distance above the lower frame. The damage to the door and the fuselage skin near the door appeared to have been caused by an outward force. The fractured surface of the cargo door appeared to have been badly frayed. Because the damage appeared to be different from that seen on other wreckage pieces, an attempt to recover the door was made by CCGS John Cabot. Shortly after the wreckage broke clear of the water, the area of the door to which the lift cable was attached broke free from the cargo door, and the wreckage settled back on to the sea bed. An attempt to relocate the door was unsuccessful.

3.2.9.7 Section 44

Section 44 containing the aircraft structure between B S 1000 and B S 1480 including that area where the fuselage and wings were mated was located and identified. This section was severely damaged but maintained its overall shape and was lying on its right side. Part of the left wing upper skin was attached to the fuselage and a large portion, about one third of the upper wing skin, separated and was lying against the fuselage crown skin. Some of the body and wing landing gears were found beside this section of the aircraft. The gear was detached from the main structure. The interior of the fuselage was extensively damaged.

3.2.9.8 Wing Structure

The wing structure was located near the forward area of the aircraft structure and towards the northern most area of the wreckage pattern. The wings showed extreme damage patterns with the top and bottom surfaces separated and the wing surfaces broken into segments.

3.2.9.9 Sections 46 and 48

Sections 46 and 48 contain that part of the aircraft structure aft of B S 1480 and, for purposes of this report, will include the horizontal stabilizer and vertical fin. This section of the aircraft was scattered in a west to east pattern about 6.5 nautical miles in length and exhibited severe break-up characteristics.

3.2.9.10 The aft cargo and bulk cargo doors were found in place and intact, and 5L, 5R and 4R entry doors were identified. Four segments of the aft pressure bulkhead were positively identified (targets 35, 37, 73 and 296). Much of the fuselage which was forward of the number five door and above the passenger floor area was not located, or if located was not recognisable as having come from a specific area of the aircraft.

3.2.9.11 Sections of the outer skin below the cargo area were located as was some of the cargo floor structure. Generally, the stringers and stiffeners are attached to the skin; however, the lower frames, which provided the cargo floor support, were detached from the skin. The rear cargo floor from B S 1600 to B S 1760 was located and was found to have little or no distortion; however, the lower skin and stringers were missing. A second portion of the aft cargo compartment floor containing cargo drive wheels and cargo roller trays was located. This structure was severely damaged and mangled.

3.2.9.12 The tail cone and the auxillary power unit (APU) housing were located and had received relatively minor damage; however, the APU had broken free and was never located.

3.2.9.13 A large portion of the outer skin panels showed signs of a force being applied from the inside out. On several pieces of wreckage, the skin was curled outwards away from the stringers and formers. This could have been the result of an overpressure.

3.2.9.14 The vertical tail was found in good condition, in a single piece with both rudders attached. The top cap was partially separated and a small dent was noticed in the middle of the leading edge at the bottom. A curved broken portion of fuselage was observed with a portion of the "Y" ring and pressure bulkhead attached. Another small segment of the pressure bulkhead was leaning on the lower section of the tail.

3.2.9.15 The horizontal stabilizer tail section was located and was one unit with the elevators attached. The actuator jackscrew was attached to the assembly. The stabilizer jackscrew ballnut was observed to be located at the upper jackscrew stop. This equates° to a full deflection of elevator trim. Since there is nothing on the DFDR or CVR to indicate a malfunction of the trim, it is deduced that this was not the lead event. It is not known if the position of the ballnut resulted from a pilot trim selection, a result of the initial event or if it rotated to the observed position under the influence of gravity. Two-thirds of the leading edge of the right horizontal stabiliser was missing and the auxilliary spar was exposed. There was localized damage to the right-hand root of the loading edge through about a span of five ribs. The leading edge skin and part of the leading edge ribs were torn downwards. Some localized damage to the root of the left leading edge was visible with the remainder of the leading edge undamaged. There was minor damage to the trailing edge of the outboard left elevator, and a major portion of the inboard left elevator was missing.

3.2.9.16 Passenger Seats

Many of the passenger seats located among the wreckage pattern and identified as having come from section 46 and 48 appeared to have the aft support legs buckled with little or no damage to the forward support legs. Seats located in the wreckage containing sections 41, 42 and 44 appeared to have varying types of damage, that is, aft support legs only buckled, and all legs buckled. One consistent feature noted was that in the majority of seats located it was possible to ascertain that the seat belts were not fastened.

3.2.10 Salvage Operations

3.2.10.1 During recovery operation the video tapes as well as photographs of the wreckage to be recovered, were supplied to the personnel on board the ship for facilitating identification and recovery of correct targets.

3.2.10.2 Whenever any component/part of the aircraft wreckage was salvaged it was essential to immediately subject the same to inspection and to identify the damage sustained during recovery operation. In order to oversee this critical operation, the Court deputed one of its Assessors, Dr. V. Ramachandran, to be on board the ships. Under his supervision, the components/parts were thoroughly washed with fresh water, dried and treated with corrosion inhibiting compounds. A detailed inspection was thereafter carried out, observations recorded and the targets were appropriately labelled and their numbers were painted thereon. A laboratory microscope was taken on board by Dr Ramachandran. With that, fragments of significance were segregated for further investigation. Indeed some of these fragments did give important clues.

3.2.10.3 All the investigating personnel on board the ship were provided with leather gloves, fisherman's shoes, raincoat, life floating suits, writing and labelling material, camera with coloured films, etc. Sufficient number of "body bags" were positioned on each ship to cater for the eventuality of recovery of bodies with the wreckage. This precaution helped when a body did come along with wreckage on

25.10.1985.

3.2.10.4 The ship John Cabot completed the operation of locating, mapping and photography of the wreckage and returned to Cork on 1.10.85 at 2020 hours. The next phase of operation was to recover the significant wreckage parts which would be useful for deciding the cause of the crash.

3.2.10.5 Subsequent to the accident to Japan Airlines Boeing 747 aircraft, suspected to have been caused by failure of the repair to the rear pressure bulkhead, NTSB and FAA decided to fund the U.S. Navy for a two week operation over the seas for recovery of significant pieces of wreckage. For this purpose, U.S. Navy appointed Commander J.R. Buckingham, a deep sea salvage expert, to head the recovery operation. An offshore supply vessel M.V. Kreuzturm, of Canada was hired by U.S. Navy to recover the wreckage with the help of Scarab on John Cabot. One nylon lift line together with winch and ram were installed on the ship prior to its sailing to Cork where it arrived on 4th October, 1985. One crane was installed on the ship Kreuzturm in Cork.

3.2.10.6 One inch dia Kevlar lines coated with black plastic for abrasion resistance and braided with Dacron lining were used by John Cabot as primary lift lines.

3.2.10.7 The structure group after studying the photographic data, had formulated a list of 32 targets for recovery on 3.10.85. A systemwise priority list proposed by the Court of Inquiry was received through Dr V. Ramachandran on 4.10.85. Using these two lists, and taking into account the operating restrictions imposed by two ship operation, a final list of targets was prepared for recovery by the ships, assigning a priority number to each target. However, as the recovery operation progressed, changes in priority list were made to achieve optimum utilisation of the ships.

3.2.10.8 A meeting was held at 1400 hrs. on 4.10.85 on board CCGS John Cabot to establish/clarify the priorities for the wreckage recovery operation and coordination between John Cabot, Kreuzturm and Cork Search Centre. All the personnel involved in the recovery operation were shown the slides and photographs of the targets which were chosen

for recovery on priority basis. The method and procedure of the recovery operation was discussed in detail and finalised. Another meeting was convened on 6.10.85
to clarify the doubts and to present the picture albums containing various photographs of targets to be recovered. The mode of attaching grippers/grabbers to the targets at strong points was clarified. A serialised list of priorities was prepared based on the mode of operation indicated by the the crew of John Cabot and Kreuzturm. Dr Ramachandran was given the authority to make on-the-spot decisions during the salvage operations.

3.2.10.9 A detail log of the activities of the ships John Cabot and Kreuzturm which started the recovery operation of 10.10.85, reveals the following :

(a) The Scarab working independently recovered the following

(1) Basket at target 192 containing copilot's chair, 2 suitcases and radar antenna (12.10.85)

(2) Target 8 - Lower fuselage skin of aft cargo compartment. (11.10.85).

(3) Target 245 - Forward belly skin just aft of radome (16.10.85).

(4) Target 350 - Economy class seats and carpet (23.10.85).

(5) Target 296 - Piece of aft pressure bulkhead.

(b) The Scarab after attaching the grippers, bridal cable and lift line to the targets buoyed off the same to Kreuzturm which recovered the following targets :

(1) Target 362/396 - Forward cargo fuselage skin from station 700 to 840 and STR 41L to 43R. (16.10.85).

(2) Target 193 - Fueselage skin from station 720 to 860 and passenger door 2L (17.10.85)

(3) Target 223 - Nose landing gear pressure deck web and stiffeners, container pieces (staion 260-340)(19.10.85).

(4) Target 181 - Wing skin with forward cargo compartment SLIPPED OFF WITH GRIPPERS (21.10.85) AND WAS LOST.

(5) Target 399/358 - Fuselage skin from station 780 to 940 and STR 7R to 35R with 2R door (25.10.85). A body entrapped in target 399/358

was recovered. Another body which came upto surface with the wreckage fell
off into sea and was lost while hauling the wreckage on board. The recovered body was identified as of Dr. Mathew Alexander, a Canadian passenger and was brought to Cork by Fisherman's vessel "Orion" at 0130 hrs. on 28.10.85 and was sent for Post Mortem etc.

(6) Target 7 - Aft cargo compartment fuselage skin from station 1480 to 1860 (26.10.85).

(7) Target 47/50 - Aft cargo floor structure with roller tracks, frames, latch etc. from station 1600 to 1760 (27.10.85).

(8) Target 117 - Three rows of coach class seats with passenger cabin floor boards, broken floor beam (28.10.85).

(9) Target 35 - Aft Pressure Bulkhead piece (30.10.85).

3.2.10.10 The Scarab experienced malfunctions with its arms, Sonar equipment, multiplex system, junction box, microprocessor unit, etc. off and on during the above period of operation. Fouling of lift line with umbilical cord was also experienced in the early stages of operation. Since the assigned recovery by Kreuzturm was over by 30.10.85, and as the Scarab became unserviceable due to breakdown of its power suppluy, the OSV MV Kreuzturm was directed to return to Cork to off-load the recovered wreckage and its operation was terminated, (Indian Government had funded the cost of operation of M.V. Kreuzturm from 21.10.85 onwards).

3.2.10.11 Since the Scrab continued to remain unserviceable, the ship John Cabot was called back to Cork. It anchored in Cork at 1100 hrs. on 5.11.85. All the wreckage on board the ship was transported to the boat yard, in the afternoon.

3.2.10.12 After detailed macro photography of the recovered wreckage, the experts group mentioned in section 1.5.16 prepared a detailed factual report after carefully inspecting each of the targets recovered. It was decided to send the wreckage to Bombay for which necessary crates were then prepared and the large pieces of wreckage were cut along the lines indicated by the experts group to facilitate their packing.

3.2.10.13 RCMP investigators carried out a close visual and microscopic examination of the fragments recovered with the wreckage, suitcases, seats and cushions, etc. For further laboratory analysis. Dr A.D. Beveridge collected a few samples.

3.2.10.14 The Scarab appeared to be serviceable on 19.11.85 and the ship John Cabot sailed for completion of recovery of left over targets, on 20.11.85. However, the serviceability of Scarab proved elusive, it became inoperable on 21.11.85 and the ship returned to Cork at 1700 hrs on 25.11.85.

3.2.10.15 Efforts were made to repair Scarab so that the ship John Cabot could sail again in order to salvage as many pieces as possible. It was fortunate that the weather had not deteriorated. Some of the important but small pieces which had to be recovered had been placed in a basket at the bottom of the ocean. The ship sailed out again after Scarab had been repared. The basket was sought to be lifted, but, unfortunately, when it reached near the surface of the sea it overturned and the contents of the basket spilled and were never traced again.

3.2.10.16 At this juncture it was decided that the salvage operations should be terminated. The ship returned and sailed for home in the first week of December 1985.

3.2.11 Examination of Wreckage

3.2.11.1 Floating Wreckage

Soon after the accident, a number of light weight parts of the aircraft were found floating over a wide area at the crash site. These were picked up by the ships engaged in rescue operations and were brought to Cork where they were kept in the boat yard. The floating wreckage recovery continued for four days i.e. upto 26th June.

3.2.11.2 Some of the wreckage items were subsequently washed to the west coast of Ireland. These were picked up by the Irish Police and were brought to Cork. Some wreckage items were taken by a ship to Halifax, Canada. These were flown to Cork by the Canadian Aviation Safety Board. With the assitance of Air India engineers, the wreckage items were

identified, labelled, photographed and laid out in the boat yard hangar for examination.

3.2.11.3 The wreckage was initially examined at Cork by the Structures, Power Plant and Systems Group. It was subsequently transported to Bombay for further examination. A few wreckage items which were taken by the Spanish trawlers to Madrid were also transported to Bombay. Some wreckage items had washed to the west coast of England. These were collected by the Accident Investigation Branch of UK and were transported to Cork and then to Bombay.

3.2.11.4 The floating wreckage recovered constituted approximately 3 to 5 per cent of the aircraft structure. The major items of the wreckage recovered were :

Various leading edge skin panels of LH nd RH wing, LH wing tip, spoilers, leading edge and trailing edge flaps, engine cowlings, flap track canon fairings aft end pieces, landing gear wheel wall doors, pieces of elevator and aileron, toilet doors, cabin floor panels, cabin overhead and upper deck bins, passenger seats, life vests, slide rafts, hand baggages, suitcases etc. and three empty oxygen bottles.

3.2.11.5 The Structures Group which had been constituted by the Court examined the floating wreckage and submitted its report. From the report the following significant information about the damage to major items of the floating wreckage is noted :

(I) VT-EFO aircraft was carrying a -7Q engine on 5th pod and a -7Q 5th pod kit in the aft cargo compartment. It had therefore, in all 14 engine fan cowls (eight working engine fan cowls plus two 5th pod engine fan cowls plus two -7T engine kit fan cowls in the aft cargo compartment plus two -7Q engine fan cowls in the aft cargo compartment). Out of these 14 fan cowls, 9 cowls (6 of working engines plus 2 of -7J kit plus one of 7Q kit) and two additional pieces of fan cowls were found. Five of the fan cowls of working engines show folding damage lines at approximately 3 O'Clock and 9 O'Clock positions. The number 3 engine inboard fan cowl has severe impact damage on its leading edge and has small inward to outward puncture holes (not penetrating through outer skin) in the lower centre region. The two fan cowls of -7J 5th pod kit stowed in the aft cargo compartment exhibit severe damage. One of these cowls is broken in two pieces. One of the pieces is cut at one corner in an arc of about 20 inches diameter and its external skin is pealed back. The external surfaces of all the three pieces have consideable scratches, tears and holes from outside to inside. None of the punctures penetrates the inner skin. Some punctures are also present from inside to outside but none of these penetrates the outer skin.

(ii) Out of the 12 spoilers, seven (number 2, 3, 5, 7, 8, 9 and 12) have been retrieved. Of these, six have their actuators attached to them in fully retracted position. Six spoilers have splits in their lower skin with split edges curled into the cores of honeycomb. Number 8 spoiler (located just inboard of number 3 engine) has a concentrated local impact damage on front spar and trailing edge beam from forward to aft and up direction over a span of 2 feet starting from outboard of spoiler actuator.

(iii) The left hand wing tip assembly with a part of H F Antenna was retrieved. No burning/discolouration marks around lightning arrester of H F system were noticed. The rib inboard of the lightning arrester was found intact. There were no burn marks anywhere on the panel.

(iv) The right hand wing leading edge top panel inboard of number 3 engine with a position of kruger flap frame along with bull nose attached was recovered. The bull nose was found crushed from top in the area just below the stay rod and the lower surface of stay rod has scratch marks from front to rear.

(v) The right hand wing root leading edge (inboard of W S 268.81) shows an impact damage at the leading edge. Bottom skin and internal structure are torn away. The leading edge skin is caved in over a span of about 3 feet and shows signs of heavy body impact in air. The impact damage shows signs of downward and backward movement of the impacting body.

(vi) A 3' x 2' piece of right hand inboard trailing edge fore flap with accordian seal was recovered. The inboard 8" portion of leading edge was found damaged by impact of an object going from lower forward to upper aft.

(vii) All the floor panels recovered from upper deck and main cabin indicate that these were detached from their attachments in an upward direction from all sides.

(viii) One main deck blow out door located between B S 2040 and 2140 left hand side was available. Out of its four metal clips, one clip was broken off with 2 nylon rivet heads sheared.

(ix) The cockpit entry door and the side bulkhead panel were found fairly intact but had come out of their attachment.

(x) Twelve toilet doors, out of a total of 16, were available and were found fairly intact, but had come out of their attachments.

(xi) The available cabin interior panels and overhead bins of the main deck and upper deck have only minor damage.

(xii) The woodent boxes which contained the fan blades of 5th pod engine and were loaded in container at position 24L in the forward cargo compartment were found broken apart with no burn marks.

3.2.11.6 Wreckage Salvaged from Sea

The wreckage salvaged from the sea was visually examined at Cork by the Committee of Experts as mentioned in section 1.5.16 and the observations thereon recorded. Subsequently detailed metallurgical examination was carried out at the Bhabha Atomic Research Centre, Bombay by
Dr. M.K. Asundi and Dr. G.E. Prasad of B.A.R.C., Mr. S. Radhakrishnan and Dr. R.V. Krishnan of National Aeronautical Laboratory and Mr. B.K. Athawale of the Explosives Research and Development Laboratory, under the guidance of Dr. V. Ramachandran. During this examination, representatives of CASB, CP Air and Boeing were present in the first week. These represntatives left Bombay while the metallurgical examination was being carried out. The metallurgical examination was continued and the aforesaid group submitted the metallurgical report to the Court in December, 1985.

3.2.11.7 Although all the recovered wreckage was examined, only those items exhibiting characteristics which provide some evidence as to what may have happened to the aircraft during its final moments of flight are discussed herein below :

3.2.11.8 Target 7 - Lower Fuselage Skin Panel
This skin panel was located below the aft cargo area and contained the keel beam. Target 7 extended from B S 1480 to 1850 and was about eight feet in width and 32 feet in length. The left edge had a full length rivet line tear and the torn edge was buckled in waves, like the trace of a sine wave. One the right side, between the one quarter and midway segment, a large flap of skin was attached. The skin was folded aft, diagonally underneath, from right to left and the paint was scoured off the leading edge. The forward break was at the joint at B S 1480. The skin tear located at about B S 1860 was irregular in nature. The forward keel joint splice plate was bent, and the keel joint bolt holes were distored and elongated.

3.2.11.9 This panel was examined by the committee of experts at BARC and according to their report the keel beam trunnion fitting beneath the outer chord of the station 1480 bulkhead had fractured at the aft set of bolt holes. The fracture surface of the right side of the trunnion fitting was clean. As per the report, it was typical of overload failure in tension. The fracture surface of the left side of the trunnion fitting was covered with corrosion products, especially, at one corner, due to sea water. After cleaning this area by the recommended techniques, scanning electron microscopy revealed morphology of overload fracture consisting of dimples. Away from this corner also the fracture was similar as being due to overload. There was no evidence of there having been any fatigue failure.

3.2.11.10 At B.A.R.C., a sample was cut from the corroded corner of the failed left side trunnion fitting and metallographic examination was carried out on the same. The said examination showed on a face perpendicular to the corroded fracture surface, pits due to corrosion by sea water. The basic microstructure was however free from intergranular cracking. It was thus concluded by the experts that the material in the region corroded by sea water had not suffered stress corrosion cracking which generally manifests as intergranular cracking.

3.2.11.11 A piece of the trunnion fitting was cut and the hardness and electrical conductivity values were measured by the said experts. As per their report, the electrical conductivity values were within the specified limits.

3.2.11.12 Target 8 - Lower Fuselage Skin Panel

This skin panel was located below the aft cargo area and extended from B S 1860 to 1960 and from stringer 46L to 46R. The forward end of target 8 matched with the aft end of Target 7. A region of fracture along the rivet holes near stringer 46L was marked for SEM examination. SEM examination after cleaning revealed that the fracture was characterised by dimples along its length, including areas adjacent to the edges of the rivet holes. These features are consistent with an overload mode of failure.

3.2.11.13 According to the metallurgical report, there was no evidence of fatigue failure on this target.

3.2.11.14 Target 35 - Portion of Rear Pressure Bulkhead

Looking forward from behind the aircraft, this segment of pressure bulkhead occupied the 9 to 1 O'Clock position, the piece from 12 to 1 O'Clock position had the flange from the outer ring attached. The web below the outer ring flange had areas of buckling. From the 11 to 12 O'Clock position the outer edge showed sinusoidal buckling, and the edge sector at 9 O'Clock position was partially collapsed and its edge was turned under. Samples taken for optical stereo microscope and SEM examination revealed that the fracture characteristics were consistent with an ovrload mode of failure.

3.2.11.15 According to the metallurgical report, there was no evidence of fatigue or any other mode of failure.

3.2.11.16 Target 296 - Portion of Rear Pressure Bulkhead

Looking forward from the rear of the aircraft, this segment of the bulkhead occuped the 7 to 9 O'Clock position. Optical and SEM examination were undertaken on this item.

3.2.11.17 The fracture alont the left-hand edge of target 296 (viewed from the rear) was examined optically prior to removing any representative samples. The fracture was at the rivet line at a skin splice, except for a length of fracture about 15 inches long near the forward end, which was through the skin away from the rivet line. Most of the rivet holes along the fracture path showed some slight elongation and skin deformation.

3.2.11.18 Representative fracture samples were cut from the left-hand side and circumferential fracture edges of the fracture surfaces. Optial and SEM examination revealed that the fracture characteristics are consistent with an overload mode of failure.

3.2.11.19 Target 47 - Aft Cargo Floor Structure

This portion of the aft cargo compartment was located between B S 1600 and B S 1760. No significant observation was noted. There was no evidence to indicate characteristics of an explosion emanating from the aft cargo compartment.

3.2.11.20 Target 117 - Floor with Seats Attached

These seats were right-section doubles, located between B S 1880 and 1980 and were from rows 46, 47 and 48, F and G (Zone E). The seats were displaced to the left with the rear legs buckled to the left. The front leg supports exhibited only minor damage. The middle and rear doubles had aisle-side seat arms bent to the right. There was no impact damage to the seat backs or seat pans, and all life vests except one were gone from the underseat container bags.

3.2.11.21 In the metallurgical report it is stated that on an examination of this target it was also found that on the underside of this floor near the forward end, a number of dents and impact marks were observed. This region appeared to have suffered shrapnel penetration. This area was radiographed but no metallic fragment was detected.

3.2.11.22 Target 193 - Fuselage Side and 2L Entry Door

The fuselage segement was located between B S 720 and 840. The door and fuselage skin were buckled outwards, approximately in line with the buckling on the fuselage and 2R entry door directly opposite.

3.2.11.23 Target 399 - Fuselage around 2R Door

This target is shown in Fig. 399-1. A detailed description is given below :

TARGET 399 Fuselage Station 780 to 940 in the longitudinal direction and stringer 7R down to stringer 35R circumferentially.

This piece contained five window frames, one in the 2R passenger entry door. Three of the window frames, including the door window frame, still contained window panes. Little overall deformation was found in the stringers and skin above the door. The structure did contain a significant amount of damage and fractures in the skin and stringers beneath the window level. In the area beneath the level of the windows, the original convex outward shape of the surface had been deformed into an inward concave shape. Further inward concavity was found in the skin between many of the stringers below stringer 28R. The skin at the forward edge of the piece was folded outward and back between stringers 25R and 30R. Over most of the remaining edges of the piece a relatively small amount of overall deformation was noted in the skin adjacent to the edge separations. Twelve holes or damage areas were numbered and are further described.

No.1 : Hole, 5 inches by 9 inches with two large flaps and one smaller curl, all folded outward. Reversing slant fractures, small area missing.

No.2 : Hole, 2 inches by 3/4 inch, one flap folded outward, reversing slant fractures, one curled sliver, no missing metal.

No.3 : Triangular shaped hole about 2 inches on each side. One flap, folding inward, with one area with a serrated edge. No missing metal, extensive cracking away from corners of the hole, reversing slant fracture.

No.4 : Tear area, 8 inches overall, with deformation inward in the centre of the area. Reversing slant fracture.

No.5 : Fracture area with two legs measuring 14 inches and about 24 inches. Small triangular shaped piece missing from a position slightly above stringer 27R. Inward fold noted near the joint of the legs. An area of 45° scuff marks extend onto this fold.

No.6 : Hole about 2.5 inches by 3 inches with a flap folded outward, reversing slant fracture. Approximately half the metal from the hole is missing.

No.7 : Hole about 3 inches by 1 inch, all metal from the hole is missing. Fracture edges are deformed outward.

No.8 : Forward edge of the skin is deformed into an "S" shaped flap.

Three inward curls noted on an edge.
No.9 : Inwardly deformed flap of metal between stringers 11R and 12R at a frame splice separation. No evidence of an impact on the outside surface.
No.10 : Door lower sill fractured and deformed downward at the aft edge of the door.
No.11 : Frame 860 missing above stringer 14R. Upper auxilliary frame of the door has its inner chord and web missing at station 860. A 10 inch piece of stringer 12R is missing aft of station 860.
No.12 : Attached piece of floor panel (beneath door) has one half of a seat track attached. The floor panel is perforated and the lower surface skin is torn.
3.2.11.24 Much of the damage on this target was on the skin and stringers beneath the window level, i.e., on the starboard side of the front cargo hold. The inside and outside surface of the skin in this region are shown in Fig. 399-2 and 399-3 respectively. There were 12 holes or damaged areas on the skin as described above, generally with petals bending outwards. The curl on a flap around hole no.1 shown in Figh 399-4 has one full turn.
This curl is in the outward direction. Cracks were also noticed around some of the holes. Part of the metal was missing in some of the holes. The edges of some of the petals showed reverse slant fracture. In one of the holes, spikes were noticed at the edge of a petal.
3.2.11.25 When this target was recovered from the sea, along with it came a large number, a few hundreds, of tiny fragments and medium size pieces, All of the fragmets were recovered from the area below the passenger entry door 2R. One of the medium size pieces recovered with this target was a floor stantion, about 35 inches long, shown in Fig. 399-5. It is a square tube. It had the mark station 880 painted on its inner face, i.e. facing the centre line of the cargo hold. The part number printed on this station is 69B06115 12 and the assembly number is ASSY 65B06115-942 E3664 1/31/78*. It was confirmed that this stantion belongs to the starboard side of the forward cargo hold. The inner face of the stantion had a fracture with a curl at the lower end, the

curl being in the outboard direction and up into the centre of the station. Fig. 399-6 is a print from the radiograph of this station. The inward curling can be seen clearly in this figure. Curling of the metal in this manner is a shock wave effect.

3.2.11.26 A piece near the fracture edge of this stantion was cut, and examined metallographically. Fig. 399-7 and 399-8 show the microstructure of this piece. Twins are seen in the grains close to the fracture edge. The normal microstructure of the stantion material is free from twins as shown in Fig. 399-9.

3.2.11.27 Fig. 399-10 shows a collection of small fragments recovered along with target 399. There were some curved fragments with small radius of curvature (A). Reverse slant fracture (B) was noticed in some of the skin pieces. A piece 3/4" x 1/2" and 3/16" thick was found to have three blunt spikes at the edge (C). This piece was metallographicaly polished on the longitudinal edge. The microstructre of the piece is shown in Fig. 399-11. It may be seen that the grains in this fragment also contain a large number of twins.

3.2.11.28 Target 362/396 Forward Cargo Skin

This piece indluded the station 815 electronic access door, portions of seven longitudinal stringers to the left of bottom centre and five longitudinal stringers to the right of bottom centre. The original shape of the piece (convex in the circumferential direction) had been deformed to a concave inward overall shape. Multiple separations were found in the skin as well as in the underlying stringers. Further inward concavity was found in the skin between most of the stringers.

3.2.11.29 The two sides of this piece are shown in Fig. 362-1 and 362-2. This piece has 25 holes or damaged areas in most of which there are multiple petals curling outwards. These holes are numbered 1 to 3, 4a, 4b, 4c and 5 to 23. These are described below. Unless otherwise noted, holes did not have any material missing :

No.1 : Hole with a large flap of skin, reversing slant fracture.

No.2 : Hole with multiple curls, reverse slant fracture.

No.3 : Hole with multiple flaps and curls, reversing slant fracture, one area of spikes (ragged sawtooth)

No.4A : One large flap, reverse slant fracture, one area of spikes.
No.4B : Hole with two flaps.
No.4C : Hole with two flaps, one area of spikes
No.5 : HOle with two flaps.
No.6 : Braching tear from the left side of the piece, reversing slant fracture.
No.7 : Hole, with one flap, one curl and one area of spikes.
No.8 : Very large tear from the left side of the piece with multiple flaps and curls, reversing slant fracture and at least two areas of spikes.
No.9 : Hole with multiple flaps, one curl.
No. 10 : 2.5 inch tear
No.11 : One flap
No. 12 : Grip hole, plus a curl with spikes on both sides of the curl.
No.13 : "U" shaped notch with gouge marks in the inboard/outboard direction. Three curls are nearby with one are of spikes. Gouges found on a nearby stringer and on a nearby flap.
No. 14 : Nearly circular hole, 0.3 inch to 0.4 inch in diameter. Small metal lipping on outside surface of the skin. Most of the metal from the hole is missing.
No. 15 : Hole in the skin beneath the first stringer to the left of centre bottom. Small piece missing.
No. 16 : Hole in the stringer above hole No. 15. Most of the metal from this hole is missing.
No. 17 : Hole through the second stringer to the left of centre bottom, 0.4 inch in diameter. The hole encompassed a rivet which attached the stringer to the outer skin. Small pieces of metal missing.
No. 18 : Hole at the aft end of the piece between the third and fourth stringers to the left of centre bottom. The hole consisted of a circular portion (0.4 inch diameter), plus a folded lip extending away from the hole. The metal from the circular area was missing.
No. 19 : Hole with metal folded from the outside to the inside, about 0.6 inch by 1.5 inch. Flap adjacent to the hole contained a heavy gouge mark on the outside surface of the skin.
No. 20 : Hole containing a piece of extruded angle.

No. 21 : Hole containing a piece of extruded angle.

No. 22 : Hole with one flap.

No. 23 : Hole about 0.3 inch in diameter, with tears away from the hole. Small piece missing.

3.2.11.30 Fig. 362-3 to 362-7 show a few of these holes. There were also cracks or tears around some of the holes. The curls around some of the holes had nearly one full turn. In the large tear between body stations 700 and 740 and stringers between 41L and 45L, there were many pronounced curls as shown in Fig. 362-8. On the edges of the petals around

several holes, reverse slant fracture was seen at a number of places. This slant fracture is at an angle of about 45° to the skin surface, the fracture continuing in the same general direction but with the slope of the slant fracture reversing frequently.

3.2.11.31 Sharp spikes were observed at the edges of the holes or at the edges of the petals around the holes No. 3, 4A, 4C, 7, 8 (at two locations), 12, 13 and 16. Some of the spikes are shown in Fig. 362-9 to 362-12. One of the holes, No. 14, on the skin was nearly elliptical with metal completely missing, as shown in Fig. 362-13. On the inside surface of the skin, paint surrounding this hole was missing. Hole No. 16 was through the hat section stringer, as shown in Fig. 362-14. In this, most of the metal was missing. On the inside of the hat section, the fracture edge of this hole had spikes, as shown in Fig. 362-15. Hole No. 17 was through the stringer and the skin, as shown in 362-16.

3.2.11.32 Through holes No. 20 and 21, extruded angles were found stuck inside, as shown in Fig. 362-17 and 362-18 respectively. In the petal around hole No. 20, there was an impact mark by hit from the angle as seen in Fig. 362-19 photographed after removing the angle. Such a mark was not present in the petals around other holes.

3.2.11.33 On the skin adjacent to hole No. 13 gouge marks were noticed, Fig. 362-20. These marks were on the inside surface of the skin. To check whether these could be due to rubbing by the bridal cable of Scarab during the recovery operations, a sample of bridal cable was obtained from "John Cabot" and gouge marks were produced by pressing this cable against an aluminium sheet. The gouge marks thus produced, as shown in Fig. 362-21, appear to be different from those observed near hole No. 13.

3.2.11.34 A piece surrounding hole No. 14 was cut out and examined in a Jeol 840 scanning electron microscope at the Naval Chemical and Metallurgical Laboratory, Bombay. Fig. 362-22 and 362-23 are the scanning electron micrographs showing the inside surface and outside surface of the skin around this hole. Flow of metal from inside to outside can be seen from these figures. Energy dispersive x-ray analysis was carried out on the edges of this hole. Only the elements present in this alloy and sea water residue were detected.

3.2.11.35 A portion of the skin containing part of hole No. 14 was cut, polished on the thickness side of the skin and examined in a metallurgical microscope. Fig. 362-24 shows the microstructure of this region. The flow of metal along the edge of the hole can be seen from the shape of the deformed grains near the hole. This can be compared with the bulk of the grains shown in Fig. 362-25, away from the hole. In addition, in Fig. 362-24, a series of twin bands can be seen in some of the grains near the hole. Fig. 362-26 shows these bands at a higher magnification. Normal deformation rates at various temperatures do not produce such twinning in aluminium or its alloys. It may be noted that this microstructural feature is absent in the microstructure of the skin, away from hole No. 14, Fig. 362-25.

3.2.11.36 Metallography was also carried out on a petal around hole No.7 and on a curl with spikes around hole No. 12. The microstructures indicate twins, however they could not be recorded due to their poor contrast.

3.2.11.37 Small pieces containing the spikes around holes No. 12 and 16 were cut and energy dispersive x-ray chemical analysis on the region of spikes in both was carried out in the Jeol 840 SEM. Only elements present in the alloys and sea water residue were detected.

3.2.11.38 A number of small fragments were found along with the forward cargo skin in target 362. Amongst them was a piece from the web of a roller tray. This has pronounced curling of the edges towards the drive wheel, Fig. 362-27.

3.2.11.39 Another small fragment was found from the above target. This piece, identified as specimen No. 12 in box No. 1, target 362, has a number of spikes along the edge. A scanning electron micrograph of the spikes is shown in Fig. 362-28. The sides of the spikes on SEM examination revealed elongated dimples as shown in Fig. 362-29, characteristic of shear mode of fracture. Metallography was carried out on the thickness side of this specimen. Fig. 362-30 and 362-31 show the microstructure near the apex of the spike and at the root of the spike respectively. Extensive twinning can be seen in these regions of the spikes.

3.2.11.40 Another fragment recovered with target 362 and identified as specimen No. 8 in box No. 1, also showed extensive twinning. The microstructure is recorded in Fig. 362-32.

3.2.11.41 Reference has also to be made to two other reports concerning wreckage.

3.2.11.42 The floating wreckage recovered was initially examined at Cork. On 25th June, Mr. Eric Newton a retired investigator of AIB, UK, was requested to examine the floating wreckage recovered and other materials with specific reference to the possibility of explosive sabotage having taken place. Mr. Newton examined the floating wreckage, passenger clothings and the other materials recovered from the crash victims The findings of Mr. Newton on the material available at that time are summarised below:

a. Taking the scatter of the wreckage and bodies into consideration and the condition of the limited wreckage recovered indicates that the aircraft had broken up in flight before impact with the sea.

b. Detailed examination of the structural wreckage recovered did not reveal any evidence of collision with another aircraft. Nothing was found suggestive of an external missile attack.

c. There was no evidence of fire internal or external.

d. There was no evidence of lightning strike.

e. Examination of all available structural parts recovered, did not reveal any evidence of significant corrosion, metal fatigue or other material defects. All fractures and failures were consistent with overstressing material and crash impact forces

f. Examination of clothing from the bodies did not show any explosive fractures or any signs of burning. The seat cushions and head cushions also did not show any explosive characteristics.

g. The damage to the suitcases (14 large and 29 small) which were examined was due to impact crash forces. The presence of 14 large suitcases could, however, indicate that one of the baggage containers had been broken to permit these suitcases to escape.

h. A number of lavatory doors and structure also did not show any damage consistent with explosion. The flight deck door showed no explosion damage inside or outside.

i The circumstatnial evidence strongly suggests a sudden and unexpected disaster occurred in flight.

j. There was no significant fire or explosion in the flight deck, first and tourist passenger cabin including several lavatories and the rear bulk cargo hold.

3.2.11.43 The other report dated 30th November, 1985 is of Mr. V.J. Clancy. Mr. Clancey had examined the wreckage and had also taken part, though only for a few days, in the metallurgical examination which was being conducted at BARC, Bombay.

3.2.11.44 Mr. Clancey examined practically all the items of wreckage which had been brought to BARC and in his report he has dealt with all of them. His report contained a description of the recovered items and also his comments thereon.

3.2.11.45 With regard to the aforesaid target 362, he observed that there were about 20 holes in it clearly resulting from penetrations from inside.

3.2.11.46 He further stated that:

"In addition to the fact that perforation was from inside there are certain features which suggest that they were made by high velocity fragments such as are produced by an explosion. These features are:

(a) Presence of toothed or spiked edges at some parts of the metal which had petalled out from the perforations.

"Tardif and Sterling (Canadian Aeronautics and Space Journal, 1969, 16, 1, 19-27) obtained spiked fractures in fragments from sheet alloy subjected closely to an explosion. They stated that they had not obtained this effect in fractures otherwise produced.

(b) Presence of marked curling, in some cases of more than 360°, of some of the petals.

Tradif and Sterling stated that such curling was a feature of explosively produced fragments.

(c) The virtual absence of scratches or score marks on the petals such as might be expected if something were slowly forced through the metal.

(d) The virtual absence of other impact marks on the inside surface such as might have been produced by a massive impact with a substantial object. This suggested that the production of at least many of the perforations were separate independent events.

(e) One perforation (identified as No. 14) resembles a "bullet hole", that is cleanly punched out - a type of hole usually associated with a high velocity missile.

"There is evidence that the forward part of this item had been folded back inwards along the line of station 760 and then bent back again along a line slightly forward of this station.

"Such folding, may be violently produced on impact with the water, could have brought broken metal of stringers or stiffeners into forceful contact with the internal surfaces producing perforations outwards. The overlap of such folding would conceivably have covered the area up to station 800 and thus included most of the perforations.

"One hole identified as No. 13, was almost certainly caused by a slipping wire rope used as a sling.

"Part of the inner surface, aft of station 780 was superficially blackened as if by soot from a fire. Swabs were taken by me of this area and are being examined by R.A.R.D.E. for evidence of fire or explosives".

3.2.11.47 There were several hundred small fragments which were recovered from the same general area as Target 362. While dealing with these Mr. Clancey observed that the production of a large number of small fragments is generally regarded as indicative of an explosion. One piece out of this was isolated, which was about one inch square of sheet alloy, and it was noted by Mr. Clancey that this piece had characteristic spikes on one edge similar to those described by Tardif and Sterling. (This piece is the same as shown in Fig. 362-28).

3.2.11.48 Mr. Clancey also examined a few suit cases which had been recovered. One particular suit case to which reference was made by him was of red plastic material with blue lining. With regard to this he stated that the damaged lining, severely tattered, resembles that of one found after an explosion in an aircraft in Angola. In that case microscopic examination showed definite evidence of damage by an explosion.

3.2.11.49 The later part of the report of Mr. Clancey contained his opinion. With regard to Target 362 his opinion was as follows:

"The features discernible to a careful close visual examination point towards the possibility of an explosion but taken alone do not justify a firm conclusion.

"Curling of petals and spiked or toothed fractures may be observed in other events than explosions despite the failure by Tardif and Sterling to obtain them in their limited number of attempts. It is probable that these features indicate a rapid rate of failure but not necessarily of a rapidity which could only be produced by an explosion.

"A more detailed study, metallurgical and fractographic, is required.

"The studies by Tardif and Sterling were done on fragments produced from aluminium alloy in contact with the explosive. Very little information is available on the behaviour of aluminium alloy some distance from the explosive and subjected to attack by secondary fragments. To determine this some trials will be necessary, to obtain reference samples for comparison.

"The single "bullet hole", No. 14, strongly supports an explosion hypothesis but, being the sole example of its kind, is not, by itself determinative.

"If the forward part of this item was forcefully and rapidly folded back to impact on the other part it might explain the other features apparent to visual examination. It would require detailed laboratory examination and tests to eliminate this possibility".

3.2.11.50 The opinion of Mr. Clancey about the small fragments was as follows:

"The production of a large number of small fragments is generally regarded as a pointer towards an explosive cause but cannot be relied upon unless it is clear that they could not have been produced by some other means. It is known that the break-up of an aircraft at high speed may produce great fragmentation.

"The single spiked fragment must be regarded as important but a single specimen is not, by itself, determinative."

3.2.11.51 It appeared to the Court that the report of Mr. Clancey required certain clarifications. It was suggested to Boeing Commercial Airplane Company by the Court that Mr. Clancey should appear as a witness. The Court received a message to the effect that Mr. Clancey felt that he could not add anything useful to his report.

3.2.11.52 A close examination of the report of Mr. Clancey shows that the opinion expressed by him in the later part of the report is at considerable variance with the observations contained in the earlier part of the report. Particularly with regard to Target 362 and the small fragments, Mr. Clancey has stated in his observations that there was strong evidence of explosion. In his opinion, however, he has stated that more detailed study is required. It is interesting to note that though Mr. Clancey has referred to the opinion of Tardif and Sterling, he has not chosen to contradict the conclusions arrived by them. Mr. Clancey has also not stated as to what could possibly have caused the special features which were noted on Target 362.

3.2.11.53 We find the metallurgical report inspires more confidence. Not only is reference and reliance made in the report to other expert opinions contained in various articles written by experts all over the world, certain explosion experiments were also carried out by the experts which led them to the same conclusion.

3.2.11.54 The particulars of the experiments so carried out and the results obtained therefrom have been stated in their report as follows:

EXPLOSION EXPERIMENTS

"To determine the damage by high velocity fragments or shock waves on a structure similar to the one in aircraft cargo hold, the following experiments were conducted on November 30 and December 1, 1985 at the Explosives Research and Development Laboratory, Pune, using plastic explosive (PEKI) and different mixtures of plastic explosive and TNT. The explosive was kept in a box made of sheet metal of 6" x 6" x 6" of 1/16" thickness. This box was kept inside another box made of sheet metal 2' x 2' x 2' of .04 or .06" thickness. The boxes were made of 2024 aluminium alloy sheets used for aircraft skin. To the inner surface of the outer box, hat section stringers similar to those used in the aircraft were riveted. The quantity of explosive used in the inner box was varied from 60 g to 100 g. The explosive was detonated with an electrical detonator. After the explosions the fragments and the panels were collected and examined.

"Experiments were also conducted to produce explosive damage on skin panels, individual hat section stringers and individual stantion tubes. In the case of stantion tubes experiments were carried out placing the explosive charge both inside and outside. The quantity of explosive used was varied from 5 g to 50 g.

"Various types of damages were recorded on all the targets. These include punched holes, petaling and curling around holes, spikes at fracture edges, curved fragments with small radius of curvature and reverse slant fracture. Fig. EXP-1 shows a collection of fragments. The features mentioned above are shown in Fig. EXP-2 to EXP-7. It may be noticed that the features produced by experimental explosion were similar to the features observed largely in target 362 of the wreckage. The small fragments had features similar to those in the fragments from targets 362 and 399.

"Metallography was carried out in (a) a specimen surrounding a punched hole in the skin (b) a specimen surrounding a hole in the stringer, (c) a curl in the stantion and (d) spikes in a fragment. In all these cases, the grains adjacent to the area of explosive damage are having twins. Two typical microstructures are shown in Fig. EXP-8 and EXP-9. Away from these areas the microstructure is normal. Thus it is confirmed that twinning in the microstructure of these structural members is a unique feature of explosive fracture, not produced by any other measns known so far."

3.2.11.55 The findings in the said metallurgical report are also strengthened by the observations of Eric Newton in the article "Investigating Explosive Sabotage in Aircraft" published in the International Journal of Aviation Safety, March 1985, p. 43. Mr. Newton is an acknowledged authority in the detection of explosive sabotage in aircraft. The conclusions contained in the article are based on his review of incidents of explosion between 1946 and 1984 which were known to him. Some of the conclusions arrived at by him which were relevant in the present case are when he states "Generally speaking, the smaller the fragment, higher the velocity of the detonation. Minute fragmentation is indicative of high explosive having been used, and provides clues to the focal point or region of the explosion. The mode of break up of the aircraft itself and its sequence of failure is usually very complicated and quite without the logic dictated by normal aerodynamic overstressing".

3.2.11.56 Mr. Newton has also observed that curling, cork-screwing, and saw tooth edges may also be indicative of an explosion though such fractures by themselves may not be conclusive evidence that an explosion was involved. Firmer evidence, according to him, was of fusing of metal, scorching, pitting and blast effect. He further states that "Perhaps the most conclusive material evidence to be found on metal specimens is cratering, very often in groups, often minute and numerous".

3.2.11.57 Mr. Newton also refers to the positive explosive signatures which remain on a detonation in an aircraft. These positive singatures, according to him, are as follows:

"(a) The formation of distinctive surface effects such as pitting or very small craters formed in metal surfaces, caused by extremely high velocity impacts from small particles of explosive material. Such craters, when viewed under the microscope, have raised and rolled over edges and often have explosive residue in the bottom of the crater.

"(b) Small fragments of metal, some less than 1 mm in diameter, which, under the scanning electron microscope, reveal features such as rolled edges, hot gas washing (orange peel effect, surface melting and pitting and general evidence of heat; such features have been proved and observed following explosive experiments with known explosives). Supporting strong evidence would be if such fragments (normally found embedded in structures, furnishing or suitcases) were found embedded in a body where evidence of burning of tissue is present at the puncture entry and where the fragment came to rest.

"(c) As well as surface effects on metal fragments produced by explosives there are deformation mechanisms which are peculiar to high rates of strain at normal temperature. At normal rates of strain metals deform by usual mechanism associated with dislocation movement. However, because this process in an explosion is thermally activated at very high rates of strain, there is insufficient time for the normal process to occur. In some metals such as copper, iron and steel, deformation in the crystals of the metal takes place by 'twinning', that is to say by parallel lines or cracks cutting across the crystal. Such a phenomenon can occur only if the specimen has been subjected to extreme shock wave loading at velocities in the order of 8000 m/sec. Such specimens, usually distorted must be selected with care, prepared in a metallurgical laboratory, polished, mounted and microscopically examined. Where such twinning of the crystals is found it establishes (a) that the specimen was close to the seat of the explosion and (b) that a military type explosive had been used with a detonating velocity of 8000 m/sec or more. Twinning is rarely produced when shock impact loadings are below 8000 m/sec.

"The above features, singly or combined, are considered to be proof positive evidence of a detonation of a high explosive; they could not be produced in any other way."

3.2.11.58 The metallurgical report indicates that the microscopic examination (conducted by them) discloses such features being present which had been described as positive signatures of the detonation of an explosive device in an aircraft by Mr. Newton. Furthermore, twinning effect has also been noticed at a number of places - around holes and in fragments. These have been categorised by Mr. Newton as positive signature of an explosion.

3.2.11.59 In the primary zone of explosion, metallic structures disintegrate into numerous tiny fragments and usually these fragments contain the above mentioned distinct signatures of explosion. In the present case the explosive damage had occurred at an altitude of 31000 feet when the aircraft was flying over the ocean. The fragments that formed due to explosion must have been scattered over a wide area and it is impossible to locate and recover all of them from the ocean bed. Nevertheless, some of the fragments which were recovered along with the targets 362 and 399 do contain signatures of explosive fracture.

3.2.11.60 From the aforesaid discussion it would, therefore, be safe to conclude that the examination of targets 362 and 399 clearly reveals that there had been a detonation of an explosive device on the Kanishka aircraft and that detonation has taken place not too far away from where these targets had been located.

FIRE

3.3.1 There is no evidence that there was any fire on board the aircraft before it met with the accident.

3.3.2 Amongst the floating wreckage, however, was found, what was later on identified as, a spares equipment box belonging to this aircraft. This box was charred on one side and partially on the bottom. The depth of charring suggested that the burning time was three to four minutes. This box contained some sand and small shellfish. The flesh from the shelfish appeared to be charred, indicating that the box was subjected to fire after the occurrence.

FLIGHT RECORDERS

3.4.1 Recovery of Flight Recorders

3.4.1.1 Recovery of the flight recorders was a very difficult and challenging job. At the site of accident, depth of water is about 6700 feet. The job involved fixing the location of recorders and then retrieving them. For this purpose three ships viz. Guardline Locator (a ship provided by Accident Investigation Branch of U.K.), Le Aoife (an Irish Naval Ship) and Leon Thevenin (a French Cable laying ship, charterd by the Government of India) were utilised. Guardline Locator and Le Aoife were solely for fixing the positions of recorders and also had the capability to lift the recorders with the help of its scarab.

3.4.1.2 Both the Cockpit Voice Recorder and the Digital Flight Data Recorder were fitted with Dukane Underwater Acoustic Beacons (Pingers) which enabled establishing the location of flight recorders under water. The Beacons are designed to provide a signal at 37.5 ñ 1 Khz frequency that can be heard for approximately 2 miles in any direction for 30 days after water entry. Its high strength case permits operation in water depth to 20,000 feet. Its pulse repetition rate is not less than 0.9 pulse per second.

3.4.1.3 On 4th July, 1985, Guardline Locator reported strong possibility of two separate sound sources of frequencies between 39 KHz and 42 KHz. On 5th July, Guardline Locator gave coordinates of an area, which it believed contained the pinger. Guardline Locator later reported that using a Dukane Hand Locator, it had located pinger (2) at 5102.6N, 1248.6W. Leon Thevenin then concentrated its search in this area for retrieving the recorders.

3.4.1.4 In response to a query, Messrs Dukane Corporation advised that Pinger transducer is made of ceramic and if cracked during impact, its frequency could be elevated. The pulse rate should, however, be uneffected. Keeping this in mind, the Leon Thevenin increased its Sonar Band one upper frequency limit from 40 KHz to 45 KHz.

3.4.1.5 On 9th July at about 2300 hours the Scarab of Leon Thevenin located the Cockpit Voice Recorder at 5102.67N, 1248.93W and the recorder was brought on the deck at 0747 hrs on 10th July. The CVR was kept in a drum filled with water. The scarab was again lowered on 10th July in the same area and at about 2130 hours faint signals were picked up on Sonar. By about 2200 hours the signals became louder and the pulse rate frequency was calculated to be 72 transmissions per minute. At about 2230 hours the DFDR was also located at 5103.10N, 1249.59W and it was brought on deck at 0245 Z on 11th July.

3.4.1.6 The DFDR was also placed alongside the CVR in the drum filled with water. Leon Thevenin was then advised to return to Cork with the Flight Recorders. Leon Thevenin reached Cork on the morning of 12th July and the flight recorders were placed in two specially fabricated water tight steel containers filled with water. The recorders were then carried to Bombay on the same day by Mr. Satendra Singh, Reginal Controller of Air Safety, Bombay, accompanied by Mr. Vishwanath of Air India for preparing read-outs and transcript of the recorders. Necessary precautions were taken to ensure that the data recorded was not affected during transportation to Bombay.

3.4.1.7 Both the recorders reached Bombay on the morning of 13th July and were kept in the office of the Regional Controller of Air Safety under Armed Police Guard.

3.4.2 Description of Flight Recorders

3.4.2.1 Kanishka was equipped with a Fairchild A-100 Cockpit Voice Recorder Serial No. 5809 and a Lockheed 209E Digital Flight Data Recorder Serial No. 1282. These were each equipped with Dukane Underwater Acoustic Beacons and were installed adjacent to each other in the cabin on the left side near the rear pressure bulkhead.

3.4.2.2 The CVR records all crew communications and sounds in the cockpit on a continuous tape loop which has a tape speed of 1-7/8 inches per second. The Recorder has two heads, one head which erases the previous recording and the second which records the current information and thus the last 30 minutes of recorded signals are retained, the previous being automatically erased. It continuously records convervations/sounds from 4 different sources on the following four separate channels:

Channel 1 : Radio channel of pilot

Channel 2 : Radio channel of flight engineer

Channel 3 : Cockpit Area Mike

Channel 4: Radio channel of co-pilot.

3.4.2.3 The serial digital signal recorded by the DFDR was generated by a Teledyne Flight Data Acquisition Unit installed in the forward electronics bay below the cabin floor. Adjacent to this unit was a Lockheed Model 280 Quick Access Recorder that recorded the same serial digital signals on to a 50 hour cassette.

3.4.2.4 The DFDR records 52 basic parameters on a magnetic tape. The tape preserves records of the last 25 hours. The serial digital signal has a bit rate of 768 bits per second and is recorded at a tape speed of 0.37 inches per second.

3.4.3 Examination of Flight Recorders and Tapes

3.4.3.1 General

The recorders brought to Bombay from Cork were opened on 16th July, 1985 at the Air India's Facilities in Bombay in the presence of the Court and Assessors. A team of foreign experts including one each representatives from both the Recorder Manufacturers, three from National Transportation Safety Board, one from Canadian Aviation Safety Board and one from NRC Flight Recorder Playback Centre, Canada were present when the tapes were taken out of the recorders. Apart from them, representatives of the Government of India and Air India were also present.

3.4.3.2 Cockpit Voice Recorder

When the unit was removed from its shipping and storage container, some mechanical damage was immediately evident. The top of the cover had been deformed inwards, probably due to initial external

strong attachments for the horizontally mounted Underwater Acoustic Beacon. The plate had torn away from the light structure behind it. The cause of the damage was not obvious. The light outer cover was removed by cutting it open with hand shears and pliers.

3.4.3.3 When the armoured and insulated containment was opened, the tape transport was found to be in relatively good condition and the tape physically undamaged. Eighteen inches of the tape was pulled from the centre of the tape stack and the tape cut near the stack well clear of the end of recording. The tape was then removed from the recorder, transferred to standard tape reels, laboriously cleaned several times with distilled water and dried with lint free absorbent material.

3.4.3.4 Digital Flight Data Recorder

When the recorder was removed from its shipping and storage container, it was noted that there was very little external damage. A cover on the rear section was removed and it was observed that, when viewed from the front of the recorder, the right hand edges of the four rearmost printed circuit cards were displaced towards the front of the recorder. The left hand edges were restrained by plug-in connectors to the boards. The rearmost card, that controls track selection on the tape, and the one in front of it, had bowed along the right-hand edges and popped out of their plastic guides in the top and bottom of the recorder. Deflection of the other two cards had occurred following failure of the attachments of the right hand ends of the plastic guides to the chassis. The damage could have been caused by a high lontitudinal decelaration, as would occur if the front face of the recorder impacted the water.

3.4.3.5 When the tape deck was opened, it was found that the tape was intact but had become dislodged from the last tape guide when the tape was moving in the direction of the odd-numbered tracks and had also jumped out of the adjacent end-of-tape sensor. One edge of the tape had been streteched in this area. The drive belt to the tape transport was still in its correct position. The tape was stuck to the third tape guide in the odd-numbered track direction and suffered some damage when it was finally detached from it. This was repeaired with a splicing tape.

3.4.3.6 The location of the record heads was marked on the back of the tape with a waterproof felt pen. It was noted that there was slightly more tape on the supply reel for the odd tracks than on the other reel. The tape reels and tape were removed from the recorder, keeping the tape wet with distilled water, and the tape transferred to the standard reels for meticulous cleaning. During the cleaning process, it was found that the edge of the tape had also been stretched locally 336 inches down- stream from the splice repair in the odd track direction. The tape was dried by patting it with absorbent lint-free material before loading it into a serviceable recorder as this was the only means by which it could be replayed at the Air India base.

3.4.3.7 The circuit card controlling track selection was removed from the accident recorder and the status of the latching relays checked to determine the last track on which recording was being made. It was found that the relay states indicated Track 1, but since this requires all relays to be set in the same condition, it was considered possible that they had been mechanically set on water impact. The card was subsequently inserted to another recorder and the Track 1 setting confirmed on a test bench.

3.4.3.8 When a change in track selection was attempted, it was found that the relays would not switch, probably due to the effects of salt water corrosion or high water pressure. It was decided that Track 1 would be considered as the most likely one to contain the accident data with the possibility that it could have occurred on any of the other tracks. When the data was recored, the accident information was found some distance past the mid-point of Track 1.

3.4.4. Recovery of Information

3.4.4.1 Cockpit Voice Recorder Tape

The spool was removed from the CVR and was washed with distilled water, dried and loaded on to another spool. The cleaned and dried tape was taken to the Bhabha Atomic Research Centre (BARC), and a copy of the tape was prepared which was used for preparing transcript and carrying out further analysis. The transcript of the CVR conversation is given in Appendix 2.

3.4.4.2 Shannon Air Traffic Control Tape

A copy of this tape that contains all radio communications between the aircraft and Shannon was provided to the Indian Authorities by the Air Traffic Control Authorities, Shannon. The recording also included the short series of unusual sounds that occurred about the time of the accident.

3.4.4.3 When the CVR and the ATC tapes were played it was found that some adjustment in speed was necessary so as to synchronize the two. This adjustment was independently carried out by different experts who analysed the CVR tapes.

3.4.4.4 Digitial Flight Data Recorder Tape

The Lockheed representative had brought a Lockheed Model 235 Copy

Recorder from his plant. This unit copies all the 25 hours of data from the recorder by running it at high speed for only two passes of the tape, an operation lasting only 16 minutes. A copy tape was made by this procedure before embarking on the standard Air India recovery procedure to serve as a back-up tape in the event of physical damage to the original tape in subsequent playback.

3.4.4.5 Air India playback equipment for the DFDR required that the tape be re-installed in another DFDR in which it was driven at high speed. In the standard playback procedure, the tape was first run to the beginning of Track 1 through 6 sequentially on to a computer tape followed by a repeat of Track 1. The computer tape was then taken to Air India's main computing facility where selected information was printed out in engineering units.

3.4.4.6 The first printouts showed that the accident was recorded on Track 1, as indicated by the latching relays, and suggested a rather abrupt end to the recording. There was a loss in bit synchronization in word 26 of the last Subframe 3 of data that was followed by a normal Subframe 4. Prior to the loss in bit synchronization, all measurements appeared normal. Plans were made to borrow the high speed oscillograph recorder previously used to studythe final CVR signals from BARC to examine the end of the recorded serial digital signal in detail.

3.4.4.7 Meanwhile, the critical section of the tape and the heads of the playback recorder were re-cleaned and a second transfer of data on to the computer tape was made. Printouts from this computer tape showed no significant difference from the first one.

3.4.4.8 The recorder was then opened and the tape positioned about 1.5 inches before the final resting place of the tape that was clearly indicated by head imprints on the magnetic oxide coating side. A high speed oscillograph record of a few seconds of data was made and visually decoded. It was found that the recorded GMT was 21 hr 16 min. This time corresponded to 15 min or about 333 inches of the tape after start of the oldest recording downstream of the accident.

3.4.4.9 The tape was then re-positioned using a Lockheed analogue playback unit, that had a display of the recorded time and a stopwatch was used to locate the accident timing. Two oscillograph copies of the end of the serial digital data were made, the second one having more data preceding the end. Visual reading of the traces confirmed that recording became erratic and irrecoverable at the end of Word 26 in Subframe 3 at the recorded time of 07 h : 14m : 35s. The erratic signal continued for about 0.27 inches of the tape before switching back to the data recorded 25 hours earlier.

3.4.4.10 Examination of the printouts confirmed a suspicion that the complete Subframe 4 of data following the partial Subframe 3, was data from 32 seconds earlier that had not been cleared from the data buffer in the computer and that Word 26 of the Subframe 3 was the last normal measurement provided by the recorder.

3.4.4.11 The end of recording occurred at the point on the tape at which some damage had been observed during the cleaning process. It was apparent that, after the end of the recording, the tape had run on for 336 inches before finally coming to rest.

3.4.4.12 A copy tape of the DFDR tape was made at Bombay and taken to Ottawa. Data from the accident flight, the preceeding Toronto-to-Montreal flight and part of the cruise conditions of the earlier flight to Toronto were transcribed on to the computer tape. The tape was edited to minimize errors and converted to engineering units using standards calibration. Time histories of all parameters for periods of interest were plotted. In addition, chart records were made of all parameters in raw data form for the total duration of the last lap of the flight.

3.4.4.13 The DFDR read out shows that the aircraft was cruising at an altitude of 31,000 ft. and a computed air speed of 296 knots till it suddently stopped recording at 07:14:35 GMT recorded time.

3.4.5 Reports received by the Court

3.4.5.1 The CVR was taken to B.A.R.C. This tape was played by the CVR group a number of times and hard copies of the time information were also prepared using an ultra violet (UV) Recorder. The group consisted of Mr. Satendra Singh, Regional Controller of Air Safety of D.G.C.A., Mr. S.N. Seshadri of BARC, Mr. Paul C. Turner of NTSB, USA, Mr. John G. Young of NTSB, USA and Mr. P. dE Niverville of CASB, Canada. On 18th July, 1985 this group made the following observations after playing the aforesaid tape (UV recording of CVR is at Fig. 1) :-

"The first visible rising signal volume was observed on channel number three the CAM channel It reaches a maximum in about 50 milliseconds. At this time noticeable disturbances are observable on the other three channels. A smaller disturbance is observable on channels 2 and 4 earlier than observable on channel 1. A major disturbance is observed to begin approx. ninety milliseconds following the initial observation on channel number 3 (CAM), on channels 1,2 and 4. Following this point at 75 milliseconds the CAM signal subsides to a lower level but much higher than observed ambient (prior to disturbance) where it remains for approximately 375 milliseconds from initiation when it ceases. Channel four goes off at the same time. Channel 1 goes off twenty five milliseconds earlier. Channel two is inconclusive and had a different pattern. All four channels exhibit a disturbance at approx. 450 milliseconds. The cockpit voice recorder power then shuts off at 650 milliseconds.

The Shannon area control centre tape made the night of the accident was examined and printed. It shows a signal was received at approximately the time the aircraft disappeared from radar. It isn't conclusive at this time that the signal originated from the accident aircraft. The signal was received in pulses for approximately five seconds."

3.4.5.2 The tape was again played on 19th July, 1985 and a further report was prepared which was signed by the aforesaid persons and Mr. B. Caiger of NRC, Canada. In this report it was stated as follows:-

"The Shannon area control centre tape was again printed at .05"/second per inch speed from approximately 22 sec. before the first broadcast from the accident aircraft at 0709.58 until Radio carrier with indecipherable modulation can be heard at 0714:01. The print contains a time encoded signal.

A similar print was made from the CVR channel 4 (Co-Pilot's) of the same audio as received on the ATC tape. Although the tape speed is different, the events when corrected for tape speed errors occur at the same time. It appears that the ATC recording contains the beginning of the aircraft breaking until power is lost to the transmitter since channel one and channel four (Capt + Co-pilot's radio) appear to contain a transmitted signal on the CVR. It is probable that the ATC signal at 0714:01 coincides with the final quarter second of CVR radio channels".

3.4.5.3 On the date i.e. 19th July, 1985, Mr. Paul Turner of NTSB also gave an additional report which is to the following effect :-

"During my observations of numerous cockpit voice recorders I have heard and observed a number of aircraft breakages due to various causes. In this case the explosive sound on the CAM channels occurs prior to any electrical disturbance observable on the selector panel signals. Electrical disturbances can generally be seen prior to audio signal when explosive sounds originate at any significant measureable distance from the microphone (15 feet) and in the area where there is significant electrical systems. It is my opinion that an explosive event occurred close to the cockpit. The CAM signal which follows the explosive event shows a very much higher noice level than cockpit ambient 85 db, indicating to me the cockpit area was penetrated and opened to the atmosphere. The selector panel signals show signatures similar to those of an aircraft breaking up and are apparantly caused by electrical systems disturbance (circuit breaker blowing, fuse switching etc.). The lack of Mayday call and apparent inadvertant signal from the cockpit crew incapacitation. The transmitter coming on due to breakup is phenomena observed previously.

This contains only my personal opinion and in no way should be considered a final determination of cause without corroborating evidence".

3.4.5.4 Copies of the tapes were also sent to some of the participants who wanted to carry out independent analysis.

3.4.5.5 With regard to DFDR the Court received reports from Dr. Caroll Roberts of NTSB and report dated 11th November of Mr. B. Caiger.

3.4.5.6 With regard to CVR the Court received reports from Mr. B.

Caiger dated 11th November, 1985, report dated November, 1985 of Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K., report dated 31st August, 1985 of Mr. S.N. Seshadri of BARC, Bombay.

3.4.6 Court Observations

3.4.6.1 Digital Flight Data Recorder

The reports of Dr. Caroll Roberts and Mr. Caiger which also coincide with the report submitted by Mr. Satendra Singh disclose that the DFDR showed no evidence of abnormal values of any of the many parameters being monitored upto a point at which the recorded data signal became irregular for a fraction of a second and recording ceased. Both the DFDR and the CVR stopped at the same time.

3.4.6.2 The short period of irregular digital data that occupied only 0.27 inches of tape, most probably indicates that the recorder was subjected to a sharp angular acceleration in the left wing down sense about the aircraft longitudinal axis.

3.4.6.3 According to Mr. Caiger's report the possibility that the digital recorder was subjected to a sharp disturbance more rapid than violent motion of the aircraft lends some credence to the possibility of a detonatiaon of an explosive device in the aircraft. The other alternative, according to Mr. Caiger, which could have led to this was that the Flight Data Acquisition Unit in the main electronics bay .or its power supply were suddenly disturbed. As the Lockheed Quick Access Recorder was not recovered from the wreckage, this possibility could not be investigated further. A perusal of the DFDR print out, however, shows that whereas there was a speed limit of 290 knots (.81 Mach) of the aircraft due to carriage of the 5th pod engine, in actual fact the aircraft's speed during cruise varied from 287 to 296 knots. Mr. H.S. Khola asked the Boeing Airplane Company to examine the effect of aircraft cruising at a speed of 296 knots with a 5th pod engine installed on it. The Boeing company sent a reply, inter alia, stating as follows:

"The operating speed limit of Air India 747-237B, JT9D-7J with fifth engine pod was 290 knots indicated airspeed, with an altitude limit of 35,200 feet. Flight testing of this model airplane configuration was successfully accomplished to a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, with no adverse effects.

In the event that the operating speed placard was exceeded an increase in perceptible vibration levels would be felt. As the dive Mach number (0.92) is approached the buffet vibration would increase to level that could become objectional to the flight crew, but would not he bazardous".

3.4.6.4 It would thus be clear that if no adverse effects could have been noticed with a dive speed of 386 knots calibrated airspeed and 0.92 Mach number, there was little likelihbood of the aircraft having been subjected to any adverse effect by reason of the speed varying from 287 to 296 knots while it was cruising at a height of about 31,000 feet.

3.4.6.5 Cockpit Voice Recorder

The Court received four reports of the CVR tape analysis. These reports were of Mr. B. Caiger, Mr. R.A. Davis, Mr. S.N. Seshadri and Mr. Paul C. Turner. Whereas the first three experts appeared and deposed in Court, Mr. Paul Turner did not come.

3.4.6.6. There were certain aspects of the report of Mr. Turner which required clarification. After the Court had failed to secure his presence, it sent a questionnaire to Mr. Turner for his answers thereto. It is indeed unfortunate that till now no reply has been received. It is in this background that the report dated 13th November, 1985 of Mr. Turner and the reports of other experts have to be judged and analysed.

3.4.6.7 Mr. B. Caiger's Report and Deposition

Mr. Caiger has said in his report that the Cockpit Area Microphone signal was studied in detail. According to him, in an aircraft, sound can be transmitted by multiplicity of paths. If an explosive device was located close to the microphone then the short wave from the disturbance would cause a sharp rise in pressure which was not noticed. From more remote location, however, structurally transmitted sounds could reach the microphone first and induce more complex signals. According to Mr. Caiger, at this time he did not have any evidence from occurrences of this nature that would permit any meaningful comparisons or conclusions.

3.4.6.8 Mr. Caiger obtained from the manufacturers details of Automatic Gain Control (AGC) on the cockpit area microphone. According to the information so provided it was indicated that the decrease in amplitude of the recorded noise over about 33 msec after the peak level was reached 40 msec from the start of the disturbance is most probably due to the AGC and that the actual envelope of the pressure levels at the microphone continued to increase until 90 msec from the start before establishing at about four times the recorded level until the 160 msec point when the recorded amplitude started to decrease rapidly. Mr. Caiger could not find any explanation for this marked reduction. Mr. Caiger further recorded that the large amplitude lower frequency signature, that immdediately followed this reduction, is similar to signatures observed by the manufacturer when there was an abrupt break in the line from the cockpit area microphone pre-amplifier output to the voice recorder. No similar signature was observed in tests on the crew audio channels when the appropriate lines to the recorder were similarly interrupted.

3.4.6.9 The observation of Mr. Caiger with regard to ATC tape was as follows :-

"The ATC recording that followed the cockpit area microphone sounds appears at first to contain a series of short intermittant sounds. Closer study reveals that the background noise only returns to its steady level for about 160 msec immediately after the first low level noise and again for about 85 msec just over halfway through the 5.4 sec duration of the recordings. At the end of all routine radio transmissions, a damped sine wave transmitter keying signature is observed with a frequency in the region of 450 Hz. In the accident recordings, only two of these are observed".

"Listening to the sounds, it also appears that a human cry occurs near the end of the recordings. Spectral analysis of these sounds and comparison with voice limitations reveals that the accident sounds do not contain all the pitch harmonic frequencies normally associated with such voice sounds. The origin of all the sounds has not been identified."

3.4.6.10 From the aforesaid investigation Mr. Caiger concluded that :-

"From the voice and data recorders, Air India Flight 182 was proceeding normally enroute from Montreal to London, England at an altitude of 31,000 feet and a computed airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound the cause of which has not yet been identified. The sound continued for about 0.35 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder".

"The initial waveform of the cockpit area microphone signal is not consistant with the sharp pressure rise expected with detonation of an explosive device close to the flight deck but, with the multiplicity of paths by which sound may be conducted from other regions of the aircraft, we cannot at this time exclude the possibility that it originated from such a device elsewhere in the aircraft".

"Within 1 to 2 seconds of the first detection of the loud sound on the cockpit area microphone, a series of unidentified noises were recorded on the Shannon ATC tape. These extended over a period of 5.4 seconds and are assumed to have origniated from VT-EFO. They gave the impression of abnormal conditions on the flight deck".

3.4.6.11 In his evidence in court, Mr. Caiger explained about Automatic Gain Control. He stated that the CAM channel of the CVR had an Automatic Gain Gontrol in a pre-amplifier that is installed close to the microphone. This AGC is designed to prevent excessively loud signals from saturating the microphone and the associated electronics. He further stated that from the tests conducted by the manufacturers it could be concluded that most likely at 45 msec. point the AGC came into effect which gradually reduced the signal over the next 33 msec. before letting it stabilise at a roughly constant value. This figure of 33 msec. was taken by Mr. Caiger not by carrying out any experiment himself but it was provided to him by the manufacturers. He also stated that there was no positive indication of structural failure being evident from the flight recorders. Mr. Caiger was asked to explain as to what was the reason for loud sound to which reference had been made in his report. In answer to the said question from the Court he said that there could be a number of reasons. The detonation of an explosive device not close to the microphone was one possibility, the occurrence of some type of structural failure was another possibility. He was further of the opinion that at the present stage of development in structural acoustics, he did not think it was possible to come up with any reasonable estimate of the location of either explosive device or some type of possible structural failure. When asked for his opinion about the sequence of events which he could determine by looking at the sound spectrum, he said as follows: "From the study that we have made which have of course been augmented by studies done by several other groups it would appear that there was a very sharp bang that was detected by the CAM. Approximately one-third of a second after this happened the line from the CAM to the CVR was disconnected but intermitant power supply was still being sent to the voice recorder for approximately one and a half seconds. During this 1-1/2 seconds period sounds were being transmitted from the 'Kanishka' aircraft that tend to suggest that the aircraft was in some distress. Though it is difficult to be specific about the basis on which we assesss the state of the aircraft, this signal ceased after a period of 5.4 seconds and we have no more audio information concerning the aircraft from that point onwards."

3.4.6.12 Mr. R.A. Davis's Report and Deposition

Mr. R.A. Davis in his report on the analysis of CVR has stated that he did not have with him a faithful copy of the original CVR tape. The tape supplied to his contained signals which warranted investigation but any measurement could be hampered by a decreased signal to noise ratio due to the copying process. Mr. Davis however analysed the tape which admittedly according to him was not of good quality. Mr. Davis in his report states that he carried out a spectrum analysis of the different channels of the CVR. The spectra did contain the sound of a bang. He however, could not find any significant low frequency content in the spectrum which according to him, would have been expected if the sound was of a high explosive detonation.

3.4.6.13 While carrying out detailed study of the tape he also looked out for any evidence of various audio warning signals which may have been buried in the noise. One such audio warning which could have been detected was that of pressurisation warning. Mr. Davis stated that this warning possessed a very defined frequency spectrum which was not present in the signal of the CVR of Kanishka. With regard to this he, however, stated that absence of this signal was not surprising as any decompression would take a finite time before reaching the warning level. Mr. Davis further observed that the presence of warnings due to attititude display disagreement, excessive speed and fire were investigated but with negative results.

3.4.6.14 During the course of investigations, Mr. Davis had compared Kanishka CVR recording with the recordings of an explosive decompression on a DC-10, a bomb in the freight hold of a B-737 and a gun shot on the flight deck of a B-737. According to Mr. Davis the spectrum of VCR tape of B-737 showed a much low frequency content with very little content at upper frequencies. This bomb, in the forward baggage hold of B-737, had exploded while the aircraft was at a low level and therefore the CVR did not have the sound accompanied with that of depressurization. That aircraft had landed safely. Mr. Davis, however, observed that if Kanishka's accident was caused by detonation of a high explosive device, then the spectra should have shown large low frequency content, but this was absent. He further opined that, even if there was a possibility of a bomb remote from the flight deck and of a low power, even then the characteristics of a bomb would still be apparent in the time record. He also analysed the spectrum of the sound of the hand gun shot on a B-737 flight deck and according to him the said signal was sharp edged and did not compare with that of Kanishka's signal.

3.4.6.15 Mr. Davis also analysed the sounds recorded on the ATC tape. He concluded that the sounds emanated from Air India's Kanishka aircraft. According to him the transmission from the ATC is "chopped" until at approximately 2.7 seconds into the transmission a loud noise lasting about 200 milliseconds is heard. This is followed about 0.5

seconds later by a sound which increases in volume. This sound was similar to that heard in other accidents where there had been a rapid increase in airspeed.

In the noise which continues until the end of the transmission is heard a crying sound. This was originally thought to be a human cry. He, however, noted that a human cry would contain more harmonics than was noticed in this case. It was also reported by Mr. Davis that knocking sounds which were heard during the transmission were initially thought to be due to hand-held microphone vibration. This was discounted because of the frequency of the sounds. He noticed that almost identical sounds were heard on the DC-10 CVR after the decompression had occured and the source of that sound had not been identified. On the DC-10 the pressurization audio warning commenced 2.2 seconds after the decompression. Analysing the ATC tape Mr. Davis observed that no such warning was identified during the open microphone transmission.

3.4.6.16 In conclusion, Mr. Davis reported as follows :-

"It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182.

"There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified.

"Although there is no evidence of a high-explosive device, the possibility cannot be ruled out that a detonation occurred in a location remote from the flight deck and was not detected on the microphone. Such a situation would be most unusual, if not unique, in that we have never failed to detect sounds of structural failure, decompression, explosives etc., on any accident CVR, even though the event occurred at the rear of the aircraft. If such a device was used on AI 182 it is considered that it would have to be a very small device in order not to be detected (unlikely in itself). Such a device would be unlikely to cause the sudden total destruction which occurred in this instance. It is considered that a device of sufficient power to produce this effect could not fail to be detected on the CVR. The B-747 explosions referred to earlier, blew holes several feet wide in the structure but the crew were still able to control and operate the aircraft.

"It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

3.4.6.17 In reply to a question it was stated by Mr. Davis, when he was examined in Court, that it was true that there was no evidence that rapid decompression was caused by any structural failure. In an answer to another question, as to whether in his opinion there is a low frequency content present in every situation whereever there has been a high explosive device detonated, Mr. Davis answered in the affirmative, he however added that "But we do not have sufficient numbers to indicate that that would always be the case". Mr. Davis, however, agreed that DC-10 aircraft was quite dissimilar to Boeing 747, and the sound of an explosive decompression in the aft cargo hold of a DC-10 would not be identical to an explosive decompression in the aft cargo hold of a Boeing 747.

3.4.6.18 Mr. Davis further agreed that he was looking for low frequencies in Kanishka tape, but he did not know what type of low frequencies should be looked out for because there was no available data anywhere in the world for the sound of a bomb explosion in a Boeing 747. Mr. Davis was however emphatic in saying that he could not measure the distance of the origin of the sound from the cockpit area mike. In his report, and also in the earlier part of the examination, Mr. Davis had referred to the absence of low frequency component in the spectrum and had sought to conclude that such absence showed that there was no detonation of a high explosive device. In an answer to the question put by the Court however, Mr. Davis appeared to have altered his stand. This is evident from the following deposition of Mr. Davis :-

"Court Ques Am I to understand that there must necessarily be a low frequency whenever an explosion occurs?

Ans. No. What we thought was there would be. There was only one sample of explosion in B-737. But we would need more accidents of that nature to able to say that yes we must have a low frequency component.

Court Ques: Am I to understand that the absence of a low frequency component would not therefore necessarily mean that the sound was not that of an explosion?

Ans. Because of the absence of a low frequency component we would not be able to say positively that there was an explosion or it was not explosion."

Court Ques : Would the frequency of a particular type of sound change depending upon the environment in which that sound occurs?

Ans Yes.

Court Ques If an event results in low frequency sounds in one type of environment, can it mean that the same event can result in a high frequency sound in a different environment?

Ans. That must be possible".

3.4.6.19 Mr. S.N. Seshadri's Report and Deposition

A detailed analysis of the CVR and the ATC tapes was also carried out by Mr. S.N. Seshadri at BARC. For the purposes of comparison, CVR tapes of Iranian Air Force Boeing 747 accident as well as that of Indian Airlines Boeing 737 accident were also analysed at BARC.

3.4.6.20 The original CVR tape of Kanishka was played on a 4 channel tape recorder modified to run at 1-7/8" per second. The output of this tape recorder was copied faithfully on an eight channel HP 3968A instrumentation tape recorder. Channels 1 to 4 were used for recording the CVR data and channels 5 for recording a time marker. For further processing and signal analysis this copy of the original tape was used.

3.4.6.21 The observations of the data so recorded, as contained in the said report inter-alia are as follows :

"Repeated and careful listening to all the four channels revealed the presence of explosive sounds on all these channels occuring nearly at the end at the same time. Speech information is present on channels 3 and 4 during the last few minutes. Channel 1 does not contain any speech data during this period. Channel 2 contains indecipherable speech data about 20 to 25 seconds before the explosive sound".

"It was decided to analyse in detail the tape data during the final few seconds within which significant audio and electrical changes were observed to be present. Data from all the four channels were displayed on a Tektronix 2-channel storage oscilloscope Model 466 for initial observations. Based on this study the relevant portion of the tape was selected for more intensive snalysis. Simultanious ultraviolet recording of all the four channels on this portion of the tape was next carried out". The following observations are relevant.

1. Channel 3, which corresponds to the area mike shows the first indication of a rising audio signal. This instant is termed, for conveniece, as zero time reference. The signal level rises from the ambient level in the cockpit by about 18.5 db in approximately 45 milliseconds. The signal then starts falling and stablises at a level about 10 db higher than the ambient level before zero time. The signal continues to remain at this level for about 275 milliseconds. The total duration of the signal from zero reference is thus about 360 milliseconds.

2. Channels 1 and 2, which are the radio channels of the pilot and the flight engineer respectively, show start of electrical disturbance signals 45 milliseconds from zero time at which the audio signal on channel 3 is at its maximum. These signals, which have do minant frequencies in the range of 70 to 210 Hz, persist for about 100 milliseconds on both channels. Subsequent to this, channel 1, shows an audio burst lasting about 200 milliseconds. Channel 2 shows a delayed audio burst lasting 25 milliseconds, 220 milliseconds from zero time, or in other words, 175 milliseconds after the peak signal from channel 3. A low amplitude tail appears after this burst and lasts around 40 milliseconds. Channel 4 which is the co-pilot's radio channel shows an electrical disturbance commencing at 85 milliseconds from zero time and lasting around 60 milliseconds. The frequency distribution during this period is similar to those on channels 1 and 2. This is followed by an audio burst of 230 milliseconds duration. The frequency spectra of the audio portions of channels 1,2 and 4 are reasonably similar."

3.4.6.22 "Correlation of Events of ATC Shannon Tape and Channel 4 of CVR tape :

"It was observed that during the last few minutes before the stoppage of the CVR, information recorded on the ATC tape and channel 4 of the CVR tape are identical. However, the ATC tape contains a series of audio bursts approximately corresponding to the instant at which a single explosive sound is recorded on channel 4. Thus a doubt arose whether the series of audio bursts recorded on the ATC tape had originated from channel 4 of Kanishka CVR since these are not recorded on the CVR tape. In order to obtain an answer to this it was necessary to check with very good accuracy the simultaneity of the explosive sound on channel 4 and the series of audio bursts on the ATC. The procedure followed for the same is given below.

"The ATC Shannon tape and the CVR tape were run on two independent tape recorders. It was found that the speeds of the two tapes were mismatched. In order to match speeds the earliest speech signal on both the tapes.

"Seven seventy that checks maintain three five zero" was used as the reference point. The speech signals which mostly contain the conversation between the co-pilot and ATC Shannon lasts for about 146 seconds. Channel four was kept ready for starting exactly at the reference point. The ATC was next played starting well before the reference point. The tape recorder playing channel 4 was started manually exactly at the time when the reference point on the ATC was audible. By noting the time of ending of the conversation on both the tapes which corresponds to

"Right Sir squaking two zero zero five one eight two" the speed of the recorder playing the ATC tape was corrected by pitch control to approach the speed of CVR tape. The process was repeated a number of times till audibly the speeds were matched. The two tapes were next synchronously played and both the channels were simultaneously recorded on a third recorder to a point well after the explosive sound on channel 4. This tape was used for all further analysis.

"The first significant observation was that the explosive sound on channel 4 coincided with the beginning of the series of audio bursts on the ATC tape as heard by the ear. It was thus clear that both the recordings correspond to those generated by Kanishka during its last moments.

"To confirm this preliminary conclusion which was judged solely by the ear, accurate instrumented tests were carried out. The two channels were simultaneously recorded on an ultraviolet recorder at the four speeds, 0.1"/sec, 1"/sec, 10"/sec and 160"/sec for study of synchronism as well as frequency details. It was noticed that the two waveforms were not exactly suynchronised though by the ear they appeared to be so. In order to find out exactly the difference in synchronisation the following tests were done:

UV recordings at 16" per second were taken at three representative points relating to the communication of ATC with Kanishka. These points correspond to speech portions at 070838 "Five eh Squawking and eh Air India", at 070958 "Right Sir Squawking" and near the blast on channel 4. It was found that the ATC was running slightly faster. At the first point the ATC was leading by 90 milliseconds, and at the second point by 130 milliseconds. The time interval between these points is about 80 sec. By extrapolating this lead to the time of the blast which occurs about 243 sec. from the second point, it is clear that the lead of the ATC with respect to channel 4 at this point will be given by 130 + (130-90) (243/80) which is approximately 250 milliseconds. This error is very small."

"Thus one can conclude that the sounds recorded on the ATC Shannon tape are those which emanated from Kanishka during its last seconds."

3.4.6.23 "Frequency Analysis:

Mr. Seshadri also carried out frequency analysis of the CVR and the ATC tapes. His opinion with regard to the same was the follows:

"Significant audio and electrical disturbances were observed in the final few seconds of the CVR tape. It was therefore decided to analyse all the four channels for their frequency contents at the various places in this pertinent region. For Fourier analysis of each signal, digitized time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

3.4.6.24 "The frequency analysis of electrical disturbances in channels 1,2 and 4 indicate presence of low frequencies in the region of 20 Hz to 600 Hz. The dominant frequencies are in the range of 70 Hz to 210 Hz.

3.4.6.25 "The frequency spectrum of the background noise in channel 3 just before the explosive sound has a broad band spectrum with some dominant frequencies in the region of 650 Hz to 1550 Hz. At the bang, many additional frequencies appear. The frequency spectrum of bang on channel 3 indicates an increase in the bandwidth.

3.4.6.26 "The frequency spectrum of channel 1 at the bang position indicates a fairly broad spectrum with dominant frequencies in the range of 150 Hz to 1 KHz. Channel 2 displays a frequency spectrum at the bang position in which low frequencies are dominant. It has a significant frequency range between 20 Hz to about 1 KHz. The frequency spectrum of channel 4 at the bang is wide-band with a broad peak in the range of 150 Hz to 800 Hz.

3.4.6.27 "At the beginning of the crackling sound, the frequency spectrum shows narrow band peaks around 1.6 KHz. About 90 and 300 milliseconds later, the spectrum changes with additional peaks appearing around 400 Hz, 600 Hz and 1150 Hz. Frequency analysis was also carried out at 600, 800 and 1000 milliseconds before the start of the crackling sound."

3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal time data of 200 milliseconds duration was processed. The frequency analysis was carried out using Bruel & Kjaer model 2033, high resolution signal analyser. Frequency spectrum was computed over a base band of 2 KHz with a resolution of 5 Hz.

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3.4.6.28 The conclusions which were arrived at by Mr. Seshadri on the basis of what he had heard and after studying the various spectra were as follows:

"The signal in channel 3 of the CVR which corresponds to the cockpit Area Mike shows the first signs of an audio disturbance. The signal peaks to its maximum of 18.5 db above ambient level in about 45 milliseconds. A loud audible blast is heard when this channel is played at this point. An analysis of the frequency spectra before this loud blast and during the blast shows a definite change in the frequency composition. From all the above results it can be concluded that an explosion occurred in the aircraft. The exact position in the aircraft at which the explosion occurred is likely to be about 40 to 50 feet from the Cockpit judging from the rise time of 45 milliseconds.

3.4.6.29 "Explosive sounds on all the four radio channels preceded by electrical disturbance reinforce the evidence provided by channel 3.

3.4.6.30 The synchronised recording and detailed analysis of the ATC and channel 4 confirm that the sounds recorded in the ATC Shannon tape are undoubtedly attributable to the transmissions from AI 182 Kanishka during its last moments. The sounds indicate possible breaking up of the aircraft in mid air and the air blast which follows a decompression. A very detailed UV recording does not indicate the presence of a second explosion."

3.4.6.31 "Copies of CVR tapes of well understood air crashes pertaining to an Indian Airlines Boeing 737 in 1979 and Iranian Air Force Boeing 747 in 1976 were analysed for possible reference in connection with the analysis of the CVR tape of Kanishka.

3.4.6.32 "A definite explosion near the Cockpit was the cause of the crash of the Indian Airlines Boeing 737. An explosive sound recorded on the Cockpit Area Mike shows a rise time of about 8 milliseconds which corresponds to a distance of about 8 feet. This indicates that the rise time is a measure of the distance from the Cockpit Area Mike at which an explosion has occurred.

3.4.6.33 "The Iranian Air Force Boeing 747 broke up in mid air. Analysis of the CVR tape clearly indicates that the frequency spectra of the electrical disturbances are similar to those obtained for Kanishka. Thus the series of audio bursts recorded on the ATC Shannon tape have been most probably generated by the break-up of kanishka in midair.

3.4.6.34 Mr. Seshadri was also examined in Court on 27th January, 1986. In his deposition he very succintly explained some aspects of the work which was done by him. He also dealt with the aspect of AGC to which reference has been made by Mr. R.A. Davis and Mr. Paul Turner in their reports. The relevant part of the testimony in this connection is as follows :-

"We wanted to make sure that the CVR recording and the ATC corresponded to the same aircraft Kanishka. When we played the tapes for the first time we found that there was a difference of about 1 second. Though this figure may be tolerable because of the accuracy of the tape speeds, we wanted to investigate further to make really sure that the ATC corresponded to Kanishka. For this purpose we had simultaneously "recorded channel 4 of the CVR and the ATC on a single tape on 2 channels after synchronising the common speech signals to the best of our ability by the ear. We started with the first speech which was available on both the tapes, namely, "770 that checks maintain 350". This was a conversation with the TWA aircraft which is available on both channel 4 and the ATC. The last sound which is recorded common to CVR and ATC is the speech of the co-pilot who says "right Sir, squaking 2005 182". After this recording though by the ear the explosive sounds on the ATC. as well as the CVR seemed to match, we wanted to check it in more detail. For this purpose we had detailed UV recordings of different portions of the synchronised tapes pertaining to the conversation between ATC and Kanishka. This was done and we noticed that the ATC was running slightly fast. We had about 80 seconds reference time of conservation from Air India Boeing Kanishka and the ATC for reference and we had to extrapolate the information in this section for another 243 seconds at which time the explosive sound occurs. During the beginning of this 80 seconds reference period, we find that the ATC was leading by 90 milli-seconds and at the end of 80 seconds the lead of ATC was 130 milli-seconds. Thus, in 80 seconds, the ATC had gained 40 milliseconds.

"This extrapolated to 243 seconds and gives a figure of 250milliseconds. This is how we arrived at the conclusion that both are synchronised within 250 milliseconds. I would like to bring to the notice of the Court that we have taken great pains to confirm this information by reapeating the tests a number of times. We did not take the 400 cycle signal available on the tape as the time reference. We took for reference the bunching of signals produced by the conversation and the gaps in between the convervation which are very clear on both tapes. Hence we are sure that our results are right. The UV recording which was made has been filed along with my report.

"The main channel which was examined was the CAM channel. This was agreed to by all the experts who were present during the first analysis of the tape at the BARC between 16th and 20th July, 1985. One of the most noticeable things is that channel 3 which corresponds to cockpit area shows the first sign of disturbance. Let us say for reference that the disturbance starts at 0 time. In about 45 milliseconds the signal rises to a peak value which is approximately 18.5 db above the ambient level before the commencement of the signal. After this point the signal decays roughly exponentially in about 40 milliseconds to be almost a steady level which is 10 db above the ambient level before the explosive sound. From this we could draw conclusions. Assuming that an explosion occurred on the aircraft. The explosion produces a shock wave with a steep wave front which travels in air as well as through the aluminium body and the speed of travel will depend upon the distance of the explosive from the point of observation. It will depend on the cube root of the explosive and it will also depend on the ratio of the distance to the cube root of the weight of the explosive. The shock wave is very fast. It can travel at about 10 times the speed of sound. Also when the shock wave hits the aluminium body of the aircraft the vibrating panels which are defined by the stringers and longerons transmit the sound to the CAM location. Because the speed of sound in aluminium is about 19,200 feet per second which is 16 to 18 times that of the speed of sound in air and the shock velocity is also about 10 to 12 times. This signal will be received

"first by the CAM. Nevertheless the shock wave gets attenuated diffracted and refracted during its travels to the cockpit. Hence the signal received at the cockpit will be an attenuated signal and this small signal we have taken as instantaneous with the time of explosion. As the time passes the sound waves travel from the explosion site reinforcing the sound in the cockpit area thereby there is a rise time. Then when all the complete sound information is transmitted we get the peak of the signal and thus the rise time corresponds to the delay between the first rise in signal to the peak as compared to the speed of sound. One may ask the question what is the speed of sound because the aircraft has an explosion and is exposed to the outside environment but since the de-pressurization of the aircraft through the explosive fracture will take a minimum of a few seconds, we can reasonably assume that the pressure of the air in the aircraft corresponds to about 5000 to 6000 feet of altitude. At this presure and temperature, the sound velocity is roughly 1000 feet per second and from the 45 milliseconds delay we concluded that the explosion should have occurred about 40 to 50 feet from the cockpit. A question may be asked that the decay of the signal might be due to the AGC of the CVR coming into action. Mr. Turner, who is an acknowledged expert in the field of CVR has reported that Messrs Fairchild tested the cockpit voice recorders with a 10 db rise and fall of signals at the threshold of AGC and they got a result indicating a decay time of 33 milliseconds. The fall in the waveform of Channel 3 is about 40 milliseconds and is well near 33 milliseconds, so an argument may be advanced that the sound continued to remain steady and the fall in the signal level was effected by the AGC. In order to confirm this we tested the Cockpit Voice Recorder which was identical to the one which was on Kanishka by applying 1 KHz waveform of rectuangular modulation. To our surprise, we found that the decay time roughly was 130 milliseconds as compared to 33 milliseconds given by Mr. Turner. We repeated the tests with an initial background and without any background at all. We further tested with ramp waveforms, in other words, "slowly rising and falling waveforms of triangular shape with modulations of 1000 cycle carrier. This also confirms our finding. In order to clarify how the tests were performed so that others can judge whether it was a realistic test, I will explain the procedure. The modulated waveform was produced by a signal generator. This was fed to an amplifier. The amplifier output was fed to a loudspeaker. The output of the amplifier was checked to ensure that there was no distortion. Thus the signal going into the loudspeaker is the same modulated signal which has been applied at the input of the amplifier. This sound coming from the loudspeaker was recorded on the CVR through the CAM in the laboratory. This is how the test was performed. We were given a CVR tape by the Department of Civil Aviation purported to be that of an explosion which occurred on a Boeing 737 aircraft which crash- landed at Madras. We did the CVR analysis of this aircraft. We first recorded the output of the CVR of Indian Airlines CAM channel on a UV recorder. We found the rise time to be very small. This was of the order of a few milliseconds, about 8 milliseconds or so. We have been told that the explosion occurred just by the side of the front toilet i.e. just behind the cockpit. This to some extent confirms that the rise time is related to the distance of the explosion from the detecting CAM. The next thing that we did was the frequency analysis of this waveform. Mr. Davis has indicated in his report that if an explosion occurs on board the aircraft there should be low frequencies present. When we analysed the frequencies of the Kaniskha aircraft Channel 3, we did not find very low frequencies in case of an explosion abroad the aircraft. When we analysed the Boeing 737 tape we did not find any low frequencies in the signals. The report of Mr. Davis also provides the frequency analysis of a pistol shot which has been fired in the cockpit of the aeroplane. This also shows no low frequency components. So our conclusion, that it is not essential for low frequencies to be present in case of an explosion abroad an aircraft, was confirmed. I will go a step further to say that the frequency received by an area mike which responds to an explosive action abroad the aircraft will contain frequencies of the structure of the defracted " and dragging shock wave, the resonant frequencies of the aluminium panels defined by the longerons and the stiffening channel members and also some frequencies which may be of objects that the shock wave encounters in its path. It is, therefore, impossible to calculate the frequency spectrum that one would expect in the cockpit due to an explosion taking place in the aircraft".

3.4.6.35 In answer to a question Mr. Seshadri categorically stated that the word "explosion" in his report meant "a bomb, a very fast device".

3.4.6.36 Mr. Paul C. Turner's Report

Lastly, a reference may be made to the report dated 13th November, 1985 of Mr. Paul C. Turner. The evaluation of Mr. Turner of the analysis done by him of the CVR and the ATC tapes, as contained in the said report, was as follows:-

"With the foregoing as background, we can make several observations. The CVR record on the CAM channel, captain's channel and flight engineer's channel show that they were all affected at about the same time; the copilot's perhaps 20 milliseconds later. Major disturbances which are recognized as electrical system disturbances can be seen to begin about 60 milliseconds after the initial disturbance. This approximates the time it would take for the electrical system protective circuitry to become active.

3.4.6.37 "A steep wave front which would be indicative of a shock wave cannot be seen on the CAM channel sound spectrum; however, the spectrum analaysis shows that impulse type sounds occurred at the beginning of the event recorded on the CAM channel of the CVR. Since audio signals propagate through aluminium approximately 16 times the speed of sound in air, the CAM channel would probably have been affected by structurally transmitted noise before being affected by airborne noise. The geometry of the aircraft was such that structure borne disturbances could be recorded before the airborne transmitted information appeared at the cockpit microphone and an air transmitted shock wave or steep wave front may not be evident on the CVR.

3.4.6.38 The captain's and copilot's selector box channels recorded signals which appeared to be electrically inducted and similar to those seen on the Huete Boeing 747 breakups. These are then followed by a signal resembling audio frequency noises similar to an open microphone in a noisy environment or the opening of a receiver squelch. Both effects have been seen during aircraft breakups. The audio noise on the captain's and copilot's channels appears to have come from a different source. The flight engineer's channel does not contain audio noise. A spectral diagram of the copilot's and captain's channel noises just show broad band noise across the spectrum. The signal frequncies extend beyond the frequency range of a microphone both on the high and the low end. It does not fit the normal microphone envelope. Spectral diagrams of the event on the CAM channel show the normal microphone preamplifier envelope summed with wide band signal of unspecified origin. Since the signal quits abruptly with a doublet, it indicates that the interference was added upstream of the CVR and was not just reflected in the CVR power supply.

3.4.6.39 "The CVR record shows a signal stayed on for about 200 milliseconds when it appears that the power may have been interrupted to both the radio channel and the CAM channel of the CVR at the same time. It further appears that the signals to the CVR were probably interrupted at 360 milliseconds from the initial disturbance possibly by severance of the signal wires. It further appears from the action of the erase head and record that the main electrical system began to fail at this point and the CVR bus voltage value dropped to a value below 70 volts but not below 20 volts. This fluctuating voltage continued intermittently for a minimum of 1-1/4 seconds at which time the voltage evidently dropped to some value below 20 volts and the recorder ceased to operate. The power for operation of the No. 1 VHF transmitter can be explained by the operation of the standby bus and battery and connection of the No. 1 VHF radio to this standby bus.

3.4.6.40 "The necking down of the signal to a low value shows that no signal was coming to the CVR from the CAM preamplifier. The lack of a signal on the radio channels, which do not need to be erased before being recorded, further suggest that the wires were severed or

"that the transmission to Cork began after what appeared to be the loss of the primary electrical system approximately 1-1/2 seconds following the event. Standby power would have become available upon loss of the primary power, the number one VHF would have become available, and CVR would have ceased to operate.

3.4.6.41 "The action of the erase circuitry in the CVR suggests that the fluctuating voltage seen was coming from the main electrical system bus. Anything else causing this fluctuating voltage down stream of the CVR circuit breaker would probably blow it.

3.4.6.42 "The signal received in Ireland indicated that a radio, most probably this aircraft's No. 1 VHF transmitter, stayed operational for about 5.4 seconds following the event at which time the entire aircraft electrical system ceased to function. This assumes that the No. 1 transmitter ceased to operate due to standby bus failure.

3.4.6.43 "In the conclusion, it appears that a catastrophic event occurred on Kanishka. It was reflected in all channels of the CVR and the CVR power supply at the same time. The main electrical bus began to fail within 0.35 second and the standby bus survived for only 6 seconds more at which time the aircraft's electrical system ceased to function. It appears that the event occurred in a manner to affect the cockpit area microphone operation severely and to force operation of the automatic gain control on the CVR. This loud noise continued for the life of the aircraft's main electrical system as reflected in the CVR.

3.4.6.44 "The mechanism of how the ATC transmission was made from Kanishka to Cork is unclear. The sound was not recorded on the CVR, indepentent studies by Canadian and British investigators have the Cork ATC call originating approximately 1-1/2 seconds following the event on the CVR. This is about the time that standby power would have become available to the No. 1 VHF.

3.4.6.45 "This report should be viewed as an accident investigation tool only and used in conjunction with other evidence gathered during the investigation.

3.4.6.46 "The United States Noard/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

3.4.6.47 It is pertinent to note that according to Mr. Turner there was "catastrophic event" which had occurrred on Kanishka. He has, however, not elucidated as to what this event was.

3.4.6.48 After the receipt of the report, the Court requested the NTSB that Mr. Turner should come and depose. It is unfortunate that permission was not granted to him. Faced with this situation and as it was thought necessary that some clarification was called for, the Court sent a telex to Mr. Turner whereby he was asked to give replies to the queries contained therein. He was requested that the reply be sent by 27th January 1986. A copy of the telex was also forwarded to the American Embassy at New Delhi for sending the same to NTSB by way of confirmation. Previously all communications addressed to NTSB were being routed through American Embassy. No reply has been received by the Court till this day either from NTSB or from Mr. Paul Turner. According to paragraph 5.14 of Annex 13 the State is required, on request from the State conducting the investigation of an accident, to provide to that State with all the relevant information available to it. It was, therefore, obligatory on the NTSB to have seen that the information sought for by the Court by way of answers to the queries was supplied.

3.4.6.49 Court Evaluation

From the reports of all the experts and the testimonies of M/s Caiger, Davis and Seshadri it is clear, and it is agreed to by all of them, that there was a breakup of the aircraft in mid-air. The experts also agreed that the sounds recorded on the ATC Shannon tape at 0714:01 Z emanated from the Kanishka aircraft.

3.4.6.50 Mr. Caiger has not said either in the report or in his statement as to what was the cause of the bang. Mr. Davis, on the other hand, is categorical in stating in his report that there was explosive decompression (meaning rapid decompression) on the aircraft. He has, however,
stated in the report that there is no evidence of an explosive device. The main reason for his coming to this conclusion is that he had not been able to find low frequencies in the spectra of the CVR of Kanishka. Mr. Seshadri, on the other hand is equally vehement in concluding that an explosive device had detonated in the front cargo hold of Kanishka.

3.4.6.51 It may be that the frequency spectrum of Kanishka CVR did not contain low frequencies but, as has been admitted by Mr. Davis himself in answer to a Court question, it is not necessary that in the case of every detonation there must necessarily be low frequencies in the spectrum. Frequency spectra of 'Kanishka CVR before 'bang' and at the 'bang' position are shown in Figs. 2 & 3, indicating presence of additional high frequncies at the bang. Indeed in the case of Indian Airlines Boeing 737, which admittedly was a case where there was an explosion of a device within about 8 feet of the CAM, the frequency analysis showed absence of low frequencies. Frequency spectrum of Indian Airlines Boeing 737 CVR is shown at Fig. 4. Merely, because therefore, there were no low frequencies present would not mean that there was no detonating device on board the Kanishka. The CVR of Indian Airlines Boeing 737 has not been analysed either by Mr. Caiger or Mr. Davis. The analysis was, however, conducted by Mr. Seshadri and as is evident from his report, there were marked similarities between the spectra of Indian Airlines 737 and Air India's Kanishka CVR. One of the important reasons for coming to this conclusion, which has been indicated by Mr. Seshadri, is the rise time of the bang signal. From the analysis of the Indian Airlines Boeing 737 tape it was observed that it had taken 8 milliseconds for the peak to be reached. It was also seen that the explosive device was approximately 8 feet away from the cockpit area mike. Keeping this in view Mr. Seshadri observed that in the case of Kanishka the peak of the bang signal was reached in about 40 milliseconds. He, therefore, concluded that the origin of the bang sound was about 40 feet away from the cockpit area mike.

3.4.6.52 It would be pertinent to note that even according to the report of Mr. Davis the rise time in the case of Kanishka, which has been given for the peak is about 40 milliseconds. He, however, does not attach much importance to this because according to him after about 40 ms automatic gain control would become effective.

3.4.6.53 Mr. Davis has no personal experience of the time which it would take for the Automatic Gain Control to take effect. He has got the figures from the manufacturer. Mr. Davis admitted that the time which it will take for the AGC to be effective is not indicated in any published document of the manufacturer.

3.4.6.54 Mr. Seshadri, however, personally carried out the experiments on a Boeing 747 by using an instrument similar to what was on board Kanishka. From the testimony of Mr. Seshadri it is apparent that the results which he got were different. As per his testimony, for the AGC to be effective it will take 130 ms. If this be so then it may be possible to conclude that in the case of Kanishka the peak was reached in 40 ms. and thereafter the signal decayed and the signal was in no way effected by the AGC.

3.4.6.55 A reference may also be made, at this stage, the frequency spectrum of the sound of the hand gun which was fired on a boeing 737 flight deck. Frequency spectrum prepared by Mr. R.A. Davis is shown at Fig. 5. He has stated that the rise time for reaching the peak is almost instantaneous. Same is the case with regard to the frequency spectrum prepared by him of a bomb in a B-737 aircraft where the bomb had been placed in the freight hold which is shown in Fig. 6. A perusal of that spectrum also shows that the peak was reached in approximately 5 ms. The forward freight hold compartment of Boeing 737 is much more than five feet away from the cockpit area mike. If the theory of Mr. Seshadri was to be applied then as per the frequency analysis of this Boeing 737 bomb, the distance from the area mike could not have been more than 5 ft. It is, however, known, as per the report of Davis, that the bomb was actually in the freight hold which would mean not nearer than about 25 feet.

3.4.6.56 From what has been stated in the various reports, as well as in the testimony of the 3 experts who apperared in the Court, the only safe conclusion which can be drawn is that possibly enough study has not been done, due to lack of adequate data, which can lead one to the conclusion as to the exact nature of the sound and the distance from which it originated.

3.4.6.57 The fact that a bang was heard is evident to the ear when the CVR as well as the ATC tapes are played. The bang could have been caused by a rapid decompression but it could also have been caused by an explsoive device. One fact which has, however, to be noticed is that the sound from the explosion must necessarily emanate a few milliseconds or seconds earlier than the sound of rapid decompression because the explosion must necessarily occur before a hole is made, which results in decompression. In the event of there being an explosive detonation then the sound from there must reach the area mike first before the sound of decompression is received by it. The sound may travel either through the air or through the structure of the aircraft, but if there is no explosion of a device, but there is nevertheless an explosive decompression for some other reason, then it is that sound which will reach the area mike. To my mind it will be difficult to say, merely by looking at the spectra of the sound, that the bang recorded on the CVR tape was from an explosive device.

3.4.6.58 There are various hypothesis and theories which the experts have to investigate before any acceptable conclusions are arrived at. It so happens that in the present case we have the opinions of four experts, but they do not agree with one another on some material aspects. Two of the experts, namely, Mr. Caiger and Mr. Davis are categorical in saying that it is not possible to measure the distance of the origin of the sound on the cockpit area mike, whereas Mr. Seshadri has come to a different conclusion. Mr. Paul Turner in his report dated 13th November, 1985 in silent on this aspect, though in his earlier report dated 19th July, 1985 he had categorically said that there was an explosive device close to the cockpit.

3.4.6.59 With regard to the nature of the sound also we have 3 different opinions. Mr. Caiger is unable to give the nature of the sound, Mr. Davis says it is rapid decompression while Mr. Seshadri says it is a sound of an explosive device followed by decompression.

3.4.6.60 In the absence of any other technical literature on the subject, it is not possible for this Court to come to the conclusion as to which of the Experts is right. The only conclusion which can, however, be arrived at is that the aircraft had broken in midair and that there has been a rapid decompression in the aircraft. Just as it is not possible to say that the spectrum discloses that the bang is due to an explosive device similarly, and as has also been admitted by Mr. Caiger and Mr. Davis, it is not possible to say that the bang is due to break up of a structure.

3.4.6.61 The bang could have been due to either of the aforesaid two causes i.e. a bomb explosion or the sound emanating due to rapid decompression. The advantage of carrying out the said analysis is that a number of possible causes of the accident are eliminated. On the other hand, if the analysis is viewed in conjunction with other evidence on the record it is further possible to determine the exact nature or cause of the bang. In the present case the bang, as already noticed, could have been due to the sound originating from the detonation of a device or by reason of rapid decompression. Other evidence on the record, however, clearly indicates that the accident occurred due to a bomb having exploded in the forward cargo hold of Kanishka. The spectra analysis and the conclusions of Mr. S.N. Seshadri are corroborated by other evidence.

TESTS AND RESEARCH

3.5.1 During the course of investigation a number of groups were formed to study and analyse evidence and data which was available. Materials like CVR, ATC and DFDR tapes were also given to the various participants.

3.5.2 The groups as well as other experts studied and analysed the material with them and submitted their reports which have been referred to earlier.

3.5.3 The experts examining the CVR tapes did carry out a number of tests. Different graphs and traces were prepared and the sound was analysed by them. The result of their analysis has been referred to in Chapter 3.4 on Flight Recorders.

3.5.4. The metallurgical examination of some of the recovered pieces was carried out at BARC. The examination of some of the pieces showed different types of damages having been recorded on the targets such as petalling and curling round the holes, spikes etc. The said team carried out certain explosion experiments. Their report on the experiments so carried out has already been set-out in paragraph 3.2 above.

3.5.5 The Indian Air Force has set up an Institute of Aviation Medicine at Bangalore. The Court visited the said Institute on 9th December 1985. During that visit an experiment was conducted in the explosive decompression and high altitude chamber to demonstrate what actually happens during explosive decompression and subsequently on exposure to hypoxia.

3.5.6 Subjects were taken to 8,000 feet in the explosive decompression chamber with oxygen. They were exposed to an altitude of 25,000 feet within one second. During the course of this explosion a loud bang was heard and inside the chamber there was misting and drop in temperature. After this the chamber was allowed to run at 22,000 feet for roughly two minutes and an experiment to show the adverse affects of hypoxia on the subjects was done. In this experiment, subjects were asked to write a given sentence while their oxygen supply was cut off. It was observed that initially the subjects kept on writing the sentence correctly and then after about 120 seconds they started making errors while writing the sentence and finally they stopped writing. At this stage oxygen was re-started and within a few seconds, the subjects started writing their sentence once again. The experiment was completed at this stage and the altitude chamber was brought down to ground level.

3.5.7 The subjects were taken out and were asked questions as to what did they feel. They explained that at the time of explosive decompression, they heard a loud bang, felt cold and saw misting inside the chamber. They also found air escaping from their lungs. On further enquiry about the experiment pertaining to hypoxia, they said that they felt light headed and after that they did not know what happened till they once again noticed that they were writing on a piece of paper.

SECURITY

3.6.1 The evidence and the statements filed on record show that Canadian Security arrangements in place prior to 23rd June, 1985 met the international requirements for civil air transportation. However, before this date, the emphasis was on preventing the boarding of weapons including explosive devices in hand baggage. Hence, the screening of checked baggage was only undertaken in conditions of a heightened threat as was the case with respect to Air India flights.

3.6.2 Air India, as required by Canadian regulation, had a security programme. Because of the threat level assessed against the Airline, Air India had more extensive security measures than almost any other Canadian or international airline. These measures were generally in accordance with the recommended procedures of the ICAO Security Manual for special risk flights. Air India had also requested and had received and arranged for extra security for the month of June, 1985. For Air India flight 181/182, Air India provided a security officer from its New York Office to oversee the security at Toronto and Montreal.

3.6.3 As it became apparent during the course of investigation that security would be an important aspect whilch would require the attention of the Court, Mr. Rodney Wallis, Director, Facilitation and Security, International Air Transport Association was good enough to appear in Court on 24th January, 1986. His testimony on certain aspects of security was recorded in camera by the Court on that date. The expert evidence has been taken into consideration while formulating some of the recommendations.

INTERNATIONAL COOPERATION

3.7.1 The manner in which persons and organisations from five different countries combined their resources and efforts in connection with this accident is an object lesson in international cooperation.

3.7.2 From the time the accident occurred, till the conclusion of the investigation proceedings by the Court in Delhi, there has been a consistent interplay amongst different persons and organisations. When all the persons got together, for the first time, at Cork the group was very heterogeneous. Each one had his own point of view, which did not necessarily coincide with that of another. At times, the atmosphere was charged with a bit of tension which continued even when the Court was constituted to investigate into the accident.

3.7.3 It was noticed that not only were the participants a bit apprehensive and suspicious but, during the course of investigation, there were also occasions when there appeared some acrimony between a few of them.

3.7.4 In such a sensitive situation, careful handling was called for. The participants' honesty of purpose could not be doubted. All that was wanted was that there should be an effort to try and understand the point of view of all the persons. This is precisely what the Court tried to do.

3.7.5 It is indeed fortunate that the efforts of the Court, in this regard, succeeded. After the Court had decided that it was not the purpose or the function of the investigation to affix responsibility for any lapse which may have been committed, one could see the general relieving of tension. With the passage of time there was a gradual building up of the confidence of the participants in the conduct of the investigation. The participants' interest for air safety transcended all barriers and any apprehension or suspicion, which was present in the minds of some, was soon dispelled. In its place there grew a deep sense of urgency, anxiety and cooperation in an effort to see that all the participants rendered utmost assistance for the satisfactory completion of the task in hand.

3.7.6 The main beneficiary of this international cooperation was not only the Court investigating the accident but it was the cause of air safety which benefited the most. Countries and Organisations went out of the way to help each other, financially and otherwise, even when they were not obliged to do so. Money and services were readily and voluntarily offered and usually the requirements of the Court were always fulfilled.

3.7.7 As the accident had occurred only about 100 miles off the coast of Ireland, the centre of activity, initially, was centred at Cork. The Government of Ireland, and the Irish people in particular, acted as though they regarded this as a national disaster. Not only did they render every assistance with regard to the search and rescue operation, hospital facilities, police etc. but the people acted as if one of their own kith and kin had died. In the situation which existed they were pillars of strength to the relatives of the deceased. Not only did complete strangers comfort such relatives but, more often than not, they even joined in their grief. The residents of Cork did everything possible to try and mitigate the sorrow of the victims' relatives. Everyone did their small bit, even the children of Cork queued up to place flowers at the coffins of the victims.

3.7.8 The Representatives of the Government of Canada also came to the scene, at the initial stages itself, and rendered full help and cooperation till the last. The major brunt of the mapping and the salvage operations was borne by Canada. Willingly and without any demur it incurred huge expenses, which must have been to the tune of a few million dollars, in carrying out these operations. It rendered full help and assitance to the Court whenever called upon to do so. For example, it offorded full facilities and help to the team which had been sent to Canada by the Court in August, 1985. It was only with the help of the Canadian Government, and the CASB and RCMP in particular, that the Court was able to obtain evidence and information relating to the accident. Without Canadian help the conduct of the investigation would have only been speculative in nature.

3.7.9 On their own, and without any request from the Court or from the Government of India, the Government of United States decided to lend a helping hand in the salvage operations. This was done at a very critical juncture when financial help and expertise were required so as to salvage the important critical pieces of the wreckage. It arranged for the services of a salvage expert and it also made necessary arrangements for the deployment of a second ship, duly fitted with necessary equipment to enable it to salvage some of the heavier pieces of the wreckage. The Court understands that the amount which was contributed in meeting the expenses by the United States was to the tune of U.S. $ 700,000.

3.7.10 The Government of United Kingdom also provided ship and helicopters in connection with the search and rescue operations. Even during the time when salvage operations were being carried out it was the British Helicopters which assisted in transporting personnel to and from the ship which were engaged in the salvage operations. The A.I.B. at Farnborough, on being asked by the Court to do so, carried out a very detailed analysis of the CVR and the ATC tapes.

3.7.11 Being the state of Registry of the aircraft and also the state holding the investigation, the major brunt of the work fell on the shoulders of officers of the Government of India and BARC. They acted as coordinators who had to oversee the work being carried out by persons belonging to diverse organisations and coming from different countries. Young engineers of Air India took turns in going aboard the ships and manning the Control Centre at Cork. They worked in conjunction with the engineers of Boeing and CASB and the crew members of the ships during the salvage operations. Without their enthusiastic participation the progress of the salvage operations would have been severely hampered.

3.7.12 The Scientists from BARC and National Aeronautical Laboratory, Bangalore were ever ready and willing to work together with the experts from abroad. Whenever called upon to do so, they rendered whatever assistance which was desired by the Court and the other participants.

3.7.13 It was seen that when the persons, coming from different countries and backgrounds, worked together with sincerety and honesty of purpose then they functioned smoothly and harmoniously, and usually arrived at an agreed solution or finding. These days it is indeed rare to see such a degree of international cooperation between different persons, organisations and countries.

ANALYSIS AND CONCLUSIONS

4.1 From the evidence which is available what has now to be determined is as to what caused the accident.

4.2 Finding the cause of the accident is usually a deduction from known set of facts. In the present case known facts are not very many, but there are a number of possible events which might have happened which could have led to the crash.

4.3 The first task is to try and marshal the facts which may have a bearing as to the cause of the accident.

4.4 It is undisputed, and there is ample evidence on the record to prove it, that Air India's Kanishka had a normal and uneventful flight out of Montreal. The aircraft had been in air for about five hours and was cruising smoothly at an altitude of 31,000 feet. The readout from the CVR shows that there was no emergency on board till the catastrophic event had occurred. This is corroborated by the printout available from the DFDR. The event occurred at approximately 0714 Z and that brought the aircraft down, and it probably hit the surface of the sea within a distance of 5 miles. The time within which the plane came down at such a steep angle could not have been more than very few minutes. There was a sudden snapping of the communication between the aircraft and the ground. The aircraft had also suddenly disappeared from the radar.

4.5 It is evident that an event had occurred at 31,000 feet which had brought down 'Kanishka'. What could have possibly happened to it? The aircraft was apparently incapacitated and this was due either to it having been hit from outside; or due to some structural failure; or due to the detonation of an explosive device within the aircraft.

4.6 Evidence indicates that after the event had occurred, though the pilots did not or were not in a position to communicate with the ground, they nevertheless appeared to have taken some action. According to Mr. Laflamme, witness No. 12, the examination of the wreckage showed that spoilers had been deployed and this must have been done with a view to enter into emergency descent. He has further speculated that such an emergency descent would support or perhaps cause a rupture in the forward area or a partial damage to the hydraulic system or damage to the control system which created such a condition that the pilots were not able to control the flight. The wreckage fruther showed that the jack screw for the stabilizer trim was found in the nose-up position and it was hard to explain how this got there merely as a result of impact with the water. The trim being in that position could only have been due to the pilot selecting it or as a result of a situation created by an explosion. In that position, and at a high aircraft speed, there would have been an extremely high g-loading on the aircraft.

4.7 It can further be speculated that if an explosion takes place in the forward cargo compartment, the oxygen stream might have been damaged so that when the pilots donned their masks as part of the emergency drill for explosive decompression, they were not breathing enriched oxygen and the time of useful consciousness at about 31,000 feet would be significantly less than 30 seconds under high stress and if the pilots became unconscious as a result of this, then the aircraft would have got out of control which would explain the subsequent events.

4.8 None of the participants have produced any evidence which could lead one to the conclusion, that there was any external hit to the aircraft. In fact in the report dated 13th November, 1985, Mr. Paul Turner has stated as follows:

"The United States Norad/Space Command has confirmed that there was no incoming space debris in the vicinity of Ireland on June 23, 1985."

4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.

4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.

4.11 The circumstantial and direct evidence which leads to the aforesaid conclusion is as follows :

A. Connection with an explosion at Narita Airport :

On 23rd June, 1985 there was an explosion at the Narita Airport. The explosion occurred when a bomb exploded in a suit case which was to be interlined to Air India's Flight No. 301 from Tokyo to Bangkok. The following events, which had occurred prior to this explosion, clearly establish the connection between the two incidents :

(i) On 19 June 1985, at approximately 1800 PDT (0100 GMT, 20 June), a CP Air reservations agent in Vancouver received a telephone call from a male with a slight Indian accent. He identified himself as Mr. Singh and informed the agent that he was making bookings for two different males also with the surname of Singh. One booking was made in the name of Jaswand Singh with CP 086 from Vacouver to Dorval on 22 June 1985 to link with AI 182 departing from Mirabel. The other booking was to Bangkok using CP 003 from Vancouver to Tokyo and AI 301 from Tokyo to Bangkok. This booking was made in the name of Mohinderbel Singh. A local telephone contact number was given and the call lasted about one-half hour.

(ii) On the same date at approxmimately 1920 PDT (0220 GMT), another reservations agent for CP Air was contacted and requested to change the booking for Jaswand Singh. The confirmed flight on CP 086 was cancelled and a reservation was made on CP 060 from Vancouver to Toronto, and a request to be wait-listed on AI 181/182 from Toronto to Delhi was made.

(iii) On 20 June, 1985 at about 1210 PDT (1910 GMT), a male appearing to be of Indian origin purchased the tickets with cash from a CP Air Ticket office in Vancouver. The booking in the name of Mohinderbel Singh was changed to L. Singh and the booking using the name of Jaswand Singh changed to 'M. Singh'. The telephone contact number was also changed. The final itinerary was as follows :

(a) M. Singh - CP 060 Vancouver - Toronto Confirmed Scheduled to depart Vancouver at 0900 PDT, 22 June 1985

- AI 181 Toronto - Montreal Wait-listed Scheduled to depart Toronto at 1835 EDT, 22nd June, 1985

- AI 182 Montreal - Delhi Wait-listed Scheduled to depart Montreal at 2020 EDT, 22nd June, 1985

(b) L. Singh - CP 003 Vacouver - Tokyo Confirmed Scheduled to depart Vancouver at 1315 PDT, 22 June, 1985

- Air India 301 Tokyo - Bangkok Confirmed Scheduled to depart Tokyo at 1705 time in Tokyo, local 23 June, 1985

(iv) On 22 June, 1985 at about 0630 PDT (1330 GMT), a caller identifying himself as Mr. Manjit Singh called the CP Air reservations office. The caller spoke with a heavy Indian accent and wanted to know if his booking on AI 181/182 was confirmed. The caller was informed by the agent that the was still wait-listed out of Toronto and offered to make alternate arrangements to Delhi. The caller stated that he would rather go to the airport and take his chances. The caller also asked if he could send his luggage from Vancouver to Delhi and was told he could not check his baggage past Toronto unless his flight was confirmed.

(v) On Saturday morning, 22 June, 1985, a CP Air passenger agent worked check-in position number 26 at the CP AIR ticket counter, Vancouver International Airport, and recalls dealing with a passenger of Indian origin booked on CP 060 and then on to Delhi. The passenger stated that he wanted his bag tagged right to Delhi from Vancouver. After checking the computer, the agent explained that since he was not confirmed past Toronto his baggage could not be interlined. The passenger insisted and, as the line-up were long, the agent relented and interlined his suitcase. The flight manifest for CP 060 shows that 'M. Singh' checked in through this passenger agent, was assigned seat 10B, and checked one piece of baggage.

(vi) The flight manifest for CP 003 shows that on the same day the person using the name of 'L. Singh' with an interline ticket to Bangkok also checked through the same counter, was assigned seat 38H, and checked one piece of baggage.

(vii) A check of CP Air's records and interviews with passengers on flights CP 003 and CP 060 indicates that the persons identifying themselves as 'M. Singh' and 'L. Singh' did not board these respective flights.

(viii) In a statement of William Long, annexed to the affidavit of I.G. Pole, Police Officer, City of Toronto, he has stated that on 22nd June, 1985 he was employed as a driver whose responsibility was to deliver interlined baggage between terminal 2 to Terminal 1 and vice versa at Toronto. He has further stated that he had picked up 4 bags from Terminal 1 which were destined for terminal 2 Air India. Three of these bags were from U.S. Air originating from New York city. Regarding the last bag he stated as follows :

"The fourth bag destined for Air India was, I distinctly remember looking at the baggage tag and it was pink with the CP logo in blue and letters saying CP on it there were also numbers but I can't remember the number, from CP Air and I remember it was from Vancouver. On the bottom of the tag it said vancouver using the initials YVR and the flight number which I can't remember. The bag was destined for India. When I arrived at the CP Air belt there were a number of bags from other airlines on the belt included in these were the three U.S. Air bags destined for Air India. As I was finishing loading the carts, a CP Air station attendant who had been unloading bags from containers, I noticed as I checked once more for anymore bags, drop another bag on the conveyer belt. This was the bag destined for Air India. It was dark brown Samsonite Hard sided Type 01A on the Baggage Identification Chart. After they were loaded onto the cart I took them over to Air Canada domestic belt at Gate 89-91".

To further questions posed to him, Long stated that this bag from CP Air weighed approximately 70 lbs and there was something which rattled inside the bag. He could not say what it was but he said that "it sounded small". When specifically asked whether he thought there was something big inside the bag, he answered in the affirmative, and added that he did not know what was in it but it was heavy. There was discrepancy in the time when he is alleged to have picked up the bags which he had indicated in his schedule when compared with CP Air Vancouver flight which had arrived at 1622 hours. When this was pointed out to Long, he answered "I could have may be got the time wrong, it was during the busy period. It could have been an estimate time. But I do remember the bag came off CP air. It could have been 16:34 Hrs. I don't know."

(ix) The aircraft departed from Toronto for Mirable and London with the suitcase unaccompained by the passenger who had checked it in at Vancouver. Similarly, CP Air 003 departed Toronto for Tokyo with the baggage of one passenger 'L. Singh' to be interlined to Air India flight AI 301 to Bangkok even though 'L Singh' had not boarded that flight.

(x) The linking of the two occurrences namely the blast at Narita Airport and the Air India accident becomes startingly evident if we look at the following chronology of events:

CPA 003 (VANCOUVER-TOKYO) CPA 060 (VANCOUVER-TORONTO) Connection to Connecting to Air India 301 Air India 182 WESTBOUND EASTBOUND All Times GMT Thurs 20 June, 1985 0057 A male called C.P. Air Reservations in Vancouver and after discussing a number of routings, booked a one-way ticket and CPA 060 to Toronto with connections to Air India 182 under the name of Jaswand SINGH. A return ticket was also booked on CPA 003 to Tokyo connecting with Air India 301 to Bangkok in the name of Mohinderbel SINGH.

1912 A male attended the CP Air Ticket Office in Vancouver. He paid $ 3005.00 in cash for the above tickets after changing the ticket of Mohinderbel SINGH to L. SINGH and changing from a return to a one-way ticket. He changed the Jaswand SINGH ticket to M. SINGH.

Saturday 22 June A Mr. SINGH called Reservations and got 1330 confirmation on his one-way ticket to Toronto with luggage to be sent through to India. M. SINGH checked in with seat 10B confirmed to 1550 Toronto. Wanted suitcase interlined to AI 182. Agent relents. 1618 CPA 060 departed Vancouver 18 minutes late. M. SINGH not in assigned seat. L. SINGH checked in for CPA 003 and one suitcase interlined to Air India 301. Assigned seat 38H. CPA 060 arrived Toronto 2022 12 minutes late. Some passengers and baggage interlined to AI 181.

CPA 003 departed 17 min. late for Tokyo. L. SINGH not in 2037 assigned seat. Sunday 23 June Air India 181 departed 0015 Toronto for Mirabel 1 hour 40 minutes late. 0100 Air India arrived Mirabel. 0218 Air India 182 departed Mirabel 1 hour 38 minutes late. CPA 003 arrived Narita Airport, Tokyo. Arrived 14 minutes early 0541 Baggage cart explodes in transit area. 2 killed, 4 injured, 0619 0714 Air India 182 disappeared from Radar

Air India 301 departed Narita. 0805 0815 Air India 182 Scheduled arrival Heathrow (fuel stop).

(xi) It would indeed to too much of a coincidence that two persons, whose tickets were bought at the same time and who had checked in under the names of 'L. Singh' and 'M. Singh' missed their respective flights, more so when 'M. Singh' had insisted at the check in counter at Vancouver that he should be interlined, even though his seat from Toronto on AI 181/182 was not confirmed, and his baggage (one suitcase) accepted and be routed through to Delhi. If there had been some reason for 'gate no-show' by both of them, one would ordinarily have expected both, or at least one of them, to have made efforts, at that time or thereafter, either to ask for refund of money or they should have contacted the airline staff at the Airport and asked that they should be put on another flight.

(xii) A large amount of money had been spent on the purchase of the two tickets and a question which comes to mind is as to why was this money spent if both the tickets were to be wasted and no one was to travel on them, after having checked in and obtained boarding cards. Furthermore, no effort has been made by any of these two persons to try and lodge a claim for the baggage which they had checked in.

(xiii) The aforesaid facts clearly indicate the connection between the travel plans of so called 'L. Singh' and 'M. Singh'. In fact the manner in which the reservations were changed to the names of 'M. Singh' and 'L. Singh' shows the anxiety of some one to hide behind the identity of persons who bore notorious names.

(xiv) The interlined baggage exploded at Narita Airport and there is strong probability that the suticase from Vancouver, which was interlined to AI 182, contained a device similar to the one which had exploded at Narita Airport on 23 June, 1985.

B. CVR and DFDR both stopped simultaneously:

There was simultaneous interruption of electrical power to the flight recorders. The electrical supply could have been interrupted either because of the cables being cut or because of total electric failure. Power supply wires to the CVR and the DFDR run under the passenger cabin ceiling on the left and the right hand side. The supply of electricity through these cables originates from the MEC compartment, which is in front of the forward cargo hold. If the CVR and the DFDR had stopped due to the breakage of electrical supply wires as a result of possible explosion in the aft cargo hold there would have had to be an instantaneous break of almost the entire section of fuselage, because both these recorders had stoped simultaneously. In such a catastrophic event it is not possible that the bottom skin panels of the aft cargo compartment would remain undistorted, or would have no rupture or holes in them. Furthermore, in such an event the tail portion of the aircraft would have been found in the beginning of the wreckage trail, but this was not so. On the other hand, and explosion in the forward cargo compartment would have resulted in damage to the electrical buses located in the MEC and that would, in turn, result in cutting off the electrical power supply causing simultaneous stoppage of the recorders.

C. The ATC Transponder Stopped Transmitting :

The transponder is located at the bottom of the one of the forward rakes immediately forward of the front cargo compartment. Signals from this also stopped being received by the secondary radar at Shannon. Keeping in view that the CVR and the DFDR had stopped simultaneously at about the same time, when the signals from ATC transponder had also ceased, it is reasonable to presume that there must have been a complete breackdown of electrical supply which had affected all the three units. The only event which could have caused such a damage to paralyse the entire MEC compartment could only have been an explosion in the forward cargo hold. It was not possible that any rapid decompression caused by a structural failure could have disrupted the entire electricl power supply from the MEC compartment. In known cases of aircraft being subjected to rapid decompression there has never been such an instantaneous and total stoppage of electrical power and in fact aircrafts have been known to have continued to fly and communicate with the ground even after decompression.

D. Non-supply of Oxygen :

Oxygen supply cylinders are located in the ceiling of the forward cargo compartment. Any rupture of the only pipeline which supplies oxygen to the passengers would result in there being no surge of oxygen flow, which alone drops the oxygen masks. The inspection of the wreckage shows that there is no indication of the oxygen masks ever having dropped. A rupture of this pipeline, simultaneously with power rupture, could only have been caused if there had been a detonation of the explosive device in the front cargo hold.

E. Damage in air :

The examination of the floating and the other wreckage shows that the right hand wing leading edge, the No. 3 engine fan cowl, right hand inboard mid flap leading edge and the leading edge of the right hand stabilizer were damaged in flight. This damage could have occurred only if objects had been ejected from the front portion of the aircraft when it was still in the air. The cargo door of the front cargo compartment was also found ruptured from above. This also indicates that the explosion perhaps occurred in the forward cargo compartment causing the objects to come out and thereby damaging the components on the right hand side.

F. Evidence of Overpressurization :

The examination of the structural panels and the other parts of the forward cargo compartment and the aft cargo compartment, recovered from the sea bed, indicates that overpressure condition had occurred in both the cargo compartments. The failure of the passenger cabin floor panels in upward direction also indicates that overpressure was created in both the compartments. It cannot be disputed that whenever an explosive detonates very high pressure shockwaves are formed which travel in all directions and high speed fragments of the container, or the loose material, also move away from the source of explosion. It is, therefore, clear that there was overpressurization in the cargo compartments which resulted in such rupture of the cabin floor panels.

G. Holes in the front cargo hold panels

While the skin panels of the aft cargo compartment are fairly straight and undamaged, the panels of the front cargo compartment are ruptured and have a large number of holes. This shows that there was occurrence of an event in the front cargo compartment and not in the aft cargo compartment.

H. Buckling of Seats :

The seats towards the rear of the aircraft had only the aft legs buckled, whereas the seats towards the front had both the front and the aft legs buckled. This indicated that the whole floor was subjected to a vertical force and was more severe towards the front. Moreover, the upper deck storage cabin was found among floating wreckage. The bottom of this cabin was pushed up in the shape of a dome with no evidence of impact damage. This deformation was indicative of having been caused, possibly, as a result of a shockwave.

I. Metallurgical Examination Results :

A metallurgical examination, especially of Targets 362 and 399, clearly confirms that there was an explosion in the forward cargo compartment. Microscopy around some of the holes discloses that they have such characteristics like twinning which can be present only if the holes had been puntured due to the detonation of an explosive device.

J. CVR Tape Analysis :

The report of CVR tape analysis by Mr. S.N. Seshadri also corroborates the aforesaid evidence i.e. that there was a bomb in the forward cargo hold of the aircraft.

RECOMMENDATIONS

5.1 ICAO, IATA and the States should :-

(a) undertake an ongoing review of established aviation security standards to prevent the placement of explosive substances on board commercial aircraft;

(b) establish a programme of monitoring the implimentation of security measures in airports around the world, in cooperation with the Governments concerned. For each airport studied, it should report its findings and recomend any improvements that may be required;

(c) consider establishing a group of civil aviation experts to investigate serious breaches of security. The purpose of these investigations would be to determine the facts of an incident so that necessary measures could be developed and implemented world wide to prevent similar breaches in the future.

Note : As it may take some time for ICAO and IATA to implement these recommendations, at least those countries which have international air traffic should take up effective measures without delay.

5.2 ICAO should :-

(a) develop a model clause on security that could be used in the bilateral air agreements that govern the exchange of air traffic rights between countries;

(b) consider establishing standards for the training of security personnel.

5.3 IATA should develop practical procedures for reconciliation of interlined passengers and their baggage at intermediate airports.

5.4 Interlining of checked-in baggage should not be done if a passenger does not have a confirmed reservation on the onward carrier flight.

5.5 The baggage of interlined passengers should be matched with passengers by the onward carriers before loading the baggage on the aircraft.

5.6 Whenever a Government becomes aware of particular high risk security threat it should notify not only the airline at risk, but also all connecting airlines in order that extra precaution can be taken at potential points of introduction of interline baggage into the system.

5.7 When an Airline is aware of a high security threat it should communicate the same to the host state as well as, if possible and prudent, to the other airlines operating there.

5.8 Passenger count should be done at boarding gate and in case of 'no gate show' of a passenger, his baggage must be off-loaded.

5.9 All checked-in baggage, whether it has been screened by X-ray machine or not, should be personally matched and identified with the passengers boarding an aircraft. Any baggage which is not so identified should be off-loaded. This is advisable as examination of the baggage with the help of an X-ray machine has its own limitations and is not fool proof. Some explosives hidden in Radios, Cameras etc. may not be readily detected by such a machine. In fact an explosive not placed in a metallic container will not be detectable by an X-ray machine. Similarly, a plastic explosive can be given an innocuous shape or form so as to avoid detection by an X-Ray. Reliance on an X-Ray machine alone may in fact provide a false sense of security.

5.10 Effectiveness of the instrument known as PD-4 is highly questionable. It is not advisable to rely on it.

5.11 All unaccompanied baggage should be placed on the aircraft after their contents have been physically checked. In the alternative, it should be loaded only after it has been placed in a decompression chamber and the host state is satisfied that the baggage is clean and the shipper has been identified.

5.12 Airlines should have effective backup security equipment or procedures available in case of machanical break down of security equipment.

5.13 All hand baggage, including that of the crew, should be opened and the contents physically checked even if the said baggage has been x-rayed. This will no doubt be a bit time consuming and laborius but if security is to be meaningful, then slight inconvenience has to be endured in order to ensure a safer flight.

5.14 The manufacturers of aircraft should take effective steps for protecting sensitive parts of the aircraft from explosive damage.

5.15 Studies should be undertaken to determine the feasibility of physically separating the avionics bay and emergency oxygen systems from the cargo area in aircraft so that these sensitive and essential areas of the aircraft cannot be damaged or destroyed by a relatively small explosive deivce concealed in luggage.

5.16 The seats should have safety belts which can act as restraint for the upper part of the body e.g. like a shoulder harness with inertial restraint.

5.17 The seats in the aircraft should be so designed so as to incorporate shock absorbing systems within the seat and they should be manufactured by using material which does not break easily.

5.18 In addition to the cockpit voice recorder, there should be in the cockpit a video/scanning camera which would record the movements and the audio sounds in the cockpit. This will not only assist in ascertaining as to how the pilots act during as emergency but, in the case of hijacking, would also assist in the identification of the hijackers.

5.19 The CVR should record all the conservation and sounds in the cockpit for the entire duration of the flight, and not merely for the last 30 minutes.

5.20 The CVR and the DFDR should be powered from two alternative sources of energy.

5.21 The oxygen for the flight crew should be supplied from two different sources i.e. in the event of an emergency the pilot and the co-pilot must don the oxygen mask and the oxygen must be supplied from different source.

5.22 Suitable provisions should be incorporated in Annex 13 which would give power to an Investigator to record evidence outside the country of investigation and also to summon witness from abroad. It should also be mandatory on the contracting States to give information

sought for by an Investigator.
(B. N. KIRPAL)
February 26, 1986 COURT
We agree with the conclusions and recommendations stated above.
ASSESSORS
(V. Ramachandran) (J.S. Gharia)
(J.S. Dhillon) (J.K. Mehra)
(B.K. Bhasin)

ACKNOWLEDGEMENTS

When I was appointed as the Court to investigate into the accident, the magnitude of the task involved was known. With the help, assistance and cooperation of a team of dedicated workers, the work was, however, completed in not too long time. The assistance received from those who helped me cannot be too highly praised.

From amongst my Assessors, Captian B.K. Bhasin was the only one who was permanently stationed in Delhi. We met for the first time on 15th July, 1985 and little did I realise then that, by the time our work would be over, how much I would be depending upon him. Not only was his advice on the technical aspects of flying and air safety invaluable but, whenever any difficulty or a problem arose, I invariably turned to him for assistance and advice which I readily got. I found him having a very practical and positive approach to all the problems but, at the same time, he very rightly was not prepared to compromise on any principal issues.

The only interest Dr. V. Ramachandran appeared to have was to do his work to perfection. No praise can be too high for the manner in which this Metallurgist from landlocked Bangalore volunteered and boarded the salvage ships which were carrying out operations in the cold and choppy waters of Atlantic Ocean. He sarificed all comforts and went to sea with a view to be present on board the ships at the time when salvaged pieces of wreckage were brought on board. His deep knowledge of metallurgy greatly assisted the examination of the salvaged pieces of wreckage. In this connection the entire metallurgical examination was planned and organised by him.

Whenever any information was required concerning explosives, Mr. J.S. Gharia was ever eager and in a position to provide the information.

Mr. J.K. Mehra looked into the engineering aspect of the accident and he spent a lot of time in going through various Air-India Maintenance Manuals. He always made discussions very lively and interesting.

Captain J.S. Dhillon came out of his retirement and provided useful information to the Court on some aspects of flying.

This work would never have been satisfactorily completed without the help and assistance received by the Court from late Mr. S.N. Seshadri of Bhabha Atomic Research Centre. From the time when the CVR was first played by him at BARC on 16 July, 1985 till the very end, he most willingly and pleasantly undertook any assignment which was given to him by the Court. It was a great national loss when he suddenly passed away on 2nd February, 1986, only a few days after he had deomonstrated his brilliance when his testimony, regarding the analysis of the CVR tape, was recorded by me in the Court.

I am also grateful to the other Scientists and staff of B.A.R.C. who rendered considerable assistance to the Court. The facilities made available by Dr. P.K. Iyengar, Director, B.A.R.C. with regard to the finalisation and completion of the report cannot be easily forgotten. In the absence of late Mr. S.N. Seshadri, with whom I had developled a personal rapport, Dr. Ashok Mohan and Mr. V.K. Chadda met with all our requirements in the finalisation and preparation of the Report. Dr. Asundi of BARC and the other Metallurgists of that Organisation and of the National Aeronautical Laboratory also spent a considerable amount of their time and energy in successfully carrying out metallurgical tests and examination of the salvaged pieces.

During the investigation I had to visit Ireland on two occasions. I immediately realised the extent of help, assistance and guidance which was being rendered to all of us by Mr. Kiran Doshi, the Indian Ambassador to Ireland. There was no problem to which he did not have a solution. On my visit to Dublin not only did I enjoy the hospitality of Kiran and his wife Razia but it also gave an opportunity to personally meet Mr. Mitchel, the Minister of Communications, and senior officials of his Ministry, and to express my gratitude to them for all the help and assistance which the Government and people of Ireland had, most willingly, rendered.

At Tokyo the Indian Ambassador and members of his staff looked after all our needs and arranged meetings with the Japanese officials whom we wanted to meet.

As representatives of the Court in Cork, Mr. P.R. Chandrasekhar and Mr. C.D. Kolhe did a commendable job. They kept me informed of the progress which was taking place at Cork and, whenever required to do so, they took vital decisions while coordinating the mapping and salvage operations.

Mr. H.S. Khola, Director of Air Safety, New Delhi willingly carried out all the directions of the Court. Special mention must also be made of Mr. Satendra Singh, Regional Controller of Air Safety, Bombay, who worked day and night when the flight recorders were first opened and the copies of the tapes made and the data analysed.

I have also to express my gratitude to the Counsel who assisted the Court in the Investigation. Without their help and cooperation, it would not have been possible to complete the work in 7-1/2 months.

On my trip to Bombay, the Staff and Management of Centaur Hotel made my stay very comfortable. It was like a home away from home.

The work done during the salvage operarations by four young engineers of Air-India was highly commendable and valuable. All of them namely, Mr. Balasubramanium, Mr. L.S. Carvalho, Mr. G.D. Nayar and Mr. A.K. Sheode, worked round the clock even during adverse climatic conditions.

The Registrar of the Delhi High Court, Ms. Usha Mehra spared no efforts in rendering every assistance whenever the same was required. She ably marshalled all the resources available in the High Court in order to ensure the smooth and efficient functioning of my office. My own personal staff in particular, headed by Mr. V.P. Ahuja, Court Master and Mr. Balram Chopra, Private Secretary, as usual, rose to the occasion. While Mr. Ahuja kept complete control of hundreds of documents and affidavits which had been filed, Mr. Chopra besides bearing the brunt of the typing work, very ably supervised the work of other Stenographers. It was most fortunate that I was able to persuade Mr. S.N. Sharma to accept the trying job of being the Secretary to the Court. His vast experience in such Investigations, he had been a Secretary in three such Investigations earlier, made my task much lighter. Moreover, as an Aircraft Engineer, he was always ready to explain technical intricacies involved in the case. Without his help I could not have completed my work within the stipulated time.

(B. N. KIRPAL)

26th February, 1986 COURT

POSITIVELY IDENTIFIED DEBRIS AIR INDIA 747 VT-EFO KANISHKA AIRCRAFT

SECTION TARGET LAT LONG DESCEIPTION 41 DOOR 192 51 03.28 12 47.74 FIRST CLASS AND COCKPIT AREA (+ UPPER DECK DOOR) 41 131 51 03.21 12 47.93 LEFT HAND UPPER DECK SLIDE MECHANISM 41 134 51 03.28 12 47.81 NOSE LANDING GEAR 41 265 51 02.37 12 44.51 LANDING GEAR DOOR (NOSE GEAR) 41 244 51 03.56 12 48.19 UPPER DECK WINDOW TRIM (REVEAL) 41 63 51 02.51 12 47.37 2 FIRST CLASS SEATS 41 77 51 02.59 12 47.83 2 FIRST CLASS SEATS 42 DOOR 193 51 03.30 12 47.85 PIECE OF FUSELAGE, WING PLUS LANDING GEAR (#2 LEFT DOOR) 42 138 51 03.37 12 47.77 SMALL PIECE OF WRECKAGE (BS 800) 42 200 51 03.347 12 47.831 Dual Heat Exchanger 42 DOOR 204 51 03.33 12 47.87 FORWARD CARGO DOOR + FLOOR 42 255 51 03.72 12 48.01 GALLEY COMPLEX (UPPER DECK) 42 232 51 03.49 12 47.92 'P93' RACK MARKED 'DANGER HIGH VOLTAGE' (BS 670) 42 327 51 01.62 12 43.03 NACA SCOOP 42 DOOR 358 51 03.39 12 47.86 MASS OF DEBRIS (#2 RIGHT DOOR) 42 361 51 03.384 12 47.848 BOX MARKED "FAN BLADES" 42 362 51 03.372 12 47.840 MASS OF DEBRIS FUSELAGE SKIN 42 383 51 03.32 12 47.81 MASS OF DEBRIS WITH UPPER DECK FLOOR 44 DOOR 137 51 03.30 12 47.80 CENTER FUSELAGE SECTION WITH #3 LEFT DOOR 6

WINDOWS AFT OF DOOR AND 13 WINDOWS FORWARD. LEFT UPPER WING SKIN AND ONE MAIL LANDING GEAR ATTACHED. 44 103 51 02.86 12 46.37 LANDING GEAR DOOR 44 105 51 02.81 12 46.04 LEFT WHEEL WELL LANDING GEAR DOOR 44 186 51 03.32 12 47.825 KEEL BEAM 44 195 51 03.32 12 47.78 WING STRUCTURE 44 224 51 03.46 12 48.49 TWO WHEELS FROM MAIN LANDING GEAR 44 239 51 03.62 12 47.38 MAIN BRAKE UNIT WITHOUT AXEL, PLUS EQUALIZING ROD 44 240 51 03.62 12 47.44 MAIN TIRE AND RIM 44 241 51 03.62 12 47.40 MAIN TIRE AND RIM PLUS AXEL 44 242 51 03.61 12 47.40 MAIN BRAKE UNIT 44 267 51 03.35 12 44.45 PART OF LANDING GEAR DOOR 44 275 51 02.13 12 44.10 BODY LANDING GEAR DOOR 44 279 51 02.30 12 44.64 MAIN LANDING GEAR DOOR 44 280 51 02.26 12 44.61 SECTION OF MAIN LANDING GEAR DOOR 44 343 51 03.285 12 47.809 MAIN LANDING GEAR DOOR 59 51 02.57 12 45.73 SECTION OF LANDING GEAR 44 218 51 03.41 12 47.86 STEP WELL AREA (STA 1250-1480)
46 6 51 02.79 12 49.44 SMALL MOTOR 10" x 8" (FAN) 46 7 51 02.90 12 49.92 LOWER SKIN OF CARGO AREA 4' x8' (BS 1480)) 46 #11 51 02.04 12 45.44 PIECE OF OUTER SKIN BODY STATION #1760 PART NO. 65B04325-403 46 25 51 02.21 12 46.27 BODY FRAME (BS 1660-1680) 46 26 51 02.20 12 46.72 CABIN SECTION WITH 4 WINDOWS (ABOVE 'T' IN REG No.) 46 28 51 02.31 12 47.02 SKIN PANEL 1460-1800 46 33 51 02.49 12 48.28 AFT FUSELAGE SKIN PANEL 'YOUR PALACE IN THE SKY' (AFT OF #5 DOOR) 46 34 51 02.49 12 48.29 RIGHT HAND FUSELAGE SKIN PANEL AT DOOR #5 46 DOOR 40 51 02.47 12 47.41 CARGO DOORS C2, C3 46 47 51 02.39 12 46.61 REAR CARGO FLOOR 46 50 51 02.38 12 46.60 CARGO FLOOR (STA 1500) 46 DOOR 74 51 02.49 12 47.71 FIVE FRAMES AND DOOR-PORT SIDE AFT (#5 LEFT DOOR) 46 78 51 02.52 12 47.95 FRAME SECTION (SHEAR WEB STA 2000-2020) 46 87 51 02.58 12 48.43 BUILT UP STRUCTURE (STA 2412) 46 DOOR 97 51 02.52 12 47.38 FUSELAGE SKIN SECTION WINDOW BELT AREA WITH DOOR FOLDED UNDER FRAME 46 DOOR 101 51

02.84 12 47.14 5 WINDOWS AND DOOR (#4 RIGHT DOOR) 46 292 51 01.81 12 44.24 FRAME (STA 2240) 46 321 51 02.39 12 46.61 '4R' DOOR ENTRANCE WITH NO DOOR AND 10 WINDOWS (BS 1700) 320 51 01.84 12 44.59 FUSELAGE BOTTOM SKIN NEAR OUTFLOW VALUE 46 336 51 01.34 12 42.03 BULK CARGO COMPARTMENT FLOOR AND STRUCTURE 46 369 51 02.17 12 46.20 FUSELAGE PANEL SECTION, 4 WINDOWS 48 31 51 02.37 12 48.43 HORIZONTAL STAB 48 37 51 02.47 12 47.99 VERTICAL TAIL FIN (+ PRESSURE BULKHEAD SECTION) 48 35 51 02.50 12 48.08 AFT PRESSURE BULKHEAD (25%) 48 22 51 02.19 12 45.68 ELECTRICAL PANEL (RUDDER RATIO JUNCTION BOX) 48 27 51 02.20 12 46.83 APU HOUSING 48 66 51 02.59 12 47.54 BODY FRAME (BS 25XX) 48 67 51 02.55 12 47.50 FUSELAGE SKIN (3 FRAMES FORWARD OF APU BS 2638) 48 68 51 02.57 12 47.55 FUSELAGE SECTION (BS 2598) 48 73 51 02.51 12 47.70 PART OF PRESSURE BULKHEAD 48 75 51 02.47 12 47.63 FRAME FOR OVERHEAD LUGGAGE COMPARTMENT (ROW 46 F-G) 48 88 51 02.90 12 48.84 CONTROL LINKAGE FROM TAIL OF AIRCRAFT (ELEVATOR CONTROL QUADRANT) 48 99 51 02.71 12 47.92 FUSELAGE SKIN SECTION (BS 2598) 48 296 51 02.03 12 43.17 PART OF PRESSURE BULKHEAD 48 314 51 01.84 12 44.19 APU AIR DUCT 48 371 51 02.51 12 48.28 AFT FUSELAGE SKIN 10'x15' (HORIZ. STAB CUTOUT)
SECTION TARGET LAT LONG ENGINES 7.13 108 51 02.97 12 47.12 AIRCRAFT ENGINE (WITH STRUT) 149 51 03.26 12 47.38 ENGINE AND STRUT 154 51 03.32 12 47.75 ENGINE SECTION (5th ENGINE) 171 51 03.16 12 47.16 TURBINE SECTION OF ENGINE (POSSIBLY COMPLETE ENGINE) 235 51 03.63 12 47.07 AIRCRAFT ENGINE ENGINE PARTS 106 51 02.98 12 46.41 ENGINE COWLING (INLET) MARKED 'A124' (5th ENGINE) 109 51 02.97 12 47.11 STARTER FOR AIRCRAFT ENGINE 111 51 03.02 12 47.20 ENGINE COWL 116 51 02.99 12 47.80 ENGINE DEVICE 124 51 02.85 12 48.47 FIFTH ENG CENTER DOME 150 51 03.25 12 47.36 PART OF ENGINE 151

51 03.29 12 47.42 SMALL PART OF ENGINE 152 51 03.31 12 47.44 LOWER PORTION OF ENGINE 153 51 03.31 12 47.44 LOWER ENGINE COWLING 155 51 03.32 12 47.44 FAN INNER EXIT AREA 156 51 03.32 12 47.43 PART OF ENGINE 158 51 03.23 12 47.35 PART OF ENGINE COWLING 159 51 03.25 12 47.29 ENGINE COWLING 161 51 03.26 12 47.29 PORTION OF ENGINE COWL 165 51 03.20 12 47.21 THRUST REVERSER SLEEVE 166 51 03.20 12 47.21 UNIDENTIFIED ENGINE PARTS 167 51 03.21 12 47.24 UNIDENTIFIED ENGINE PARTS 168 51 03.20 12 47.22 UNIDENTIFIED ENGINE PART 169 51 03.18 12 47.20 UNIDENTIFIED ENGINE PARTS 170 51 03.19 12 47.19 PART OF DIAPHRAM (OIL COOLER) 172 51 03.25 12 47.21 ENGINE EXHAUST CONE 173 51 03.27 12 47.38 ENGINE EXHAUST CONE AND EXHAUST 237 51 03.690 12 47.10 ENGINE PARTS CASE 238 51 03.72 12 47.10 ENGINE INLET COWL 206 51 03.34 12 47.50 SECTION OF ENGINE EXHAUST STAGE #7 207 51 03.35 12 47.49 ENGINE HOT SECTION AREA 208 51 03.37 12 47.51 ENGINE TAIL CONE 214 51 03.19 12 47.36 CASCADE VANE

STRUTS 7.12 4 51 02.87 12 49.05 #3 ENGINE NACELLE STRUT 157 51 03.23 12 47.36 STRUT (SIMILAR TO 149) 110 51 03.15 12 47.16 NACELLE STRUT WING PARTS 17 120 51 03.01 12 47.98 OUTBOARD AILERON (50%) 16 135 51 03.28 12 47.81 TRAILING EDGE FLAP AND DRAG JACK 16 136 51 03.31 12 47.81 TRAILING EDGE FLAP JACK SKREW 12 140 51 03.35 12 47.83 LEADING EDGE SECTION OF WING 14 145 51 03.34 12 47.85 WING LEADING EDGE VARIABLE CAMBER FLAP 16 177 51 03.34 12 47.91 TRAILING EDGE FLAP 12 181 51 03.38 12 47.87 LOWER CARGO COMPARTMENT AND WING LOWER SKIN 16 183 51 03.38 12 47.87 SECTION OF FLAP SKIN 16 188 51 03.33 12 47.81 TRAILING EDGE FLAP WITH JACK SKREW 16 189 51 03.32 12 47.80 TRAILING EDGE FLAP WITH SKREW JACK 16 191 51 03.32 12 47.78 FLAP ACTUATOR AND FLAP TRACK 16 194 51 03.32 12 47.77 TRAILING EDGE OF FORE FLAP 16 253 51 03.32 12

47.86 PIECE OF TRAILING EDGE FLAP 16 254 51 03.40 12 47.86 PIECE OF TRAILING EDGE FLAP 16 264 51 02.47 12 44.74 TRAILING EDGE FLAP FAIRING 16 277 51 02.18 12 44.40 WING FLAP 16 344 51 03.294 12 47.802 TRAILING EDGE FLAP AND FLAP TRACK 16 384 51 03.33 12 47.80 T/E FLAP TAPER AND DRIVE SHAFT 16 398 51 03.325 12 47.85 PIECE OF TE MID FLAP 15 190 51 03.32 12 47.79 SPOILER ACTUATOR 14 187 51 03.34 12 47.81 LEADING EDGE FLAP SECTION 14 387 51 03.33 12 47.853 PIECE OF L/E FLAP MECHANISM
12 54 51 02.38 12 45.86 LE FROM WING 12 202 51 03.33 12 47.86 WING LOWER SKIN 12 221 51 03.39 12 47.89 UPPER EDGE LEFT WING 12 225 51 03.38 12 48.78 SMALL PIECE OF WING LEADING EDGE PANEL 12 222 51 03.38 12 47.94 WING FILLER & WING PARTS 12 243 51 03.59 12 47.85 PIECE OF LEADING EDGE FLAP 12 252 51 03.38 12 47.84 LOWER WING SECTION 12 262 51 03.85 12 46.92 MID LOWER WING SKIN, ONE AFT FLAP TRACK WITH JACK SKREW 12 266 51 02.36 12 44.46 LANDING GEAR DOOR 12 297 51 01.91 12 43.18 PART OF WING TIP 12 345 51 03.28 12 47.842 'REAR WING SPAR' 12 365 51 03.338 12 47.842 REAR SPAR RIB WITH SPOILER ACTUATOR 12 379 51 03.315 12 47.785 WING REAR SPAR AND SPOILER STA 1150 12 381 51 03.40 12 47.88 LE OF WING SECTION 12 182 51 03.38 12 47.87 POSSIBLE REAR SPAR, (WING STA 802 I.D. ON PART) 17 274 51 02.19 12 43.57 LEFT INBOARD AILERON

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: Jaswindersingh <jaswinderp@hotmail.com>

Subject: PA 103 AAR

http://www.open.gov.uk/aaib/n739pa.htm

Air Accidents Investigation Branch
Aircraft Accident Report No 2/90 (EW/C1094)

Report on the accident to
Boeing 747-121, N739PA
at Lockerbie, Dumfriesshire, Scotland
on 21December 1988

Contents

Operator: Pan American World Airways
Aircraft Type: Boeing 747-121
Nationality: United States of America
Registration: N 739 PA
Place of Accident Lockerbie, Dumfries, Scotland
Latitude 55¡ 07' N
Longitude 003¡ 21' W
Date and Time (UTC): 21 December 1988 at 19.02:50 hrs
All times in this report are UTC
SYNOPSIS

The accident was notified to the Air Accidents Investigation Branch at 19.40

hrs on the 21 December 1988 and the investigation commenced that day. The members of the AAIB team are listed at Appendix A.

The aircraft, Flight PA103 from London Heathrow to New York, had been in level cruising flight at flight level 310 (31,000 feet) for approximately seven minutes when the last secondary radar return was received just before 19.03 hrs. The radar then showed multiple primary returns fanning out downwind. Major portions of the wreckage of the aircraft fell on the town of Lockerbie with other large parts landing in the countryside to the east of the town. Lighter debris from the aircraft was strewn along two trails, the longest of which extended some 130 kilometres to the east coast of England. Within a few days items of wreckage were retrieved upon which forensic scientists found conclusive evidence of a detonating high explosive. The airport security and criminal aspects of the accident are the subject of a separate investigation and are not covered in this report which concentrates on the technical aspects of the disintegration of the aircraft.

The report concludes that the detonation of an improvised explosive device led directly to the destruction of the aircraft with the loss of all 259 persons on board and 11 of the residents of the town of Lockerbie. Five recommendations are made of which four concern flight recorders, including the funding of a study to devise methods of recording violent positive and negative pressure pulses associated with explosions. The final recommendation is that Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft's structure and systems to explosive damage.

1. FACTUAL INFORMATION

1.1 History of the Flight

Boeing 747, N739PA, arrived at London Heathrow Airport from San Francisco and parked on stand Kilo 14, to the south-east of Terminal 3. Many of the passengers for this aircraft had arrived at Heathrow from Frankfurt, West Germany on a Boeing 727, which was positioned on stand Kilo 16, next to N739PA. These passengers were transferred with their baggage to N739PA which was to operate the scheduled Flight PA103 to New York Kennedy. Passengers from other flights also joined Flight PA103 at Heathrow. After a 6 hour turnround, Flight PA103 was pushed back from the stand at 18.04 hrs and was cleared to taxy on the inner taxiway to runway 27R. The only relevant Notam warned of work in progress on the outer taxiway. The departure was unremarkable.

Flight PA103 took-off at 18.25 hrs. As it was approaching the Burnham VOR it took up a radar heading of 350¡ and flew below the Bovingdon holding point at 6000 feet. It was then cleared to climb initially to flight level (FL) 120 and subsequently to FL 310. The aircraft levelled off at FL 310 north west of Pole Hill VOR at 18.56 hrs. Approximately 7 minutes later, Shanwick Oceanic Control transmitted the aircraft's oceanic clearance but this transmission was not acknowledged. The secondary radar return from Flight PA103 disappeared from the radar screen during this transmission. Multiple primary radar returns were then seen fanning out downwind for a considerable distance. Debris from the aircraft was strewn along two trails, one of which extended some 130 km to the east coast of England. The upper winds were between 250¡ and 260¡ and decreased in strength from 115 kt at FL 320 to 60 kt at FL 100 and 15 to 20 kt at the surface.

Two major portions of the wreckage of the aircraft fell on the town of Lockerbie; other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Residents of Lockerbie reported that, shortly after 19.00 hrs, there was a rumbling noise like thunder which rapidly increased to deafening proportions like the roar of a jet engine under power. The noise appeared to come from a meteor-like object which was trailing flame and came down in the north-eastern part of the town. A larger, dark, delta shaped object, resembling an aircraft wing, landed at about the same time in the Sherwood area of the town. The delta shaped object was not on fire while in the air, however, a very large fireball ensued which was of short duration and carried large amounts of debris into the air, the lighter particles being deposited several miles downwind. Other less well defined objects were seen to land in the area.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	16	243	11
Serious	-	-	2
Minor/None	-	-	3

CLICK HERE TO RETURN TO INDEX

1.3 Damage to aircraft

The aircraft was destroyed

1.4 Other damage

The wings impacted at the southern edge of Lockerbie, producing a crater whose volume, calculated from a photogrammetric survey, was approximately 560 cubic metres. The weight of material displaced by the wing impact was estimated to be well in excess of 1500 tonnes. The wing impact created a fireball, setting fire to neighbouring houses and carrying aloft debris which was then blown downwind for several miles. It was subsequently established that domestic properties had been so seriously damaged as a result of fire and/or impact that 21 had to be demolished and an even greater number of homes required substantial repairs. Major portions of the aircraft, including the engines, also landed on the town of Lockerbie and other large parts, including the flight deck and forward fuselage section, landed in the countryside to the east of the town. Lighter debris from the aircraft was strewn as far as the east coast of England over a distance of 130 kilometres.

1.5 Personnel information

1.5.1 Commander: Male, aged 55 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 720, Lockheed L1011 and Douglas DC3
Medical Certificate: Class 1,valid to April 1989, with the limitation that the holder shall wear lenses that correct for distant vision and possess glasses that correct for near vision

Flying experience:
Total all types: 10,910 hours
Total on type: 4,107 hours
Total last 28 days 82 hours
Duty time: Commensurate with company requirements
Last base check: 11 November 1988
Last route check: 30 June 1988
Last emergencies check: 8 November 1988

1.5.2 Co-pilot: Male, aged 52 years
Licence: USA Airline Transport Pilot's Licence
Aircraft ratings: Boeing 747, Boeing 707, Boeing 727
Medical Certificate: Class 1, valid to April 1989, with the limitation that the holder shall possess correcting glasses for near vision

Flying experience:
Total all types: 11,855 hours
Total on type: 5,517 hours
Total last 28 days: 51 hours
Duty time: Commensurate with company requirements
Last base check: 30 November 1988
Last route check: Not required
Last emergencies check: 27 November 1988

1.5.3 Flight Engineer: Male, aged 46 years
Licence: USA Flight Engineer's Licence
Aircraft ratings: Turbojet
Medical certificate: Class 2, valid to June 1989, with the limitation that the holder shall wear correcting glasses for near vision
Flying experience:
Total all types: 8,068 hours
Total on type: 487 hours
Total last 28 days: 53 hours
Duty time: Commensurate with company requirements
Last base check: 30 October 1988
Last route check: Not required
Last emergencies check: 27 October 1988

1.5.4 Flight Attendants: There were 13 Flight Attendants on the aircraft, all of whom met company proficiency and medical requirements
CLICK HERE TO RETURN TO INDEX
1.6 Aircraft information

1.6.1 Leading particulars
Aircraft type: Boeing 747-121
Constructor's serial number: 19646
Engines: 4 Pratt and Whitney JT9D-7A turbofan

1.6.2 General description

The Boeing 747 aircraft, registration N739PA, was a conventionally designed long range transport aeroplane. A diagram showing the general arrangement is shown at Appendix B, Figure B-1 together with the principal dimensions of the aircraft.

The fuselage of the aircraft type was of approximately circular section over most of its length, with the forward fuselage having a diameter of 21† feet where the cross-section was constant. The pressurised section of the fuselage (which included the forward and aft cargo holds) had an overall length of 190 feet, extending from the nose to a point just forward of the tailplane. In normal cruising flight the service pressure differential was at the maximum value of 8.9 pounds per square inch. The fuselage was of conventional skin, stringer and frame construction, riveted throughout, generally using countersunk flush riveting for the skin panels. The fuselage frames were spaced at 20 inch intervals and given the same numbers as their stations, defined in terms of the distance in inches from the datum point close to the nose of the aircraft [Appendix B, Figure B-2]. The skin panels were joined using vertical butt joints and horizontal lap joints. The horizontal lap joints used three rows of rivets together with a cold bonded adhesive.

Accommodation within the aircraft was predominately on the main deck, which extended throughout the whole length of the pressurised compartment. A separate upper deck was incorporated in the forward part of the aircraft. This upper deck was reached by means of a spiral staircase from the main deck and incorporated the flight crew compartment together with additional passenger accommodation. The cross-section of the forward fuselage differed considerably from the near circular section of the remainder of the aircraft, incorporating an additional smaller radius arc above the upper deck section joined to the main circular arc of the lower cabin portion by elements of straight fuselage frames and flat skin.

In order to preserve the correct shape of the aircraft under pressurisation loading, the straight portions of the fuselage frames in the region of the upper deck floor and above it were required to be much stiffer than the frame portions lower down in the aircraft. These straight sections were therefore of very much more substantial construction than most of the curved sections of frames lower down and further back in the fuselage. There was considerable variation in the gauge of the fuselage skin at various locations in the forward fuselage of the aircraft.

The fuselage structure of N739PA differed from that of the majority of Boeing

747 aircraft in that it had been modified to carry special purpose freight containers on the main deck, in place of seats. This was known as the Civil Reserve Air Fleet (CRAF) modification and enabled the aircraft to be quickly converted for carriage of military freight containers on the main deck during times of national emergency. The effect of this modification on the structure of the fuselage was mainly to replace the existing main deck floor beams with beams of more substantial cross-section than those generally found in passenger carrying Boeing 747 aircraft. A large side loading door, generally known as the CRAF door, was also incorporated on the left side of the main deck aft of the wing.

Below the main deck, in common with other Boeing 747 aircraft, were a number of additional compartments, the largest of which were the forward and aft freight holds used for the storage of cargo and baggage in standard air-transportable containers. These containers were placed within the aircraft hold by means of a freight handling system and were carried on a system of rails approximately 2 feet above the outer skin at the bottom of the aircraft, there being no continuous floor, as such, below these baggage containers. The forward freight compartment had a length of approximately 40 feet and a depth of approximately 6 feet. The containers were loaded into the forward hold through a large cargo door on the right side of the aircraft.

1.6.3 Internal fuselage cavities

Because of the conventional skin, frame and stringer type of construction, common to all large public transport aircraft, the fuselage was effectively divided into a series of 'bays'. Each bay, comprising two adjacent fuselage frames and the structure between them, provided, in effect, a series of interlinking cavities bounded by the frames, floor beams, fuselage skins and cabin floor panels etc. The principal cavities thus formed were:

(i) A semi-circular cavity formed in between the fuselage frames in the lower lobe of the hull, i.e. from the crease beam (at cabin floor level) on one side down to the belly beneath the containers and up to the opposite crease beam, bounded by the fuselage skin on the outside and the containers/cargo liner on the inside [Appendix B, Figure B-3, detail A].

(ii) A horizontal cavity between the main cabin floor beams, the cabin floor panels and the cargo bay liner. This extended the full width of the fuselage and linked the upper ends of the lower lobe cavity [Appendix B, Figure B-3, detail B].

(iii) A narrow vertical cavity between the two containers [Appendix B,

Figure B-3, detail C].
(iv) A further narrow cavity around the outside of the two containers, between the container skins and the cargo bay liner, communicating with the lower lobe cavity [Appendix B, Figure B-3, detail D].
(v) A continuation of the semi-circular cavity into the space behind the cabin wall liner [Appendix B, Figure B-3, detail E]. This space was restricted somewhat by the presence of the window assembly, but nevertheless provided a continuous cavity extending upwards to the level of the upper deck floor. Forward of station 740, this cavity was effectively terminated at its upper end by the presence of diaphragms which formed extensions of the upper deck floor panels; aft of station 740, the cavity communicated with the ceiling space and the cavity in the fuselage crown aft of the upper deck.

All of these cavities were repeated at each fuselage bay (formed between pairs of fuselage frames), and all of the cavities in a given bay were linked together, principally at the crease beam area [Appendix B, Figure B-3, region F]. Furthermore, each of the set of bay cavities was linked with the next by the longitudinal cavities formed between the cargo hold liner and the outer hull, just below the crease beam [Appendix B, Figure B-3, detail F]; i.e. this cavity formed a manifold linking together each of the bays within the cargo hold.

The main passenger cabin formed a large chamber which communicated directly with each of the sub floor bays, and also with the longitudinal manifold cavity, via the air conditioning and cabin/cargo bay de-pressurisation vent passages in the crease beam area. (It should be noted that a similar communication did not exist between the upper and lower cabins because there were no air conditioning/depressurisation passages to bypass the upper deck floor.)

1.6.4 Aircraft weight and centre of gravity

The aircraft was loaded within its permitted centre of gravity limits as follows:

Loading: lb kg
Operating empty weight 366,228 166,120
Additional crew 130 59
243 passengers (1) 40,324 18,291
Load in compartments:
1 11,616 5,269
2 20,039 9,090

3 15,057 6,830
4 17,196 7,800
5 2,544   1,154
Total in compartments (2) 66,452 30,143
Total traffic load   106,776 48,434
Zero fuel weight 472,156 214,554
Fuel (Take-off) 239,997 108,862
Actual take-off weight(4)   713,002 323,416
Maximum take-off weight 733,992 332,937

Note 1:
Calculated at standard weights and including cabin baggage.

Note 2:
Despatch information stated that the cargo did not include dangerous goods, perishable cargo, live animals or known security exceptions.

1.6.5 Maintenance details

N739PA first flew in 1970 and spent its whole service life in the hands of Pan American World Airways Incorporated. Its Certificate of Airworthiness was issued on 12 February 1970 and remained in force until the time of the accident, at which time the aircraft had completed a total of 72,464 hours flying and 16,497 flight cycles. Details of the last 4 maintenance checks carried out during the aircraft's life are shown below:

DATE   SERVICE HOURS   CYCLES
27 Sept 88   C Check (Interior upgrade)   71,502 16,347
2 Nov 88 B Service Check 71,919 16,406
27 Nov 88 Base 1 72,210 16,454
13 Dec 88 Base 2 72,374 16,481

The CRAF modification programme was undertaken in September 1987. At the same time a series of modifications to the forward fuselage from the nose back to station 520 (Section 41) were carried out to enable the aircraft to continue in service without a continuing requirement for structural inspections in certain areas.

All Airworthiness Directives relating to the Boeing 747 fuselage structure between stations 500 and 1000 have been reviewed and their applicability to this aircraft checked. In addition, Service Bulletins relating to the structure in this area were also reviewed. The applicable Service Bulletins, some of which implement the Airworthiness Directives are listed below together with their subjects. The dates, total aircraft times and total aircraft cycles at which each relevant inspection was last carried out have been reviewed and their status on aircraft N739PA at the time of the accident has been established.

N739PA Service Bulletin compliance:

SB 53-2064 Front Spar Pressure Bulkhead Chord Reinforcement and Drag Splice Fitting Rework.
Modification accomplished on 6 July 1974.
Post-modification repetitive inspection IAW (in accordance with) AD 84-18-06 last accomplished on 19 November 1985 at 62,030 TAT hours (Total Aircraft Time) and 14,768 TAC (Total Aircraft Cycles).
SB 53-2088 Frame to Tension Tie Joint Modification - BS760 to 780.
Repetitive inspection IAW AD 84-19-01 last accomplished on 19 June 1985 at 60,153 hours TAT and 14,436 TAC.
SB 53-2200 Lower Cargo Doorway Lower Sill Truss and Latch Support Fitting Inspection Repair and Replacement.
Repetitive inspection IAW AD 79-17-02 R2 last accomplished 2 November 1988 at 71,919 hours TAT and 16,406 TAC.
SB 53-2234 Fuselage - Auxiliary Structure - Main Deck Floor - BS 480 Floor Beam Upper Chord Modification.
Repetitive inspection per SB 53A2263 IAW AD 86-23-06 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
SB 53-2237 Fuselage - Main Frame - BS 540 thru 760 and 1820 thru 1900 Frame Inspection and Reinforcement.
Repetitive inspection IAW AD 86-18-01 last accomplished on 27 February 1987 at 67,088 hours TAT and 15,627 TAC.
SB 53-2267 Fuselage - Skin - Lower Body Longitudinal Skin Lap Joint and Adjacent Body Frame Inspection and Repair.
Terminating modification accomplished 100% under wing-to-body fairings and approximately 80% in forward and aft fuselage sections on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.
Repetitive inspection of unmodified lap joints IAW AD 86-09-07 R1 last accomplished on 18 August 1988 at 71,043 hours TAT and 16,273 TAC.
SB 53A2303 Fuselage - Nose Section - station 400 to 520 Stringer 6 Skin Lap Splice Inspection, Repair and Modification.
Repetitive inspection IAW AD 89-05-03 last accomplished on 26 September 1987 at 67,376 hours TAT and 15,680 TAC.

This documentation, when viewed together with the detailed content of the above service bulletins, shows the aircraft to have been in compliance with the requirements laid down in each of those bulletins. Some maintenance items were outstanding at the time the aircraft was despatched on the last flight, however, none of these items relate to the structure of the aircraft and none had any relevance to the accident.

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1.7 Meteorological Information

1.7.1 General weather conditions

An aftercast of the general weather conditions in the area of Lockerbie at about 19.00 hrs was obtained from the Meteorological Office, Bracknell. The synoptic situation included a warm sector covering northern England and most of Scotland with a cold front some 200 nautical miles to the west of the area moving eastwards at about 35 knots. The weather consisted of intermittent rain or showers. The cloud consisted of 4 to 6 oktas of stratocumulus based at 2,200 feet with 2 oktas of altocumulus between 15,000 and 18,000 feet. Visibility was over 15 kilometers and the freezing level was at 8,500 feet with a sub-zero layer between 4,000 and 5,200 feet.

1.7.2 Winds

There was a weakening jet stream of around 115 knots above Flight Level 310. From examination of the wind profile (see below), there appeared to be insufficient shear both vertically and horizontally to produce any clear air turbulence but there may have been some light turbulence.

Flight Level	Wind
320	260¡/115 knots
300	260¡/ 90 knots
240	250¡/ 80 knots
180	260¡/ 60 knots
100	250¡/ 60 knots
050	260¡/ 40 knots
Surface	240¡/ 15 to 20 gusting 25 to 30 knots

1.8 Aids to navigation

Not relevant.

1.9 Communications

The aircraft communicated normally on London Heathrow aerodrome, London control and Scottish control frequencies. Tape recordings and transcripts of all radio telephone (RTF) communications on these frequencies were available.

At 18.58 hrs the aircraft established two-way radio contact with Shanwick Oceanic Area Control on frequency 123.95 MHz. At 19.02:44 hrs the clearance delivery officer at Shanwick transmitted to the aircraft its oceanic route clearance. The aircraft did not acknowledge this message and made no subsequent transmission.

1.9.1 ATC recording replay

Scottish Air Traffic Control provided copy tapes with time injection for both Shanwick and Scottish ATC frequencies. The source of the time injection on the tapes was derived from the British Telecom "TIM" signal.

The tapes were replayed and the time signals corrected for errors at the time of the tape mounting.

1.9.2 Analysis of ATC tape recordings

From the cockpit voice recorder (CVR) tape it was known that Shanwick was transmitting Flight PA103's transatlantic clearance when the CVR stopped. By synchronising the Shanwick tape and the CVR it was possible to establish that a loud sound was heard on the CVR cockpit area microphone (CAM) channel at 19.02:50 hrs ±1 second.

As the Shanwick controller continued to transmit Flight PA103's clearance instructions through the initial destruction of the aircraft it would not have been possible for a distress call to be received from N739PA on the Shanwick frequency. The Scottish frequency tape recording was listened to from 19.02 hrs until 19.05 hrs for any unexplained sounds indicating an attempt at a distress call but none was heard.

A detailed examination and analysis of the ATC recording together with the flight recorder, radar, and seismic recordings is contained in Appendix C.

1.10 Aerodrome information

Not relevant

1.11 Flight recorders

The Digital Flight Data Recorder (DFDR) and the Cockpit Voice Recorder (CVR) were found close together at UK Ordnance Survey (OS) Grid Reference 146819, just to the east of Lockerbie, and recovered approximately 15 hours after the accident. Both recorders were taken directly to AAIB Farnborough for replay. Details of the examination and analysis of the flight recorders together with the radar, ATC and seismic recordings are contained in Appendix C.

1.11.1 Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded and that the recorder had simply stopped at 19.02:50 hrs ±1 second.

1.11.2 Cockpit voice recorder

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1 Flight Engineer's RTF.
Channel 2 Co-Pilot's RTF.
Channel 3 Pilot's RTF.

Channel 4   Cockpit Area Microphone.

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings were audible on the RTF channels. The CAM channel was particularly noisy, probably due to the combination of the inherently noisy flight deck of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high flight deck noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified and could have been of either acoustic or electrical origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual crew behaviour. The tape record ended, at 19.02:50 hrs ±1 second, with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording whilst the crew were copying their transatlantic clearance from Shanwick ATC.

1.12 Wreckage and impact information

1.12.1 General distribution of wreckage in the field

The complete wing primary structure, incorporating the centre section, impacted at the southern edge of Lockerbie. Major portions of the aircraft, including the engines, also landed in the town. Large portions of the aircraft fell in the countryside to the east of the town and lighter debris was strewn to the east as far as the North Sea. The wreckage was distributed in two trails which became known as the northern and southern trails respectively and these are shown in Appendix B, Figure B-4. A computer database of approximately 1200 significant items of wreckage was compiled and included a brief description of each item and the location where it was found

Appendix B, Figures B-5 to B-8 shows photographs of a model of the aircraft on which the fracture lines forming the boundaries of the separate items of structure have been marked. The model is colour coded to illustrate the way in which the wreckage was distributed between the town of Lockerbie and the northern and southern trails.

1.12.1.1 The crater

The aircraft wing impacted in the Sherwood Crescent area of the town leaving a crater approximately 47 metres (155 feet) long with a volume calculated to be 560 cubic metres.

The projected distance, measured parallel from one leading edge to the other wing tip, of the Boeing 747-100 was approximately 143 feet, whereas the span is known to be 196 feet. This suggests that impact took place with the wing structure yawed. Although the depth of the crater varied from one end to the other, its widest part was clearly towards the western end suggesting that the wing structure impacted whilst orientated with its root and centre section to the west.

The work carried out at the main crater was limited to assessing the general nature of its contents. The total absence of debris from the wing primary structure found remote from the crater confirmed the initial impression that the complete wing box structure had been present at the main impact.

The items of wreckage recovered from or near the crater are coloured grey on the model at Appendix B, Figures B-5 to B-8.

1.12.1.2 The Rosebank Crescent site

A 60 feet long section of fuselage between frame 1241 (the rear spar attachment) and frame 1960 (level with the rear edge of the CRAF cargo door) fell into a housing estate at Rosebank Crescent, just over 600 metres from the crater. This section of the fuselage was that situated immediately aft of the wing, and adjoined the wing and fuselage remains which produced the crater. It is colour coded yellow on the model at Appendix B, Figures B-5 to B-8. All fuselage skin structure above floor level was missing except for the following items:

Section containing 3 windows between door 4L and CRAF door;
The CRAF door itself (latched) apart from the top area containing the hinge;
Window belt containing 8 windows aft of 4R door aperture
Window belt containing 3 windows forward of 4R door aperture;
Door 4R.

Other items found in the wreckage included both body landing gears, the right wing landing gear, the left and right landing gear support beams and the cargo door (frames 1800-1920) which was latched. A number of pallets, luggage containers and their contents were also recovered from this site.

1.12.1.3 Forward fuselage and flight deck section.

The complete fuselage forward of approximately station 480 (left side) to station 380 (right side) and incorporating the flight deck and nose landing gear was found as a single piece [Appendix B, Figure B-9] in a field approximately 4 km miles east of Lockerbie at OS Grid Reference 174808. It was evident from the nature of the impact damage and the ground marks that it had fallen almost flat on its left side but with a slight nose-down attitude and with no discernible horizontal velocity. The impact had caused almost complete crushing of the structure on the left side. The radome and right nose landing gear door had detached in the air and were recovered in the southern trail.

Examination of the torn edges of the fuselage skin did not indicate the presence of any pre-existing structural or material defects which could have accounted for the separation of this section of the fuselage. Equally so, there were no signs of explosive blast damage or sooting evident on any part of the structure or the interior fittings. It was noted however that a heavy, semi-eliptical scuff mark was present on the lower right side of the fuselage at approximately station 360. This was later matched to the intake profile of the No 3 engine.

The status of the controls and switches on the flight deck was consistent with normal operation in cruising flight. There were no indications that the crew had attempted to react to rapid decompression or loss of control or that any emergency preparations had been actioned prior to the catastrophic disintegration.

1.12.1.4 Northern trail

The northern trail was seen to be narrow and clearly defined, to emanate from a point very close to the main impact crater and to be orientated in a direction which agreed closely with the mean wind aftercast for the height band from sea level to 20,000 ft. Also at the western end of the northern trail were the lower rear fuselage at Rosebank Crescent, and the group of Nos. 1, 2 and 4 engines which fell in Lockerbie.

The trail contained items of structure distributed throughout its length, from the area slightly east of the crater, to a point approximately 16 km east, beyond which only items of low weight / high drag such as insulation, interior trim, paper etc, were found. For all practical purposes this trail ended at a range of 25 km.

The northern trail contained mainly wreckage from the rear fuselage, fin and the inner regions of both tailplanes together with structure and skin from the upper half of the fuselage forward to approximately the wing mid-chord position. A number of items from the wing were also found in the northern trail, including all 3 starboard Kreuger flaps, most of the remains of the port Kreuger flaps together with sections of their leading edge attachment structures, one portion of outboard aileron approximately 10 feet long, the aft ends of the flap-track fairings (one with a slide raft wrapped around it), and fragments of glass reinforced plastic honeycombe structure believed to be from the flap system, i.e. fore-flaps, aft-flaps, mid-flaps or adjacent fairings. In addition, a number of pieces of the engine cowlings and both HF antennae (situated projecting aft from the wing-tips) were found in this trail.

All items recovered from the northern trail, with the exception of the wing, engines, and lower rear fuselage in Rosebank Crescent, are coloured red on the model of the aircraft in Appendix B, Figures B-5 to B-8.

1.12.1.5 Southern trail

The southern trail was easily defined, except within 12 km of Lockerbie where it tended to merge with the northern trail. Further east, it extended across southern Scotland and northern England, essentially in a straight band as far as the North Sea. Most of the significant items of wreckage were found in this trail within a range of 30 km from the main impact crater. Items recovered from the southern trail are coloured green on the model of the aircraft at Appendix B, Figures B-5 to B-8.

The trail contained numerous large items from the forward fuselage. The flight deck and nose of the aircraft fell in the curved part of this trail close to Lockerbie. Fragments of the whole of the left tailplane and the outboard portion of the right tailplane were distributed almost entirely throughout the southern trail. Between 21 and 27 km east of the main impact point (either side of Langholm) substantial sections of tailplane skin were found, some bearing distinctive signs of contact with debris moving outwards and backwards relative to the fuselage. Also found in this area were numerous isolated sections of fuselage frame, clearly originating from the crown region above the forward upper deck.

1.12.1.6 Datum line

All grid references relating to items bearing actual explosive evidence, together with those attached to heavily distorted items found to originate immediately adjacent to them on the structure, were plotted on an Ordnance Survey (OS) chart. These references, 11 in total, were all found to be distributed evenly about a mean line orientated 079¡(Grid) within the southern trail and were spread over a distance of 12 km. The distance of each reference from the line was measured in a direction parallel to the aircraft's track and all were found to be within 500 metres of the line, with 50% of them being within 250 metres of the line. This line is referred to as the datum line and is shown in Appendix B, Figure B-4.

1.12.1.7 Distribution of wreckage within the southern trail

North of the datum line and parallel to it were drawn a series of lines at distances of 250, 300, 600 and 900 metres respectively from the line, again measured in a direction parallel to the aircraft's track. The positions on the aircraft structure of specific items of wreckage, for which grid references were known with a high degree of confidence, within the bands formed between these lines, are shown in Appendix B, Figures B-10 to 13. In addition, a separate assessment of the grid references of tailplane and elevator wreckage established that these items were distributed evenly about the 600 metre line.

1.12.1.8 Area between trails

Immediately east of the crater, the southern trail converged with the northern trail such that, to an easterly distance of approximately 5 km, considerable wreckage existed which could have formed part of either trail. Further east, between 6 and 11 km from the crater, a small number of sections and fragments of the fin had fallen outside the southern boundary of the northern trail. Beyond this a large area existed between the trails in which there was no wreckage.

1.12.2 Examination of wreckage at CAD Longtown

The debris from all areas was recovered by the Royal Air Force to the Army Central Ammunition Depot Longtown, about 20 miles from Lockerbie. Approximately 90% of the hull wreckage was successfully recovered, identified, and laid out on the floor in a two-dimensional reconstruction [Appendix B, Figure B-14]. Baggage container material was incorporated into a full three-dimensional reconstruction. Items of wreckage added to the reconstructions was given a reference number and recorded on a computer database together with a brief description of the item and the location where it was found.

1.12.2.1 Fuselage

The reconstruction revealed the presence of damage consistent with an explosion on the lower fuselage left side in the forward cargo bay area. A small region of structure bounded approximately by frames 700 & 720 and stringers 38L & 40L, had clearly been shattered and blasted through by material exhausting directly from an explosion centred immediately inboard of this location. The material from this area, hereafter referred to as the 'shatter zone', was mostly reduced to very small fragments, only a few of which were recovered, including a strip of two skins [Appendix B, Figure B-15] forming part of the lap joint at the stringer 39L position.

Surrounding the shatter zone were a series of much larger panels of torn fuselage skin which formed a 'star-burst' fracture pattern around the shatter zone. Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range. In contrast, the star-burst fractures, outside the boundary of the shatter zone, displayed evidence of more typical overload tearing, though some tears appeared to be rapid and, in the area below the missing panels, were multi-branched. These surrounding skin panels were moderately sooted in the regions adjacent to the shatter zone, but otherwise were lightly sooted or free of soot altogether. (Forensic analysis of the soot deposits on frame and skin material from this area confirmed the presence of explosive residues.) All of these skin panels had pulled away from the supporting structure and had been bent and torn in a manner which indicated that, as well as fracturing in the star burst pattern, they had also petalled outwards producing characteristic, tight curling of the sheet material.

Sections of frames 700 and 720 from the area of the explosion were also recovered and identified. Attached to frame 720 were the remnants of a section of the aluminium baggage container (side) guide rail, which was heavily distorted and displayed deep pitting together with very heavy sooting, indicating that it had been very close to the explosive charge. The pattern of distortion and damage on the frames and guide rail segment matched the overall pattern of damage observed on the skins.

The remainder of the structure forming the cargo deck and lower hull was, generally, more randomly distorted and did not display the clear indications of explosive processes which were evident on the skin panels and frames nearer the focus of the explosion. Nevertheless, the overall pattern of damage was consistent with the propagation of explosive pressure fronts away from the focal area inboard of the shatter zone. This was particularly evident in the fracture and bending characteristics of several of the fuselage frames ahead of, and behind station 700.

The whole of the two-dimensional fuselage reconstruction was examined for general evidence of the mode of disintegration and for signs of localised damage, including overpressure damage and pre-existing damage such as corrosion or fatigue. There was some evidence of corrosion and dis-bonding at the cold-bond lap joints in the fuselage. However, the corrosion was relatively light and would not have compromised significantly the static strength of the airframe. Certainly, there was no evidence to suggest that corrosion had affected the mode of disintegration, either in the area of the explosion or at areas more remote. Similarly, there were no indications of fatigue damage except for one very small region of fatigue, involving a single crack less than 3 inches long, which was remote from the bomb location. This crack was not in a critical area and had not coincided with a fracture path.

No evidence of overpressure fracture or distortion was found at the rear pressure bulkhead. Some suggestion of 'quilting' or 'pillowing' of skin panels between stringers and frames, indicative of localised overpressure, was evident on the skin panels attached to the larger segments of lower fuselage wreckage aft of the blast area. In addition, the mode of failure of the butt joint at station 520 suggested that there had been a rapid overpressure load in this area, causing the fastener heads to 'pop' in the region of stringers 13L to 16L, rather than producing shear in the fasteners. Further evidence of localised overpressure damage remote from the source of the explosion was found during the full three-dimensional reconstruction, detailed later in paragraph 1.12.3.2.

An attempt was made to analyse the fractures, to determine the direction and sequence of failure as the fractures propagated away from the region of the explosion. It was found that the directions of most of the fractures close to the explosion could be determined from an analysis of the fracture surfaces and other features, such as rivet and rivet hole distortions. However, it was apparent that beyond the boundary of the petalled region, the disintegration process had involved multiple fractures taking place simultaneously - extremely complex parallel processes which made the sequencing of events not amenable to conventional analysis.

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1.12.2.2 Wing structure and adjacent fuselage area

On completion of the initial layout at Longtown it became evident that, in the area from station 1000 to approximately station 1240 the only identifiable fuselage structure consisted of elements of fuselage skin, stringers and frames from above the cabin window belts. The wreckage from in and around the crater was therefore sifted to establish more accurately what sections of the aircraft had produced the crater. All of the material was highly fragmented, but it was confirmed that the material comprised mostly wing structure, with a few fragments of fuselage sidewall and passenger seats. The badly burnt state of these fragments made it clear that they were recovered from the area of the main impact crater, the only scene of significant ground fire. Amongst these items a number of cabin window forgings were recovered with sections of thick horizontal panelling attached having a length equivalent to the normal window spacing/frame pitch. This arrangement, with skins of this thickness, is unique to the area from station 1100 to 1260. It is therefore reasonable to assume that these fragments formed parts of the missing cabin sides from station 1000 to station 1260, which must have remained attached to the wing centre section at the time of its impact. Because of the high degree of fragmentation and the relative insignificance of the wing in terms of the overall explosive damage pattern, a reconstruction of the wing material was not undertaken. The sections of the aircraft which went into the crater are colour coded grey in Appendix B, Figures B-5 to B-8.

1.12.2.3 Fin and aft section of fuselage

Examination of the structure of the fin revealed evidence of in-flight damage to the leading edge caused by the impact of structure or cabin contents. This damage was not severe or extensive and the general break-up of the fin did not suggest either a single readily defined loading direction, or break-up due to the effects of leading edge impact. A few items of fin debris were found between the northern and southern trails.

A number of sections of fuselage frame found in the northern trail exhibited evidence of plastic deformation of skin attachment cleats and tensile overload failure of the attachment rivets. This damage was consistent with that which would occur if the skin had been locally subjected to a high loading in a direction normal to its plane. Although this was suggestive of an internal overpressure condition, the rear fuselage revealed no other evidence to support this possibility. Examination of areas of the forward fuselage known to have been subjected to high blast overpressures revealed no comparable evidence of plastic deformation in the skin attachment cleats or rivets, most skin attachment failures appearing to have been rapid.

Calculations made on the effects of internal pressure generated by an open ended fuselage descending at the highest speed likely to have been experienced revealed that this could not generate an internal pressure approaching that necessary to cause failure in an intact cabin structure.

1.12.2.4 Baggage containers

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited damage consistent with being close to a detonating high explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence of explosive damage. It was evident, from the main wreckage layout, that the explosion had occurred in the forward cargo hold and, although all baggage container wreckage was examined, only items from this area which showed the relevant characteristics were considered for the reconstruction. Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to Lockerbie, whilst that from the forward hold was scattered along the southern wreckage trail.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this, two adjacent containers, one of metal construction the other fibreglass, were identified as exhibiting damage likely to have been caused by the explosion. Those parts which could be positively identified as being from these two containers were assembled onto one of three simple wooden frameworks, one each for the floor and superstructure of the metal container and one for the superstructure of the fibreglass container. From this it was positively determined that the explosion had occurred within the metal container (serial number AVE 4041 PA), the direct effects of this being evident also on the forward face of the adjacent fibreglass container (serial number AVN 7511 PA) and on the local airframe on the left side of the aircraft in the region of station 700. It was therefore confirmed that this metal container had been loaded in position 14L in agreement with the aircraft loading records. While this work was in progress a buckled section of the metal container skin was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device (IED).

The reconstruction of these containers and their relationship to the aircraft structure is described in detail in Appendix F. Examination of all other components of the remaining containers revealed only damage consistent with ejection into the high speed slipstream and/or ground impact, and that only one device had detonated within the containers on board the aircraft.

1.12.3 Fuselage three-dimensional reconstruction

1.12.3.1 The reconstruction

The two-dimensional reconstruction successfully established that there had been an explosion in the forward hold; its location was established and the general damage characteristics in the vicinity of the explosion were determined. However, the mechanisms by which the failure process developed from local damage in the immediate vicinity of the explosion to the complete structural break-up and separation of the whole forward section of the fuselage, could not be adequately investigated without recourse to a more elaborate reconstruction.

To facilitate this additional work, wreckage forming a 65 foot section of the fuselage (approximately 30 feet each side of the explosion) was transported to AAIB Farnborough, where it was attached to a specially designed framework to form a fully three-dimensional reconstruction [Appendix B, Figures B-16 and B-17] of the complete fuselage between stations 360 & 1000 (from the separated nose section back to the wing cut out). The support framework was designed to provide full and free access to all parts of the structure, both internally and externally. Because of height constraints, the reconstruction was carried out in two parts, with the structure divided along a horizontal line at approximately the upper cabin floor level. The previously reconstructed containers were also transported to AAIB Farnborough to allow correlation of evidence with, and partial incorporation into, the fuselage reconstruction.

Structure and skin panels were attached to the supporting framework by their last point of attachment, to provide a better appreciation of the modes and direction of curling, distortion, and ultimate separation. Thus, the panels of skin which had petalled back from the shatter zone were attached at their outer edges, so as to identify the bending modes of the panels, the extent of the petalled region, and also the size of the resulting aperture in the hull. In areas more remote from the explosion, the fracture and tear directions were used together with distortion and curling directions to determine the mode of separation, and thus the most appropriate point of attachment to the reconstruction. Cabin floor beam segments were supported on a steel mesh grid and a plot of the beam fractures is shown at Appendix B, Figure B-18.

The cargo container base elements were separated from the rest of the container reconstruction and transferred to the main wreckage reconstruction, where the re-assembled container base was positioned precisely onto the cargo deck. To assist in the correlation of the initial shatter zone and petalled-out regions with the position of the explosive device, the boundaries of the skin panel fractures were marked on a transparent plastic panel which was then attached to the reconstruction to provide a transparent pseudo-skin showing the positions of the skin tear lines. This provided a clear visual indication of the relationship between the skin panel fractures and the explosive damage to the container base, thus providing a more accurate indication of the location of the explosive device.

1.12.3.2 Summary of explosive features evident

The three-dimensional reconstruction provided additional information about the region of tearing and petalling around the shatter zone. It also identified a number of other regions of structural damage, remote from the explosion, which were clearly associated with severe and rapidly applied pressure loads acting normal to the skin's internal surface. These were sufficiently sharp-edged to pre-empt the resolution of pressure induced loads into membrane tension stresses in the skin: instead, the effect was as though these areas of skin had been struck a severe 'pressure blow' from within the hull.

The two types of damage, i.e. the direct blast/tearing/petalling damage and the quite separate areas of 'pressure blow' damage at remote sites were evidently caused by separate mechanisms, though it was equally clear that each was caused by explosive processes, rather than more general disintegration.

The region of petalling was bounded (approximately) by frames 680 and 740, and extended from just below the window belt down nearly to the keel of the aircraft [Appendix B, Figure B-19, region A]. The resulting aperture measured approximately 17 feet by 5 feet. Three major fractures had propagated beyond the boundary of the petalled zone, clearly driven by a combination of hull pressurisation loading and the relatively long term (secondary) pressure pulse from the explosion. These fractures ran as follows:

(i) rearwards and downward in a stepped fashion, joining the stringer 38L lap joint at around station 840, running aft along stringer 38L to around

station 920, then stepping down to stringer 39L and running aft to terminate at the wing box cut-out [Appendix B, Figure B-19, fracture 1].
(ii) downwards and forward to join the stringer 44L lap joint, then running forward along stringer 44L as far as station 480 [Appendix B, Figure B-19, fracture 2].
(iii) downwards and rearward, joining the butt line at station 740 to run under the fuselage and up the right side to a position approximately 18 inches above the cabin floor level [Appendix B, Figures B-19 and B-20, fracture 3].

The propagation of tears upwards from the shatter zone appeared to have taken the form of a series of parallel fractures running upwards together before turning towards each other and closing, forming large flaps of skin which appear to have separated relatively cleanly.

Regions of skin separation remote from the site of the explosion were evident in a number of areas. These principally were:

(i) A large section of upper fuselage skin extending from station 500 back to station 760, and from around stringers 15/19L up as far as stringer 5L [Appendix B, Figures B-19 and B-20, region B], and probably extending further up over the crown. This panel had separated initially at its lower forward edge as a result of a pressure blow type of impulse loading, which had popped the heads from the rivets at the butt joint on frame 500 and lifted the skin flap out into the airflow. The remainder of the panel had then torn away rearwards in the airflow.
A region of 'quilting' or 'pillowing', i.e. spherical bulging of skin panels between frames and stringers, was evident on these panels in the region between station 560 and 680, just below the level of the upper deck floor, indicative of high internal pressurisation loading [Appendix B, Figure B-19, region C].
(ii) A smaller section of skin between stations 500 and 580, bounded by stringers 27L and 34L [Appendix B, Figure B-19, region D], had also been 'blown' outwards at its forward edge and torn off the structure rearwards. A characteristic curling of the panel was evident, consistent with rapid, energetic separation from the structure.
(iii) A section of thick belly skin extending from station 560, stringers 40R to 44R, and tapering back to a point at stringer 45R/station720 [Appendix B, Figure B-19 and B-20, region E], had separated from the structure as a result of a very heavy 'pressure blow' load at its forward end which had popped the heads off a large number of substantial skin fasteners. The panel had then torn away rearwards from the structure, curling up tightly onto itself as it did so -

indicating that considerable excess energy was involved in the separation process (over and above that needed simply to separate the skin material from its supporting structure).
(iv) A panel of skin on the right side of the aircraft, roughly opposite the explosion, had been torn off the frames, beginning at the top edge of the panel situated just below the window belt and tearing downwards towards the belly [Appendix B, Figure B-20, region F]. This panel was curled downwards in a manner which suggested significant excess energy.

Appendix B, Figure B-21 shows a plot of the fractures noted in the fuselage skins between stations 360 and 1000.

The cabin floor structure was badly disrupted, particularly in the general area above the explosion, where the floor beams had suffered localised upward loading sufficient to fracture them, and the floor panels were missing. Elsewhere, floor beam damage was mainly limited to fractures at the outer ends of the beams and at the centreline, leaving sections of separated floor structure comprising a number of half beams joined together by the Nomex honeycomb floor panels.

1.12.3.3 General damage features not directly associated with explosive forces.

A number of features appeared to be a part of the general structural break-up which followed on from the explosive damage, rather than being a part of the explosive damage process itself. This general break-up was complex and, to a certain extent, random. However, analysis of the fractures, surface scores, paint smears and other features enabled a number of discreet elements of the break-up process to be identified. These elements are summarised below.

(i) Buckling of the window belts on both sides of the aircraft was evident between stations 660 and 800. That on the left side appeared to be the result of in-plane bending in a nose up sense, followed by fracture. The belt on the right side had a large radius curve suggesting lateral deflection of the fuselage possibly accompanied by some longitudinal compression. This terminated in a peeling failure of the riveted joint at station 800.
(ii) On the left side three fractures, apparently resulting from in-plane bending/buckling distortion, had traversed the window belt [Appendix B, Figure B-21, detail G]. Of these, the forward two had broken through the window apertures and the aft fracture had exploited a rivet line at the region of reinforcement just forward of the L2 door aperture. On the right side, the window belt had peeled rearwards, after buckling had occurred, separating

from the rest of the fuselage, following rivet failure, at the forward edge of the R2 door aperture.
(iii) All crown skins forward of frame 840 were badly distorted and a number of pieces were missing. It was clearly evident that the skin sections from this region had struck the empennage and/or other structure following separation.
(iv) The fuselage left side lower lobe from station 740 back to the wing box cut-out, and from the window level down to the cargo deck floor (the fracture line along stringer 38L), had peeled outwards, upwards and rearwards - separating from the rest of the fuselage at the window belt. The whole of this separated section had then continued to slide upwards and rearwards, over the fuselage, before being carried back in the slipstream and colliding with the outer leading edge of the right horizontal stabiliser, completely disrupting the outer half. A fragment of horizontal stabiliser spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door [Appendix B, Figure B-22].
(v)   A large, clear, imprint of semi-eliptical form was apparent on the lower right side at station 360 which had evidently been caused by the separating forward fuselage section striking the No 3 engine as it swung rearwards and to the right (confirmed by No 3 engine fan cowl damage).

1.12.3.4 Tailplane three-dimensional reconstruction

The tailplane structural design took the form of a forward and an aft torque box. The forward box was constructed from light gauge aluminium alloy sheet skins, supported by closely pitched, light gauge nose ribs but without lateral stringers. The aft torque box incorporated heavy gauge skin/stringer panels with more widely spaced ribs. The front spar web was of light gauge material. Leading edge impacts inflicted by debris would therefore have had the capacity to reduce the tailplane's structural integrity by passing through the light gauge skins and spar web into the interior of the aft torque box, damaging the shear connection between top and bottom skins in the process and thereby both removing the bending strength of the box and opening up the weakened structure to the direct effects of the airflow.

Examination of the rebuilt tailplane structure at AAIB Farnborough left little doubt that it had been destroyed by debris striking its leading edges. In addition, the presence on the skins of smear marks indicated that some unidentified soft debris had contacted those surfaces whilst moving with both longitudinal and lateral velocity components relative to the aircraft.

The reconstructed left tailplane [Appendix B, Figure B-23] showed evidence that disruption of the inboard leading edge, followed respectively by the forward torque box, front spar web and main torque box, occurred as a result of frontal impact by the base of a baggage container. Further outboard, a compact object appeared to have struck the underside of the leading edge and penetrated to the aft torque box. In both cases, the loss of the shear web of the front spar appeared to have permitted local bending failure of the remaining main torque box structure in a tip downwards sense, consistent with the normal load direction. For both events to have occurred it would be reasonable to assume that the outboard damage preceded that occurring inboard.

The right tailplane exhibited massive leading edge impact damage on the outboard portion which also appeared to have progressed to disruption of the aft torsion box. A fragment of right tailplane spar cap was found embedded in the fuselage structure adjacent to the two vent valves, just below, and forward of, the L2 door and it is clear that this area of forward left fuselage had travelled over the top of the aircraft and contributed to the destruction of the outboard right tailplane.

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1.12.4 Examination of engines

All four engines had struck the ground in Lockerbie with considerable velocity and therefore sustained major damage, in particular to most of the fan blades. The No 3 engine had fallen 1,100 metres north of the other three engines, striking the ground on its rear face, penetrating a road surface and coming to rest without any further change of orientation i.e. with the front face remaining uppermost. The intake area contained a number of loose items originating from within the cabin or baggage hold. It was not possible initially to determine whether any of the general damage to any of the engine fans or the ingestion noted in No 3 engine intake occurred whilst the relevant engines were delivering power or at a later stage.

Numbers 1, 2 and 3 engines were taken to British Airways Engine Overhaul Limited for detailed examination under AAIB supervision in conjunction with a specialist from the Pratt and Whitney Engine Company. During this examination the following points were noted:

(i) No 2 engine (situated closest to the site of the explosion) had evidence of blade "shingling" in the area of the shrouds consistent with the results of major airflow disturbance whilst delivering power. (This effect is produced when random bending and torsional deflection occurs, permitting the mid-span shrouds to disengage and repeatedly strike the adjacent aerofoil surfaces of the blades). The interior of the air intake contained paint smears and other evidence suggesting the passage of items of debris. One such item of significance was a clear indentation produced by a length of cable of diameter and strand size similar to that typically attached to the closure curtains on the baggage containers.

(ii) No 3 engine, identified on site as containing ingested debris from within the aircraft, nonetheless had no evidence of the type of shingling seen on the blades of No 2 engine. Such evidence is usually unmistakable and its absence is a clear indication that No 3 engine did not suffer a major intake airflow disturbance whilst delivering significant power. The intake structure was found to have been crushed longitudinally by an impact on the front face although, as stated earlier, it had struck the ground on its rear face whilst falling vertically.

(iii) All 3 engines had evidence of blade tip rubs on the fan cases having a combination of circumference and depth greater than hitherto seen on any investigation witnessed on Boeing 747 aircraft by the Pratt and Whitney specialists. Subsequent examination of No 4 engine confirmed that it had a similar deep, large circumference tip rub. These tip-rubs on the four engines were centred at slightly different clock positions around their respective fan cases.

The Pratt and Whitney specialists supplied information which was used to interpret the evidence found on the blades and fan cases including details of engine dynamic behaviour necessary to produce the tip rub evidence. This indicated that the depth and circumference of tip rubs noted would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left.

Pratt and Whitney also advised that:

(i) Airflow disruption such as that presumed to have caused the shingling observed on No 2 engine fan blades was almost invariably the result of damage to the fan blade aerofoils, resulting from ingestion or blade failure.

(ii) Tip rubs of a depth and circumference noted on all four engines could be expected to reduce the fan rotational energy on each to a negligible value within approximately 5 seconds.

(iii) Airflow disruption sufficient to cause the extent of shingling noted on the fan blades of No 2 engine would also reduce the rotational fan energy to a negligible value within approximately 5 seconds.

1.13 Medical and pathological information

The results of the post mortem examination of the victims indicated that the majority had experienced severe multiple injuries at different stages, consistent with the in-flight disintegration of the aircraft and ground impact. There was no pathological indication of an in-flight fire and no evidence that any of the victims had been injured by shrapnel from the explosion. There was also no evidence which unequivocally indicated that passengers or cabin crew had been killed or injured by the effects of a blast. Although it is probable that those passengers seated in the immediate vicinity of the explosion would have suffered some injury as a result of blast, this would have been of a secondary or tertiary nature.

Of the casualties from the aircraft, the majority were found in areas which indicated that they had been thrown from the fuselage during the disintegration. Although the pattern of distribution of bodies on the ground was not clear cut there was some correlation with seat allocation which suggested that the forward part of the aircraft had broken away from the rear early in the disintegration process. The bodies of 10 passengers were not recovered and of these, 8 had been allocated seats in rows 23 to 28 positioned over the wing at the front of the economy section. The fragmented remains of 13 passengers who had been allocated seats around the eight missing persons were found in or near the crater formed by the wing. Whilst there is no unequivocal proof that the missing people suffered the same fate, it would seem from the pattern that the missing passengers remained attached to the wing structure until impact.

1.14 Fire

Of the several large pieces of aircraft wreckage which fell in the town of Lockerbie, one was seen to have the appearance of a ball of fire with a trail of flame. Its final path indicated that this was the No 3 engine, which embedded itself in a road in the north-east part of the town. A small post impact fire posed no hazard to adjacent property and was later extinguished with water from a hosereel. The three remaining engines landed in the Netherplace area of the town. One severed a water main and the other two, although initially on fire, were no risk to persons or property and the fires were soon extinguished.

A large, dark, delta shaped object was seen to fall at about the same time in the Sherwood area of the town. It was not on fire while in the air, however, a fireball several hundred feet across followed the impact. It was of relatively short duration and large amounts of debris were thrown into the air, the lighter particles being carried several miles downwind, while larger pieces of burning debris caused further fires, including a major one at the Townfoot Garage, up to 350 metres from the source. It was determined that the major part of both wings, which included the aircraft fuel tanks, had formed the crater. A gas main had also been ruptured during the impact.

At 19.04 hrs the Dumfries Fire Brigade Control received a call from a member of the public which indicated that there had been a "huge boiler explosion" at Westacres, Lockerbie, however, subsequent calls soon made it clear that it was an aircraft which had crashed. At 19.07 hrs the first appliances were mobile and at 1910 hrs one was in attendance in the Rosebank area. Multiple fires were identified and it soon became apparent that a major disaster had occurred in the town and the Fire Brigade Major Incident Plan was implemented. During the initial phase 15 pumping appliances from various brigades were deployed but this number was ultimately increased to 20.

At 22.09 hrs the Firemaster made an assessment of the situation. He reported that there was a series of fires over an area of the town centre extending 1† by € mile. The main concentration of the fire was in the southwest of the town around Sherwood Park and Sherwood Crescent. Appliances were in attendance at other fires in the town, particularly in Park Place and Rosebank Crescent. Water and electricity supplies were interrupted and water had to be brought into the town.

By 02.22 hrs on 22 December, all main seats of fire had been extinguished and the firemen were involved in turning over and damping down. At 04.42 hrs small fires were still occurring but had been confined to the Sherwood Crescent area.

1.15 Survival aspects

1.15.1 Survivability

The accident was not survivable.

1.15.2 Emergency services

A chronology of initial responses by the emergency services is listed below:-

Time Event
19.03 hrs Radio message from Police patrol in Lockerbie to Dumfries and Galloway Constabulary reporting an aircraft crash at Lockerbie.
19.04 hrs Emergency call to Dumfries and Galloway Fire Brigade.
19.37 hrs First ambulances leave for Dumfries and Galloway Royal Infirmary with injured town residents. (2- serious; 3- minor)
19.40 hrs Sherwood Park and Sherwood Crescent residents evacuated to Lockerbie Town Hall.
20.25 hrs Nose section of N739PA discovered at Tundergarth (approximately 4 km east of Lockerbie).

During the next few days a major emergency operation was mounted using the guidelines of the Dumfries and Galloway Regional Peacetime Emergency Plan. The Dumfries and Galloway Constabulary was reinforced by contingents from Strathclyde and Lothian & Borders Constabularies. Resources from HM Forces were made available and this support was subsequently authorised by the Ministry of Defence as Military Aid to the Civil Power. It included the provision of military personnel and a number of helicopters used mainly in the search for and recovery of aircraft wreckage. It was apparent at an early stage that there were no survivors from the aircraft and the search and recovery of bodies was mainly a Police task with military assistance.

Many other agencies were involved in the provision of welfare and support services for the residents of Lockerbie, relatives of the aircraft's occupants and personnel involved in the emergency operation.

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1.16 Tests and research

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity spherically propagating shock wave which will expand outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant because it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter, irrespective of charge size, thus providing a means of calculating the standoff distance of the explosive charge from the fuselage skin. Calculations suggest that a charge standoff distance of aproximately 25 inches would result in a shattered region approximately 18 to 20 inches in diameter, comparable to the size of the shattered region evident in the wreckage. This aspect is covered in greater detail in [Appendix G].

1.17 Additional information

1.17.1 Recorded radar information

Recorded radar information on the aircraft was available from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen from which it was clear that the flight had progressed in a normal manner until secondary surveillance radar (SSR) was lost.

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. The last secondary return from the aircraft was recorded at 19.02:46.9 hrs, identifying N739PA at Flight Level 310, and at the next radar return there is no SSR data, only 4 primary returns. It was concluded that the aircraft was, by this time, no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items had been ejected at high speed probably to both right and left of the aircraft.

Each rotation of the radar head thereafter showed the number of returns increasing, with those first identified across track having slowed down very quickly and followed a track along the prevailing wind line. The radar evidence then indicated that a further break-up of the aircraft had occurred and formed a parallel wreckage trail to the north of the first. From the absence of any returns travelling along track it was concluded that the main wreckage was travelling almost vertically downwards for much of the time.

A detailed analysis of the recorded radar information, together with the radar, ATC and seismic recordings is contained in Appendix C.

1.17.2 Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event measuring 1.6 on the Richter scale and, with appropriate corrections for the times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

An analysis of the seismic recording, together with the radar, ATC and radar information is contained in Appendix C.

1.17.3 Trajectory analysis

A detailed trajectory analysis was carried out by Cranfield Institute of Technology in an effort to provide a sequence for the aircraft disintegration. This analysis comprised several separate processes, including individual trajectory calculations for a limited number of key items of wreckage and mathematical modelling of trajectory paths adopted by a series of hypothetical items of wreckage encompassing the drag/weight spectrum of the actual wreckage.

The work carried out at Cranfield enabled the reasons for the two separate trails to be established. The narrow northern trail was shown to be created by debris released from the aircraft in a vertical dive between 19,000 and 9,000 feet overhead Lockerbie. The southern trail, longer and straight for most of its length, appeared to have been created by wreckage released during the initial disintegration at altitude whilst the aircraft was in level flight. Those items falling closest to Lockerbie would have been those with higher density which would travel a significant distance along track before losing all along-track velocity, whilst only drifting a small distance downwind, owing to the high speed of their descent. The most westerly items thus showed the greatest such effect. The southern trail therefore had curved boundaries at its western end with the curvature becoming progressively less to the east until the wreckage essentially fell in a straight band. Thus wreckage in the southern trail positioned well to the east could be assumed to have retained negligible velocity along aircraft track after separation and the along-track distribution could be used to establish an approximate sequence of initial disintegration.

The analysis calculated impact speeds of 120 kts for the nose section weighing approximately 17,500 lb and 260 kts for the engines and pylons which each weighed about 13,500 lb. Based on the best available data at the time, the analysis showed that the wing (approximately 100,000 lb of structure containing an estimated 200,000 lb of fuel) could have impacted at a speed, in theory, as high as 650 kts if it had 'flown' in a streamlined attitude such that the drag coefficient was minimal. However, because small variations of wing incidence (and various amounts of attached fuselage) could have resulted in significant increases in drag coefficient, the analysis also recognized that the final impact speed of the wing could have been lower.

1.17.4 Space debris re-entry

Four items of space debris were known to have re-entered the Earth's atmosphere on 21 December 1988. Three of these items were fragments of debris which would not have survived re-entry, although their burn up in the upper atmosphere might have been visible from the Earth's surface. The fourth item landed in the USSR at 09.50 hrs UTC.

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2 ANALYSIS

2.1 Introduction

The airport security and criminal aspects of the destruction of Boeing 747 registration N739PA near Lockerbie on 21 December 1988 are the subjects of a separate investigation and are not covered in this report. This analysis discusses the technical aspects of the disintegration of the aircraft and considers possible ways of mitigating the effects of an explosion in the future.

2.2 Explosive destruction of the aircraft

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

The datum line, discussed at paragraph 1.12.1.6, was derived from a detailed analysis of the distribution of specific items of wreckage, including those exhibiting positive evidence of a detonating high performance plastic explosive. The scatter of these items about the datum line may have been due partly to velocities imparted by the force of the detonating explosive and partly by the difficulty experienced in pinpointing the location of the wreckage accurately in relatively featureless terrain and poor visibility. However, the random nature of the scatter created by these two effects would have tended to counteract one another, and a major error in any one of the eleven grid references would have had little overall effect on the whole line. There is, therefore, good reason to have confidence in the validity of the datum line.

The items used to define the datum line, included those exhibiting positive evidence of a detonating high performance plastic explosive, would have been the first pieces to have been released from the aircraft. The datum line was projected westwards until it intersected the known radar track of the aircraft in order to derive the position of the aircraft along track at which the explosive items were released and therefore the position at which the IED had detonated. This position was OS grid reference 146786 and is annotated Point C in Appendix B, Figure B-4. Point C was well within the circle of accuracy (±525 metres) of the position at which the loud noise was heard on the CVR (Point B). There can, therefore, be no doubt that the loud noise on the CVR was directly associated with the detonation of the IED and that this explosion initiated the disintegration process and directly caused the loss of the aircraft.

2.3 Flight recorders

2.3.1 Digital flight data recordings

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to € second. These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the recording from the DFDR fitted to N739PA, which is detailed in Appendix C, showed that the recorded data simply stopped. Following careful examination and correlation of the various sources of recorded information, it was concluded that this occurred because the electrical power supply to the recorder had been interrupted at 19.02:50 hrs ±1 second. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or was old data from a previous recording.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when the aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

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2.3.2 Cockpit voice recorders

The analysis of the cockpit voice recording, which is detailed in Appendix C, concluded that there were valid signals available to the CVR when it stopped at 19.02:50 hrs ±1 second because the power supply to the recorder was interrupted. It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case. In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

2.3.3 Detection of explosive occurrences

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985, RARDE were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems. This recommendation was accepted.

Preliminary results from the trials indicate that, if a suitable sensor can be developed, its output will need to be recorded in real time and therefore it may require wiring to the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

2.4 IED position within the aircraft

From the detailed examination of the reconstructed luggage containers, discussed at paragraph 1.12.2.4 and in Appendix F, it was evident that the IED had been located within a metal container (serial number AVE 4041 PA), near its aft outboard quarter as shown in Appendix F, Figure F-13. It was also clear that the container was loaded in position 14L of the forward hold which placed the explosive charge approximately 25 inches inboard from the fuselage skin at frame 700. There was no evidence to indicate that there was more than one explosive charge.

2.5 Engine evidence

To produce the fan blade tip rub damage noted on all engines by means of airflow inclined to the axes of the nacelles would have required a marked nose down change of aircraft pitch attitude combined with a roll rate to the left while all of the engines were attached to the wing.

The shingling damage noted on the fan blades of No 2 engine can only be attributed to airflow disturbance caused by ingestion related fan blade damage occurring when substantial power was being delivered. This is readily explained by the fact that No 2 engine intake is positioned some 27 feet aft and 30 feet outboard of the site of the explosion and that the interior of the intake exhibited a number of prominent paint smears and general foreign object damage. This damage included evidence of a strike by a cable similar to that forming part of the closure curtain of a typical baggage container. It is inconceivable that an independent blade failure could have occurred in the short time frame of this event. By similar reasoning, the absence of such shingling damage on blades of No 3 engine was a reliable indication that it suffered no ingestion until well into the accident sequence.

The combination of the position of the explosive device and the forward speed of the aircraft was such that significant sized debris resulting from the explosion would have been available to be ingested by No 2 engine within milliseconds of the explosion. In view of the fact that the tip rub damage observed on the fan case of No 2 engine is of similar magnitude to that observed on the other three engines it is reasonable to deduce that a manoeuvre of the aircraft occurred before most of the energy of the No 2 engine fan was lost due to the effect of ingestion (seen only in this engine). Since this shingling effect could only readily be produced as a by-product of ingestion whilst delivering considerable power, it is reasonable to assume that this was also occurring before loss of major fan energy due to tip rubbing took place. Hence both phenomena must have been occurring simultaneously, or nearly so, to produce the effects observed and must have occupied a time frame of substantially less than 5 seconds. The onset of this time period would have been the time at which debris from the explosion first inflicted damage to fan blades in No 3 engine and, since the fan is only approximately 40 feet from the location of the explosive device, this would have been an insignificant time interval after the explosion.

It was therefore concluded from this evidence that the wing with all of the engines attached had achieved a marked nose down and left roll attitude change well within 5 seconds of the explosion.

2.6 Detachment of forward fuselage

Examination of the three major structural elements either side of the region of station 800 on the right side of the fuselage makes it clear that to produce the curvature of the window belt and peeling of the riveted joint at the R2 door aperture requires the door pillar to be securely in position and able to react longitudinal and lateral loads. This in turn requires the large section of fuselage on the right side between stations 760 and 1000 (incorporating the right half of the floor) to be in position in order to locate the lower end of the door pillar. Thus both these sections must have been in position until the section from station 560 to 800 (right side) had completed its deflection to the right and peeled from the door pillar. Separation of the forward fuselage must thus have been complete by the time all three items mentioned above had fallen free.

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2.7 Speed of initial disintegration

The distribution of wreckage in the bands between the datum line and the 250, 300, 600 and 900 metre lines was examined in detail. The positions of these items of structure on the aircraft are shown in Appendix B, Figures B-10 to B-13. It should be noted that the position on the ground of these items, although separated by small distances when measured in a direction along aircraft track, were distributed over large distances when measured along the wreckage trail. All were recovered from positions far enough to the east to be in that part of the southern trail which was sufficiently close, theoretically, to a straight line for any curvature effect to be neglected.

The wreckage found in each of the bands enabled an approximate sequence of break-up to be established. It was clear that as the distance travelled from the datum line increased, items of wreckage further from the station of the IED were encountered. The items shown on the diagram as falling on the 250 metre band also include those fragments of lower forward fuselage skin having evidence of explosive damage and presumed to have separated as a direct result of the blast. However, a few portions of the upper forward fuselage were also found within the 250 metre band, suggesting that these items had also separated as a result of the blast.

By the time the 300 metre line was reached much of the structure from the right side in the region of the explosive device had been shed. This included the area of window belt, referred to in paragraph 2.6 above, which gave clear indications that the forward structure had detached to the right and finally peeled away at station 800. It also included the areas of adjacent structure immediately to the rear of station 800 about which the forward structure would have had to pivot. By the time the 600 metre line was reached, there was clearly insufficient structure left to connect the forward fuselage with the remainder of the aircraft. Wreckage between the 600 and 900 metre lines consisted of structure still further from the site of the IED.

There is evidence that a manoeuvre occurred at the time of the explosion which would have produced a significant change of the aircraft's flight path, however, it is considered that the change in the horizontal velocity component in the first few seconds would not have been great. The original groundspeed of the aircraft was therefore used in conjunction with the distribution of wreckage in the successive bands to establish an approximate time sequence of break-up of the forward fuselage. Assuming the original ground speed of 434 Kts, the elapsed flight times from the datum to each of the parellel lines were calculated to be:

Distance (metres)	250	300	600	900
Time (seconds)	1.1	1.3	2.7	4.0

Thus, there is little doubt that separation of the forward fuselage was complete within 2 to 3 seconds of the explosion.

The separate assessment of the known grid references of tailplane and elevator wreckage in the southern trail revealed that those items were evenly distributed about the 600 metre line and therefore that most of the tailplane damage occurred after separation of the forward fuselage was complete.

2.8 The manoeuvre following the explosion

The engine evidence, timing and mode of disintegration of the fuselage and tailplane suggests that the latter did not sustain significant damage until the forward fuselage disintegration was well advanced and the pitch/roll manoeuvre was also well under way.

Examination of the three dimensional reconstruction makes it clear that both main and upper deck floors were disrupted by the explosion. Since pitch control cables are routed through the upper deck floor beams and the roll control cables through the main deck beams, there is a strong possibility that movement of the beams under explosive forces would have applied inputs to the control cables, thus operating control surfaces in both axes.

2.9 Secondary disintegration

The distribution of fin debris between the trails suggests that disintegration of the fin began shortly before the vertical descent was established. No single mode of failure was identified and the debris which had struck the leading edge had not caused major disruption. The considerable fragmentation of the thick panels of the aft torque box was also very different from that noted on the corresponding structure of the tailplanes. It was therefore concluded that the mode of failure was probably flutter.

The finding, in the northern trail, of a slide raft wrapped around a flap track fairing suggests that at a later stage of the disintegration the rear of the aircraft must have experienced a large angle of sideslip. The loss of the fin would have made this possible and also subjected the structure to large side loads. It is possible that such side loading would have assisted the disintegration of the rear fuselage and also have caused bending failure of the pylon attachments of the remaining three engines.

2.10 Impact speed of components

The trajectory analysis carried out by Cranfield Institute of Technology calculated impact speeds of 120 kts for the nose section, and 260 kts for the engines and pylons. These values were considered to be reliable because the drag coefficients could be estimated with a reasonable degree of confidence. Based on the best available data at the time, the analysis also showed that the wing could have impacted at a speed, in theory, as high as 650 kts if it had flown in a streamlined attitude such that the drag coefficient was minimal. However, it was also recognized that relatively small changes in the angle of incidence of the wing would have produced a significant increase in drag with a consequent reduction in impact speed. Refinement of timing information and radar data subsequent to the Cranfield analysis has enabled a revised estimate to be made of the mean speed of the wing during the descent.

The engine evidence indicated that there had been a large nose down attitude change of the aircraft early in the event. The Cranfield analysis also showed that the rear fuselage had disintegrated while essentially in a vertical descent between 19,000 and 9,000 feet over Lockerbie. Assuming that, following the explosion, the wing followed a straight line descending flight profile from 31,000 feet to 19,000 feet directly overhead Lockerbie and then descended vertically until impact, the wing would have travelled the minimum distance practicable. The ground distance between the geographical position at which the disintegration started (Figure B-4, Point B) and the crater made by the wing impact was 2997 ±525 metres (9833 ±1722 feet). The time interval between the explosion and the wing impact was established in Appendix C as 46.5 ±2 seconds. Based on the above times and distances the mean linear speed achieved by the wing would have been about 440 kts.

The impact location of Nos 1, 2, and 4 engines closely grouped in Lockerbie was consistent with their nearly vertical fall from a point above the town. If they had separated at about 19,000 feet and the wing had then flown as much as one mile away from the overhead position before tracking back to impact, the total flight path length of the wing would not have required it to have achieved a mean linear speed in excess of 500 kts.

Any speculation that the flight path of the wing could have been longer would have required it to have undergone manoeuvres at high speed in order to arrive at the 19,000 feet point. The manoeuvres involved would almost certainly have resulted in failure of the primary wing structure which, from distribution of wing debris, clearly did not occur. Alternatively the wing could have travelled more than one mile from Lockerbie after reaching the 19,000 feet point, but this was considered unlikely. It is therefore concluded that the mean speed of the wing during the descent was in the region of 440 to 500 kts.

2.11 Sequence of disintegration

Analysis of wreckage in each of the bands, taken in conjunction with the engine evidence and the three-dimensional reconstruction, suggests the following sequence of disintegration:

(i) The initial explosion triggered a sequence of events which effectively destroyed the structural integrity of the forward fuselage. Little more then remained between stations 560 and 760 (approximately) than the window belts and the cabin sidewall structure immediately above and below the windows, although much of the cargo-hold floor structure appears to have remained briefly attached to the aircraft. [Appendix B, Figure B-24]
(ii) The main portion of the aircraft simultaneously entered a manoeuvre involving a marked nose down and left roll attitude change, probably as a result of inputs applied to the flying control cables by movement of structure.
(iii) Failure of the left window belt then occurred, probably in the region of station 710, as a result of torsional and bending loads on the fuselage imparted by the manoeuvre (i.e. the movement of the forward fuselage relative to the remainder of the aircraft was an initial twisting motion to the right, accompanied by a nose up pitching deflection).
(iv) The forward fuselage deflected to the right, pivoting about the starboard window belt, and then peeled away from the structure at station 800. During this process the lower nose section struck the No 3 engine intake causing the engine to detach from its pylon. This fuselage separation was apparently

complete within 3 seconds of the explosion.
(v) Structure and contents of the forward fuselage struck the tail surfaces contributing to the destruction of the outboard starboard tailplane and causing substantial damage to the port unit. This damage occurred approximately 600 metres track distance after the explosion and therefore appears to have happened after the fuselage separation was complete.
(vi) Fuselage structure continued to break away from the aircraft and the separated forward fuselage section as they descended.
(vii) The aircraft maintained a steepening descent path until it reached the vertical in the region of 19,000 feet approximately over the final impact point. Shortly before it did so the tail fin began to disintegrate.
(viii) The mode of failure of the fin is not clear, however, flutter of its structure is suspected.
(ix) Once established in the vertical dive, the fin torque box continued to disintegrate, possibly permitting the remainder of the aircraft to yaw sufficiently to cause side load separation of Nos 1, 2 and 4 engines, complete with their pylons.
(x) Break-up of the rear fuselage occurred during the vertical descent, possibly as a result of loads induced by the yaw, leaving a section of cabin floor and baggage hold from approximately stations 1241 to 1920, together with 3 landing gear units, to fall into housing at Rosebank Terrace.
(xi) The main wing structure struck the ground with a high yaw angle at Sherwood Crescent.
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2.12 Explosive mechanisms and the structural disintegration

The fracture and damage pattern analysis was mainly of an interpretive nature involving interlocking pieces of subtle evidence such as paint smears, fracture and rivet failure characteristics, and other complex features. In the interests of brevity, this analysis will not discuss the detailed interpretation of individual fractures or damage features. Instead, the broader 'damage picture' which emerged from the detailed work will be discussed in the context of the explosive mechanisms which might have produced the damage, with a view to identifying those features of greatest significance.

It is important to keep in mind that whilst the processes involved are considered and discussed separately, the timescales associated with shock wave propagation and the high velocity gas flows are very short compared with the structural response timescales. Consequently, material which was shattered or broken by the explosive forces would have remained in place for a sufficiently long time that the structure can be considered to have been intact throughout much of the period that these explosive propagation phenomena were taking place.

2.12.1 Direct blast effect

2.12.1.1 Shock wave propagation

The direct effect of the explosive detonation within the container was to produce a high intensity spherically propagating shock wave which expanded from the centre of detonation close to the side of the container, shattering part of the side and base of the container as it passed through into the gap between the container and the fuselage skin. In breaking out of the container, some internal reflection and Mach stem interaction would have occurred, but this would have been limited by the absorptive effect of the baggage inboard, above, and forward of the charge. The force of the explosion breaking out of the container would therefore have been directed downwards and rearwards.

The heavy container base was distorted and torn downwards, causing buckling of the adjoining section of frame 700, and the container sides were blasted through and torn, particularly in the aft lower corner. Some of the material in the direct path of the explosive pressure front was reduced to shrapnel sized pieces which were rapidly accelerated outwards behind the primary shock front. Because of the overhang of the container's sloping side, fragments from both the device itself and the container wall impacted the projecting external flange of the container base edge member, producing micro cratering and sooting. Metallurgical examination of the internal surfaces of these craters identified areas of melting and other features which were consistent only with the impact of very high energy particles produced by an explosion at close quarters. Analysis of material on the crater surfaces confirmed the presence of several elements and compounds foreign to the composition of the edge member, including material consistent with the composition of the sheet aluminium forming the sloping face of the container.

On reaching the inner surface of the fuselage skin, the incident shock wave energy would partially have been absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of its energy would have been transmitted, as a shock wave, through the skin and into the atmosphere [Appendix B, Figure B-25], but a significant amount of energy would have been returned as a reflected shock wave, back into the cavity between the container and the fuselage skin where Mach stem shock waves would have been formed. Evidence of rapid shattering was found in a region approximately bounded by frames 700 & 720 and stringers 38L & 40L, together with the lap joint at 39L.

The shattered fuselage skin would have taken a significant time to move, relative to the timescales associated with the primary shock wave propagation. Clear evidence of soot and small impact craters were apparent on the internal surfaces of all fragments of container and structure from the shatter zone, confirming that the this material had not had time to move before it was hit by the cloud of shrapnel, unburnt explosive residues and sooty combustion products generated at the seat of the explosion.

Following immediately behind the primary shock wave, a secondary high pressure wave - partly caused by reflections off the baggage behind the explosive material but mainly by the general pressure rise caused by the chemical conversion of solid explosive material to high temperature gas - emerged from the container. The effect of this second pressure front, which would have been more sustained and spread over a much larger area, was to cause the fuselage skin to stretch and blister outwards before bursting and petalling back in a star-burst pattern, with rapidly running tear fractures propagating away from a focus at the shatter zone. The release of stored energy as the skin ruptured, combined with the outflow of high pressure gas through the aperture, produced a characteristic curling of the skin 'petals' - even against the slipstream. For the most part, the skins which petalled back in this manner were torn from the frames and stringers, but the frames and stringers themselves were also fractured and became separated from the rest of the structure, producing a very large jagged hole some 5 feet longitudinally by 17 feet circumferentially (upwards to a region just below the window belt and downwards virtually to the centre line).

From this large jagged hole, three of the fractures continued to propagate away from the hole instead of terminating at the boundary. One fracture propagated longitudinally rearwards as far as the wing cut-out and another forwards to station 480, creating a continuous longitudinal fracture some 43 feet in length. A third fracture propagated circumferentially downwards along frame 740, under the belly, and up the right side of the fuselage almost as far as the window belt - a distance of approximately 23 feet.

These extended fractures all involved tearing or related failure modes, sometimes exploiting rivet lines and tearing from rivet hole to rivet hole, in other areas tearing along the full skin section adjacent to rivet lines, but separate from them. Although the fractures had, in part, followed lap joints, the actual failure modes indicated that the joints themselves were not inherently weak, either as design features or in respect of corrosion or the conditions of the joints on this particular aircraft.

Note: The cold bond process carried out at manufacture on the lap joints had areas of disbonding prior to the accident. This disbonding is a known feature of early Boeing 747 aircraft which, by itself, does not detract from the structural integrity of the hull. The cold bond adhesive was used to improve the distribution of shear load across the joint, thus reducing shear transfer via the fasteners and improving the resistance of the joint to fatigue damage; the fasteners were designed to carry the full static loading requirements of the joint without any contribution from the adhesive. Thus, the loss of the cold bond integrity would only have been significant if it had resulted in the growth of fatigue cracks, or corrosion induced weaknesses, which had then been exploited by the explosive forces. No evidence of fatigue cracking was found in the bonded joints. Inter-surface corrosion was present on most lap joints but only one very small region of corrosion had resulted in significant material thinning; this was remote from the critical region and had not played any part in the break-up.

The cracks propagating upwards as part of the petalling process did not extend beyond the window line. The wreckage evidence suggests that the vertical fractures merged, effectively closing off the fracture path to produce a relatively clean bounding edge to the upper section of the otherwise jagged hole produced by the petalling process. There are at least two probable reasons for this. Firstly the petalling fractures above the shattered zone did not diverge, as they had tended to do elsewhere. Instead, it appears that a large skin panel separated and peeled upwards very rapidly producing tears at each side which ran upwards following almost parallel paths. However, there are indications that by the time the fractures had run several feet, the velocity of fracture had slowed sufficiently to allow the free (forward) edge of the skin panel to overtake the fracture fronts, as it flexed upwards, and forcibly strike the fuselage skin above, producing clear witness marks on both items. Such a tearing process, in which an approximately rectangular flap of skin is pulled upwards away from the main skin panel, is likely to result in the fractures merging. Secondly, this merging tendency would have been reinforced in this particular instance by the stiff window belt ahead of the fractures, which would have tended to turn the fractures towards the horizontal.

It appears that the presence of this initial ('clean') hole, together with the stiff window belt above, encouraged other more slowly running tears to break into it, rather than propagating outwards away from the main hole.

2.12.1.2 Critical crack considerations

The three very large tears extending beyond the boundary of the petalled region resulted in a critical reduction of fuselage structural integrity.

Calculations were carried out at the Royal Aerospace Establishment to determine whether these fractures, growing outwards from the boundary of the petalled hole, could have occurred purely as a result of normal differential pressure loading of the fuselage, or whether explosive forces were required in addition to the pressurisation loads.

Preliminary calculations of critical crack dimensions for a fuselage skin punctured by a 20 by 20 inches jagged hole indicated that unstable crack growth would not have occurred unless the skin stress had been substantially greater than the stress level due to normal pressurisation loads alone. It was therefore clear that explosive overpressure must have produced the gross enlargement of the initially small shattered hole in the hull. Furthermore, it was apparent from the degree of curling and petalling of the skin panels within the star-burst region that this overpressure had been relatively long term, compared with the shock wave overpressure which had produced the shatter zone. A more refined analysis of critical crack growth parameters was therefore carried out in which it was assumed that the long term explosive overpressure was produced by the chemical conversion of solid explosive material into high temperature gas.

An outline of the fracture propagation analysis is given at Appendix D. This analysis, using theoretical fracture mechanics, showed that, after the incident shock wave had produced the shatter zone, significant explosive overpressure loads were needed to drive the star-burst fractures out to the boundary of the petalled skin zone. Thereafter, residual gas overpressure combined with fuselage pressurisation loads were sufficient to produce the two major longitudinal cracks and a single major circumferential crack, extending from the window belt down to beyond the keel centreline.

2.12.1.3 Damage to the cabin floor structure

The floor beams in the region immediately above the baggage container in which the explosive had detonated were extensively broken, displaying clear indications of overload failure due to buckling caused by localised upward loading of the floor structure.

No direct evidence of bruising was found on the top panel of the container. It therefore appears that the container did not itself impact the floor beams, but instead the floor immediately above the container was broken through as a result of explosive overpressure as gases emerged from the ruptured container and loaded the floor panels. Data on floor strengths, provided by Boeing, indicated that the cabin floor (with the CRAF modification) would fail at a uniform static differential pressure of between 3.5 and 3.9 psi (high pressure below the cabin floor), and that the floor panel to floor beam attachments would not fail before the floor beams. Whilst there is no direct evidence of the pressure loading on the floor structure immediately following detonation, there can be no doubt that in the region of station 700 it would have exceeded the ultimate failure load by a large margin.

2.12.2 Indirect explosive damage (damage at remote sites)

All of the damage considered in the foregoing analysis, and the mechanisms giving rise to that damage, resulted from the direct impact of explosive shock waves and/or the short-term explosive overpressure on structure close to the source of the explosion. However, there were several regions of skin separation at sites remote from the explosion (see para 1.12.3.2) which were much more difficult to understand. These remote sites formed islands of indirect explosive damage separated from the direct damage by a sea of more generalised structural failure characterised by the progressive aerodynamic break-up of the weakened forward fuselage. All of these remote damage sites were consistent with the impact of very localised pressure impulses on the internal surfaces of the hull -effectively high energy 'pressure blows' against the inner surfaces produced by explosive shock waves and/or high pressure gas flows travelling through the interior spaces of the hull.

The propagation of explosive shock waves and supersonic gas flows within multiple, interlinking, cavities having indeterminate energy absorption and reflection properties, and ill-defined structural response, is extremely complex. Work has been initiated in an attempt to produce a three-dimensional computer analysis of the shock wave and supersonic flow propagation inside the fuselage, but full theoretical analysis is beyond present resources.

Because of the complexity of the problem, the following analysis will be restricted to a qualitative consideration of the processes which were likely to have taken place. Whilst such an approach is necessarily limited, it has identified a number of propagation mechanisms which appear to have been of fundamental importance to the break-up of Flight PA103, and which are likely to be critical in any future incident involving the detonation of high explosive inside an aircraft hull.

2.12.2.1 Shock wave propagation through internal cavities

When Mach stem shocks are produced not only are the shock pressures very high but they propagate at very high velocity parallel to the reflecting surface. In the context of the lower fuselage structure in the region of Mach stem formation, it can readily be seen that the Mach stem will be perfectly orientated to enter the narrow cavity formed between the outer skin and the cargo liner/containers, bounded by the fuselage frames [Appendix B, Figure B-25]. This cavity enables the Mach stem shock wave to propagate, without causing damage to the walls (due to the relatively low pressure where the Mach stem sweeps their surface), and reach regions of the fuselage remote from the source of the explosion. Furthermore, energy losses in the cavity are likely to be less than would occur in the 'free' propagation case, resulting in the efficient transmission of explosive energy. The cavity would tend to act like a 'shock tube', used for high speed aerodynamic research, confining the shock wave and keeping it running along the cavity axis, with losses being limited to kinetic heating due to friction at the walls.

Paragraph 1.6.3 contains a general description of the structural arrangements in the area of the cargo hold. Before proceeding further and considering how the shock waves might have propagated through this network of cavities, it should be pointed out that the timescale associated with the propagation of the shock waves is very short compared with the timescale associated with physical movement and separation of skin and structure fractured or damaged by the shock. Therefore, for the purpose of assessing the shock propagation through the cavities, the explosive damage to the hull can be ignored and the structure regarded as being intact. A further simplification can usefully be made by considering the structure to be rigid. This assumption would, if the analysis were quantitative, result in over-estimations of the shock strengths. However, for the purposes of a purely qualitative assessment, the assumption should be valid, in that the general trends of behaviour should not be materially altered.

It has already been argued that the shock wave emerging from the container was, in part, reflected back off the inner surface of the fuselage skin, forming a Mach stem shock wave which would then have tended to travel into the semi-circular lower lobe cavity. The Mach stem waves would have propagated away through this cavity in two directions:

(i) under the belly, between the frames [Appendix B, Figure B-3, detail A], and
(ii) up the left side, expanding into the cavity formed by the longitudinal

manifold chamber where it joins the lower lobe cavity.
As the shock waves travelled along the cavity, little attenuation or other change of characteristic was likely to have occurred until the shocks passed the entrances to other cavities, or impinged upon projections and other local changes in the cavity. A review of the literature dealing with propagation of blast waves within such cavities provides useful insights into some of the physical mechanisms involved.

As part of a research program carried out into the design of ventilation systems for blast hardened installations intended to survive the long duration blast waves following the detonation of nuclear weapons, the propagation of blast waves along the primary passages and into the side branches of ventilation ducts was studied. The research showed that 90¡ bends in the ducts produced very little attenuation of shock wave pressure; a series of six right angle bends produced only a 30% pressure attenuation, together with an extension of the shock duration. It is therefore evident that the attenuation of shock waves propagating through the fuselage cavities, all of which were short with hardly any right angle turns, would have been minimal.

It was also demonstrated that secondary shock waves develop within the entrance to any side branch from the main duct, produced by the interaction of the primary shock wave with the geometric changes in the duct walls at the side-branch location. These secondary shock waves interact as they propagate into the side branch, combining together within a relatively short distance (typically 7 diameters) to produce a single, plane shock wave travelling along the duct axis. In a rigid, smooth walled structure, this mechanism produces secondary shock overpressures in the side branch of between 30% and 50% of the value of the primary shock, together with a corresponding attenuation of the primary shock wave pressure by approximately 20% to 25%.

This potential for the splitting up and re-transmission of shock wave energy within the lower hull cavities is of extreme importance in the context of this accident. Though the precise form of the interactions is too complex to predict quantitatively, it is evident that the lower hull cavities will serve to convey the overpressure efficiently to other parts of the aircraft. Furthermore, the cavities are not of serial form, i.e. they do not simply branch (and branch again) in a divergent manner, but instead form a parallel network of short cavities which reconnect with each other at many different points, principally along the crease beams. Thus, considerable scope exists for: the additive recombination of blast waves at cavity junctions; for the sustaining of the shock overpressure over a greater time period; and, for the generation of multiple shocks produced by the delay in shock propagation inherent in the different shock path (i.e.

cavity) lengths.

Whilst it has not been possible to find a specific mechanism to explain the regions of localised skin separation and peel-back (i.e. the 'pressure blow' regions referred to in para 2.12.2), they were almost certainly the result of high intensity shock overpressures produced locally in those regions as a result of the additive recombination of shock waves transmitted through the lower hull cavities. It is considered that the relatively close proximity of the left side region of damage just below floor level at station 500, [Appendix B, Figure B-19, region D] to the forward end of the cargo hold may be significant insofar as the reflections back from the forward end of the hold would have produced a local enhancement of the shock overpressure. Similarly, 'end blockage effects' produced by the cargo door frame might have been responsible for local enhancements in the area of the belly skin separation and curl-back at station 560 [Appendix B, Figure B-19 and B-20, region E].

The separation of the large section of upper fuselage skin [Appendix B, Figure B-19 and B-20, detail B] was almost certainly associated with a local overpressure in the side cavities between the main deck window line and the upper deck floor, where the cavity is effectively closed off. It is considered that the most probable mechanism producing this region of impulse overpressure was a reflection from the closed end of the cavity, possibly combined with further secondary reflections from the window assembly, the whole being driven by reflective overpressures at the forward end of the longitudinal manifold cavity caused by the forward end of the cargo hold. The local overpressure inside the sidewall cavity would have been backed up by a general cabin overpressure resulting from the floor breakthrough, giving rise to an increased pressure acting on the inner face of the cabin side liner panels. This would have provided pseudo mass to the panels, effectively preventing them from moving inwards and allowing them to react the impulse pressure within the cavity, producing the region of local high pressure evidenced by the region of quilting on the skin panels [Appendix B, Figure B-19, region C].

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2.12.2.2 Propagation of shock waves into the cabin

The design of the air-conditioning/depressurisation-venting systems on the Boeing 747 (and on most other commercial aircraft) is seen as a significant factor in the transmission of explosive energy, as it provides a direct connection between the main passenger cabin and the lower hull at the confluence of the lower hull cavities below the crease beam. The floor level air conditioning vents along the length of the cabin provided a series of apertures through which explosive shock waves, propagating through the sub floor cavities, would have radiated into the main cabin.

Once the shock waves entered the cabin space, the form of propagation would have been significantly different from that which occurred in the cavities in the lower hull. Again, the precise form of such radiation cannot be predicted, but it is clear that the energy would potentially have been high and there would also (potentially) have been a large number of shock waves radiating into the cabin, both from individual vents and in total, with further potential to recombine additively or to 'follow one another up' producing, in effect, sustained shock overpressures.

Within the cabin, the presence of hard, reflective, surfaces are likely to have been significant. Again, the precise way in which the shock waves interacted is vastly beyond the scope of current analytical methods and computing power, but there clearly was considerable potential for additive recombination of the many different shock waves entering at different points along the cabin and the reflected shock waves off hard surfaces in the cabin space, such as the toilet and galley compartments and overhead lockers. These recombination effects, though not understood, are known phenomena. Appendix B, Figure B-26 shows how shock waves radiating from floor level might have been reflected in such a way as produce shock loading on a localised area of the pressure hull.

2.12.2.3 Supersonic gas flows

The gas produced by the explosive would have resulted in a supersonic flow of very high pressure gas through the structural cavities, which would have followed up closely behind the shock waves. Whilst the physical mechanisms of propagation would have been different from those of the shock wave, the end result would have been similar, i.e. there would have been propagation via multiple, linked paths, with potential for additive recombination and successive pressure pulses resulting from differing path lengths. Essentially, the shock waves are likely to have delivered initial 'pressure blows' which would then have been followed up immediately by more sustained pressures resulting from the high pressure supersonic gas flows.

2.13 Potential limitation of explosive damage

Quite clearly the detonation of high explosive material anywhere on board an aircraft is potentially catastrophic and the most effective means of protecting lives is to stop such material entering the aircraft in the first place. However, it is recognised that such risks cannot be eliminated entirely and it is therefore essential that means are sought to reduce the vulnerability of commercial aircraft structures to explosive damage.

The processes which take place when an explosive detonates inside an aircraft fuselage are complex and, to a large extent, fickle in terms of the precise manner in which the processes occur. Furthermore, the potential variation in charge size, position within the hull, and the nature of the materials in the immediate vicinity of the charge (baggage etc) are such that it would be unrealistic to expect to neutralise successfully the effect of every potential explosive device likely to be placed on board an aircraft. However, whilst the problem is intractable so far as a total solution is concerned, it should be possible to limit the damage caused by an explosive device inside a baggage container on a Boeing 747 or similar aircraft to a degree which would allow the aircraft to land successfully, albeit with severe local damage and perhaps resulting in some loss of life or injuries.

In Appendix E the problem of reducing the vulnerability of commercial aircraft to explosive damage is discussed, both in general terms and in the context of aircraft of similar size and form to the Boeing 747. In that discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution.

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2.14 Summary

It was established that the detonation of an IED, loaded in a luggage container positioned on the left side of the forward cargo hold, directly caused the loss of the aircraft. The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential. The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion. The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage, allow the nose and flight deck area to detach within a period of 2 to 3 seconds, and subsequently allow most of the remaining aircraft to disintegrate while it was descending nearly vertically from 19,000 to 9,000 feet.

The investigation has enabled a better understanding to be gained of the explosive processes involved in such an event and to suggest ways in which the effects of such an explosion might be mitigated, both by changes to future design and also by retrospective modification of aircraft. It is therefore recommended that Regulatory Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of the aircraft structure and systems to explosive damage.

3. CONCLUSIONS

(a) Findings

(i) The crew were properly licenced and medically fit to conduct the flight.

(ii) The aircraft had a valid Certificate of Airworthiness and had been maintained in compliance with the regulations.

(iii) There was no evidence of any defect or malfunction in the aircraft that could have caused or contributed to the accident.

(iv) The structure was in good condition and the minimal areas of corrosion did not contribute to the in-flight disintegration.

(v) One minor fatigue crack approximately 3 inches long was found in the fuselage skin but this had not been exploited during the disintegration.

(vi) An improvised explosive device detonated in luggage container serial number AVE 4041 PA which had been loaded at position 14L in the forward hold. This placed the device approximately 25 inches inboard from the skin on the lower left side of the fuselage at station 700.

(vii) The analysis of the flight recorders, using currently accepted techniques, did not reveal positive evidence of an explosive event.

(viii) The direct explosive forces produced a large hole in the fuselage structure and disrupted the main cabin floor. Major cracks continued to propagate from the large hole under the influence of the service pressure differential.

(ix) The indirect explosive effects produced significant structural damage in areas remote from the site of the explosion.

(x) The combined effect of the direct and indirect explosive forces was to destroy the structural integrity of the forward fuselage.

(xi) Containers and items of cargo ejected from the fuselage aperture in the forward hold, together with pieces of detached structure, collided with the empennage severing most of the left tailplane, disrupting the outer half of the right tailplane, and damaging the fin leading edge structure.
(xii) The forward fuselage and flight deck area separated from the remaining structure within a period of 2 to 3 seconds.
(xiii) The No 3 engine detached when it was hit by the separating forward fuselage.
(xiv) Most of the remaining aircraft disintegrated while it was descending nearly vertically from 19,000 to 9,000 feet.
(xv) The wing impacted in the town of Lockerbie producing a large crater and creating a fireball.

(b) Cause

The in-flight disintegration of the aircraft was caused by the detonation of an improvised explosive device located in a baggage container positioned on the left side of the forward cargo hold at aircraft station 700.

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4. SAFETY RECOMMENDATIONS

The following Safety Recommendations were made during the course of the investigation :

4.1 That manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and the data recoverable after power loss.
4.2 That Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.
4.3 That Airworthiness Authorities consider requiring the CVR system to contain a short duration, i.e. no greater than 1 minute, back-up power supply to enable the CVR to respond to events that result in the almost immediate loss of the aircraft's electrical power supply.
4.4 That the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.
4.5 That Airworthiness Authorities and aircraft manufacturers undertake a systematic study with a view to identifying measures that might mitigate the effects of explosive devices and improve the tolerance of aircraft structure and

systems to explosive damage.

M M Charles
Inspector of Accidents
Department of Transport

July 1990
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APPENDIX A

PERSONNEL CONDUCTING THE INVESTIGATION

The following Inspectors of the Air Accidents Investigation Branch conducted the investigation:

Mr M M Charles	Investigator-in-Charge
Mr D F King	Principal Inspector (Engineering)
Mr P F Sheppard	Assistant Principal Inspector (Engineering)
Mr A N Cable	Senior Inspector (Engineering)
Mr R G Carter	Senior Inspector (Engineering)
Mr P T Claiden	Senior Inspector (Engineering)
Mr P R Coombs	Senior Inspector (Engineering)
Mr S R Culling	Senior Inspector (Engineering)
Miss A Evans	Senior Inspector (Engineering)
Mr B M E Forward	Senior Inspector (Operations)
Mr P N Giles	Senior Inspector (Operations)
Mr S W Moss	Senior Inspector (Engineering)
Mr R Parkinson	Senior Inspector (Engineering)

Mr J D Payling	Senior Inspector (Operations)
Mr C G Pollard	Senior Inspector (Engineering)
Mr C A Protheroe	Senior Inspector (Engineering)
Mr A H Robinson	Senior Inspector (Engineering)
Mr A P Simmons	Senior Inspector (Engineering)
Mr R G Vance	Senior Inspector (Engineering)
Mr R StJ Whidborne	Senior Inspector (Operations)

The Air Accidents Investigation Branch would like to thank the following organisations from the United Kingdom, United States of America, France, and Canada who participated in the investigation:

Air Line Pilot's Association International

Boeing Commercial Airplane Company

British Airways

British Army

British Geological Survey

Bureau Enquete Accidents

Canadian Aviation Safety Bureau

Civil Aviation Authority

Cranfield Institute of Technology

Federal Aviation Administration

Federal Bureau of Investigation

Independent Union of Flight Attendants

National Transportation Safety Board

Pan American World Airways

Police Service

Royal Aerospace Establishment

Royal Air Force

Royal Armaments Research and Development Establishment

Royal Navy

Royal Ordnance

Royal Signals and Radar Establishment

United Technologies International Operations (Pratt and Whitney)

The Air Accidents Investigation Branch would also like to acknowledge the excellent work of the Dumfries & Galloway Regional Council and to thank all the many voluntary organisations who gave such unstinting support to the investigation.

APPENDIX C

ANALYSIS OF RECORDED DATA

1. Introduction

This appendix describes and analyses the different types of recorded data which were examined during the investigation of the accident to Boeing 747 registration N739PA at Lockerbie on 21 December 1988.
The recorded data consists of that from the Cockpit Voice Recorder (CVR), the Digital Flight Data Recorder (DFDR), Air Traffic Control (ATC) radio telephony (RTF), ATC radar, and British Geological Survey seismic records. The time correlation of the records is also discussed.

2. Digital flight data recorder

The flight data recorder installation conformed to ARINC 573B standard with a Lockheed Model 209 DFDR receiving data from a Teledyne Controls Flight Data Acquisition Unit (FDAU). The system recorded 22 analogue parameters and 27 discrete (event) parameters. The flight recorder control panel was located in the flight deck overhead panel. The FDAU was in the main equipment centre at the front end of the forward hold and the flight recorder was mounted in the aft equipment centre.

2.1 DFDR strip and examination

Internal inspection of the DFDR showed that there was considerable disruption to the control electronics circuits. The crash protection was removed and the plastic recording tape was found detached from its various guide rollers and tangled in the tape spools. There was no tension in the negator springs. This indicated that the tape had probably moved since electrical power was removed from the recorder. The position of the tape in relation to the record/replay heads was marked with a piece of splicing tape in order to quantify the movement. To ensure that no additional damage was caused to the tape it was necessary to cut the negator springs to separate the upper and lower tape reels.

The crinkling and stretching of the tape and the damage to the control electronics meant that the tape had to be replayed outside the recorder. AAIB experience has shown that the most efficient method of replaying stretched Lockheed recorder tapes is to re-spool the tape into a known serviceable recorder, in this case a Plessey 1584G.

2.2 DFDR replay

The 25 hour duration of the DFDR was satisfactorily replayed. Data relating to the accident flight was recorded on track 2. The only significant defect in the recording system was that normal acceleration was inoperative. There was one area on the tape, 2 minutes from the end, where data synchronisation was lost for 1 second.

Decoding and reduction of the data from the accident flight showed that no abnormal behaviour of the data sensors had been recorded. The recorded data simply stopped. Figure C-1 is a graphical representation of the main flight parameters.

2.3 DFDR analysis

In order to ensure that all recorded data from the accident flight had been decoded and to examine the quality of the data at the end of the recording, a section of tape, including both the most recently recorded data and the oldest data (data from 25 hours past), was replayed through an ultra-violet (UV) strip recorder. The data was also digitised and the resulting samples used to reconstruct the tape signal on a VDU.

Both methods of signal representation were used to determine the manner by which the recorder stopped. There was no gap between the most recently recorded data and the 25 hour old data. This showed that the recorder stopped while there was an incoming data stream from the FDAU. The recorder, therefore, stopped because its electrical supply was disconnected. The tape signal was examined for any transients or noise signals that would have indicated the presence of electrical disturbances prior to the recorder stopping. None was found and this indicated that there had been a quick clean break of the electrical supply.

The last seconds of data were decoded independently using both the UV record and the digitised signal. Only 17 bits of data were not recoverable (less that 23 milliseconds) and it was not possible to establish with any certainty if this data was from the accident flight or if it was old data from a previous recording.

A working group of the European Organisation for Civil Aviation Electronics (EUROCAE) was, during the period of the investigation, formulating new standards (Minimum Operational Performance Requirement for Flight Data Recorder Systems, Ref:- ED55) for future generation flight recorders which would have permitted delays between parameter input and recording (buffering) of up to ? second.
These standards are intended to form the basis of new CAA specifications for flight recorders and may be adopted worldwide.

The analysis of the final data recorded on the DFDR was possible because the system did not buffer the incoming data. Some existing recorders use a process whereby data is stored temporarily in a memory device (buffer) before recording. The data within this buffer is lost when power is removed from the recorder and in currently designed recorders this may mean that up to 1.2 seconds of final data contained within the buffer is lost. Due to the necessary processing of the signals prior to input to the recorder, additional delays of up to 300 milliseconds may be introduced. If the accident had occurred when tha aircraft was over the sea, it is very probable that the relatively few small items of structure, luggage and clothing showing positive evidence of the detonation of an explosive device would not have been recovered. However, as flight recorders are fitted with underwater location beacons, there is a high probability that they would have been located and recovered. In such an event the final milliseconds of data contained on the DFDR could be vital to the successful determination of the cause of an accident whether due to an explosive device or other catastrophic failure. Whilst it may not be possible to reduce some of the delays external to the recorder, it is possible to reduce any data loss due to buffering of data within the data acquisition unit.

It is, therefore, recommended that manufacturers of existing recorders which use buffering techniques give consideration to making the buffers non-volatile, and hence recoverable after power loss. Although the recommendation on this aspect, made to the EUROCAE working group during the investigation, was incorporated into ED55, it is also recommended that Airworthiness Authorities re-consider the concept of allowing buffered data to be stored in a volatile memory.

3. Cockpit voice recorder (CVR)

The aircraft was equipped with a 30 minute duration 4 track Fairchild Model A100 CVR, and a Fairchild model A152 cockpit area microphone (CAM). The CVR control panel containing the CAM was located in the overhead panel on the flight deck and the recorder itself was mounted in the aft equipment centre.

The channel allocation was as follows:-

Channel 1	Flight Engineer's RTF.
Channel 2	Co-Pilot's RTF.
Channel 3	Pilot's RTF.
Channel 4	Cockpit Area Microphone.

3.1 CVR strip and examination

To gain access to the recording tape it was necessary to cut away the the outer case and saw through part of the crash protected enclosure. No damage to the tape transport or the recording tape was found. The endless loop of tape was cut and the tape transferred to the replay equipment. The electronic modules in the CVR were crushed and there was evidence of long term overheating of the dropper resistors on the power supply module. The CAM had been crushed breaking internal wiring and damaging components on the printed circuit board.

3.2 CVR replay

The erase facility within the CVR was not functioning satisfactorily and low level communications from earlier recordings was audible on the RTF channels. The CAM channel was particularly noisy, this was probably due to the combination of the inherently noisy cockpit of the B747-100 in the climb and distortion from the incomplete erasure of the previous recordings. On two occasions the crew had difficulty understanding ATC, possibly indicating high cockpit noise levels. There was a low frequency sound present at irregular intervals on the CAM track but the source of this sound could not be identified as of either acoustic or electrical in origin.

The CVR tape was listened to for its full duration and there was no indication of anything abnormal with the aircraft, or unusual in crew behaviour. The tape record ended with a sudden loud sound on the CAM channel followed almost immediately by the cessation of recording. The sound occurred whilst the crew were copying their transatlantic clearance from Shanwick ATC.

3.3 Analysis of the CVR record

3.3.1 The stopping of the recorder

To determine the mechanism that stopped the recorder a bench test rig was constructed utilizing an A100 CVR and an A152 CAM. Figures C-2 to C-5 show the effect of shorting, earthing or disconnecting the CAM signal wires. Figure C-8 shows the CAM channel signal response to the event which occurred on Flight PA103. From this it can be seen that there are no characteristic transients similar to those caused by shorting or earthing the CAM signal wires. Neither does the signal stop cleanly and quickly as shown in Figure C-5, indicating that the CAM signal wires were not interrupted. The UV trace shows the recorded signal decaying in a manner similar to that shown in Figure C-6, which demonstrates the effect of disconnecting electrical power from the recorder. The tests were repeated on other CVRs with similar results and it is therefore concluded that Flight PA103's CVR stopped because its electrical power was removed.

Figures C-9A to C-9D show the recorded signals for the Air India B747 (AI 182) accident in the North Atlantic on 23 June 1985. These show that there is a large transient on the CAM track indicating earthing or shorting of the CAM signal wires and that recorder power-down is more prolonged, indicating attempts to restore the electrical power supply either by bus switching or healing of the fault. The Flight PA103 CVR shows no attempts at power restoration with the break being clean and final.

In order to respond to events that result in the almost immediate loss of the aircraft's electrical power supply it was therefore recommended during the investigation that the regulatory authorities consider requiring CVR systems to contain a short duration (i.e. no greater than 1 minute) back-up power supply.

3.3.2 Information concerning the event

Figure C-8 is an expanded UV trace of the final milliseconds of the CVR record. Three tracks have been used, the flight engineer's RTF channel which contained similar information to the P2's channel has been replaced with a timing signal. Individual sections of interest are identified by number. On the bottom trace, the P1 RTF track, section 1 is part of the Shanwick transatlantic clearance. During this section the loud sound on the CAM channel is evident.

Examination of the DFDR event recordings shows that the Shanwick oceanic clearance was being received on VHF2, the aerial for which is on the underside of the fuselage close to the seat of the explosion.
Section 2 identifies a transient, on the P1 channel, typical of an end of ATC transmission transient for this CVR. The start and finish of most of the recorded ATC transmissions were analysed and they produce a similar signature to the three shown in Figure C-10. The signature

on the P1 channel more closely resembles the end of transmission signature and it is open to conjecture that this transient was caused by the explosion damaging the aerial feeder and/or its supporting structure.

Section 3 shows what is considered to be a high speed power supply transient which is evident on all the RTF channels and is probably on the CAM channel, but cannot be identified because of the automatic gain control (AGC), limiting the audio event. This transient is considered to coincide with the loss of electrical power to the CVR. Section 5 identifies the period to the end of recording and this agrees well with tests carried out by AAIB and independently by Fairchild as part of the AI 182 investigation. The typical time from removal of the electrical supply until end of recording is 110 milliseconds.

During the period identified as section 4 it is considered that the disturbances on the RTF channels are electrical transients probably channelled through the communications equipment. Section 6 identifies the 170 millisecond period from the point when the sound was first heard on the CAM until the recording stopped.

The CAM unit is of the old type which has a frequency response of 350 to 3500 Hz. The useable duration of the signal is probably confined to the first 60 milliseconds of the final 170 milliseconds and even during this period the AGC is limiting the signal. In the remaining time the sound is being distorted because power to the recorder has been disconnected. The ambient cockpit noise may have been high enough to have caused the AGC to have been active prior to the event and in this event the full volume of the sound would not be audible. Distortion from the incomplete erasure of the last recording may form part of the recorded signal.

It is not clear if the recorded sound is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case.

Additionally some of the frequencies present on the recording were not present in the original sound, but are the result of the rise in total harmonic distortion caused by the increased amplitude of the incoming signal. Outputs from a frequency analysis of the recorded signal for the same frequency of input to the CVR, but at two input amplitudes, are shown in

Figures C-11 and C-12. These illustrate the effects on harmonic distortion as the signal level is increased. Finally the recorded signal does not lend itself to analysis by a digital spectrum analyser as it is, in a large measure, aperiodic and most digital signal analysis algorithms are unable to deal with a short duration signal of this type, however, it is hoped that techniques being developed in Canada will enable more information to be deduced from the end of the recording.

In the aftermath of the Air India Boeing 747 accident (AI 182) in the North Atlantic on 23 June 1985 the Royal Armaments Research and Development Establishment (RARDE) were asked informally by AAIB to examine means of differentiating, by recording violent cabin pressure pulses, between the detonation of an explosive device within the cabin (positive pulse) and a catastrophic structural failure (negative pulse). Following the Lockerbie disaster it was considered that this work should be raised to a formal research project. Therefore, in February 1989, it was recommended that the Department of Transport fund a study to devise methods of recording violent positive and negative pressure pulses, preferably utilising the aircraft's flight recorder systems.

Preliminary results from these trials indicates that if a suitable sensor can be developed its output will need to be recorded in real time and therefore it may require wiring into the CVR installation. This will further strengthen the requirement for battery back up of the CVR electrical power supply.

4. Flight recorder electrical system

4.1 CVR/DFDR electrical wiring.

The flight recorders were located in the left rear fuselage just forward of the rear pressure bulkhead. Audio information to the CVR ran along the left hand side of the aircraft, at stringer 11. Electrical power to the CVR followed a similar route on the right hand side of the aircraft crossing to the left side above the rear passenger toilets. DFDR electrical power and signal information followed the same route as the CVR audio information.

4.2 Flight recorder power supply

The DFDR, CVR and the transponders were all powered from the essential alternating current (AC) bus. This bus was capable of being powered by any generator, however, in normal operation the selector switch on the flight engineers panel is selected to "normal" connecting the essential bus to number 4 generator. When the cockpit of Flight PA103 was examined the selector switch was found in the normal position.

4.3 Aircraft alternating current power supplies

AC electrical power to the aircraft was provided by 4 engine driven generators, see Figure C-13. Each generator was driven at constant speed through a constant speed drive (CSD) and connected to a separate bus-bar through a generator control breaker (GCB). The 4 generators were connected to a parallel bus-bar (sync bus) by individual bus tie breakers (BTBs). Control and monitoring of the AC electrical system was achieved through the flight engineer's instrument panel. In normal operation the generators operated in parallel, i.e with the BTBs closed.

4.4 Fault conditions

Analysis of the CVR CAM channel signal indicated that approximately 60 milliseconds after the sound on the CAM channel an electrical transient was recorded on all 4 channels and that approximately 110 milliseconds later the CVR had ceased recording. Within the accuracy of the available timing information it is believed that the incoming VHF was lost at the same time, indicating an AC power supply fault.

The AC electrical system was protected from faults in individual systems or equipment by fuses or circuit breakers. Faults in the generators or in the distribution bus-bars and feeders were dealt with automatically by opening of the GCBs and opening or closing of the BTBs. In the event of fault conditions causing the disconnection of all 4 generators electrical power for essential services, including VHF radio, was provided by a battery located in the cockpit.

The short time interval of 55 milliseconds after which the AC supply to the flight recorders was lost limits the basis on which a fault path analysis of the AC electrical system can be undertaken. On the available information only a differential (feeder) fault could have isolated the bus-bar this quickly, with the generator field control relay taking 20 milliseconds to trip. However, in normal operation, the generators would have been operating in parallel and the essential AC bus-bar would have been supplied via the number 4 BTB from the sync bus. If the fault conditions had continued, a further 40 to 100 milliseconds would have elapsed before the BTB opened. If the BTB was open prior to the fault it would have attempted to close and restore the supply to the essential bus. Any automatic switching causes electrical transients to appear on the CVR and data losses on the FDR. Both the CVR and the FDR indicate that a clean break of the AC supply occurred with no electrical transients associated with BTBs open or closing in an attempt to restore power. In the absence of any additional information only two possibilities are apparent:

i) That all 4 generators were simultaneously affected causing a total loss of AC electrical power. The feeders for the left and right side generators run on opposite sides of the aircraft under the passenger cabin floor. The only situation envisaged that could cause simultaneous loss of all 4 generators is the disruption of the passenger cabin floor across its entire width.

ii) That disruption of the main equipment centre, housing the control units for the AC electrical system, caused the loss of all AC power. However, again it would have to affect both the left and right sides of the aircraft as the control equipment is located at left and right extremes of the main equipment centre.

The nature of the event may also produce effects that are not understood. It is also to be noted that a sudden loss of electrical power to the flight recorders has been reported in other B747 accidents, e.g. Air India, AI 182.

5. Seismic data

The British Geological Survey has a number of seismic monitoring stations in Southern Scotland. Stations close to Lockerbie recorded a seismic event caused by the wing section crashing on Lockerbie. The seismic monitors are time correlated with the British Telecom Rugby standard. Using this and calculating the time for the various waves to reach the recording stations it was possible for the British Geological Survey to conclude that the event occurred at 19.03:36.5 hrs ± 1 second.

Attempts were made to correlate various smaller seismic events with other wreckage impacts. However, this was not conclusive because the nearest recording station was above ground and due to the high winds at the time of the accident had considerable noise on the trace. In addition, little of the other wreckage had the mass or impact velocity to stimulate the sensors.

6. Time correlation

6.1 Introduction

The sources of each time encoded recording were asked to provide details of their time standard and any known errors in the timings on their recordings. Although the resolution of the recorded time sources is high it was not possible to attach an accuracy of better than ±1 second due to possible errors in synchronising the recorded time with the associated standard. The following time sources were available and used in determining the significant events in the investigation:-

i) ATC

ATC communications were recorded along with a time signal. The time source for the ATC tape was the British Telecom "Tim" signal. Any error in setting the time when individual tapes are mounted was logged.

ii) Recorded rada data

A time signal derived from the British Telecom "Rugby" standard was included on radar recordings. The Rugby and Tim times were assumed to be of equal accuracy for timing purposes.

iii) The DFDR had UTC recorded.

The source of this time was the flight engineer's clock. This clock was set manually and therefore this time was subject to a significant fixed error as well any inaccuracy in the clock.

iv) The CVR had no time signal.

However, the CVR was correlated with the ATC time through the RTF and with the DFDR, by correlating the press to talk events on the FDR with the press to talk signature on the CVR.

v) Seismic recordings

Seismic recordings included a timing signal derived from the British Telecom Rugby standard.

6.2 Analysis and correlation of times

The Scottish and Shanwick ATC tapes were matched with each other and with the CVR tape. The CVR recording speed was adjusted by peaking its recorded 400 Hz AC power source frequency. This correlation served as a double check on any fixed errors on the ATC recordings and to fix events on the CVR to UTC. The timing of the sound on the CAM channel of the CVR was made simpler because Shanwick was transmitting when it occurred. From this it was possible to determine that the sound on the CVR occurred at 19.02:50 hrs ±1 second.

With the CVR now tied to the Tim standard it was possible to match the RTF keying on the CVR with the RTF keying events on the FDR. These events on the FDR were sampled and recorded once per second, it was therefore possible for a 1 second delay to be present on the FDR. This potential error was reduced by obtaining the best fit between a number of RTF keyings and a time correlation between the FDR and CVR of ±? second was achieved. From this it was determined, within this accuracy, that electrical power was removed from the CVR and FDR at the same time.

From the recorded radar data it was possible to determine that the last recorded SSR return was at 19.02:46.9 hrs and that by the next rotation of the radar head a number of primary returns, some left and right of track, were evident. Time intervals between successive rotations of the radar head became more difficult to use as the head painted more primary returns.

The point at which aircraft wreckage impacted Lockerbie was determined using the time recorded by seismic activity detectors. A seismic event measuring 1.6 on the Richter scale was detected and, with appropriate time corrections for times of the waves to reach the sensors, it was established that this occurred at 19.03:36.5 hrs ±1 second. A further check was made by triangulation techniques from the information recorded by the various sensors.

7. Recorded radar information

7.1 Introduction

Recorded radar information on the aircraft was available from from 4 radar sites. Initial analysis consisted of viewing the recorded information as it was shown to the controller on the radar screen, from this it was clear that the flight had progressed in a normal manner until Secondary Surveillance Radar (SSR) was lost. There was a single primary return received by both Great Dun Fell and Claxby radars approximately 16 seconds before SSR returns were lost. The Lowther Hill and St. Annes radars did not see this return. The Great Dun Fell radar recording was watched for 1 hour both before and after this single return for any signs of other spurious returns, but none was seen. The return was only present for one paint and no explanation can be offered for its presence.

7.2 Limitations of recorded radar data

Before evaluating the recorded radar data it is important to highlight limitations in radar performance that must be taken into account when interpreting primary radar data. The radar system used for both primary and secondary radar utilised a rotating radar transmitter/receiver (Head). This means that a return was only visible whilst the radar head was pointing at the target, commonly called painting or illuminating the target. In the case of this accident the rotational speeds of the radar heads varied from approximately 10 seconds for the Lowther Hill Radar to 8 Seconds for the Great Dun Fell Radar.

Whilst it was possible to obtain accurate positional information within a resolution of 0.09¡ of bearing and ± 1/16 nautical mile range for an aircraft from SSR, incorporating mode C height encoding, primary radar provided only slant range and bearing and therefore positional information with respect to the ground was not accurate.

The structural break-up of an aircraft releases many items which were excellent radar reflectors eg. aluminium cladding, luggage containers, sections of skin and aircraft structure. These and other debris with reflective properties produce "clutter" on the radar by confusing the radar electronics in a manner similar to chaff ejected by military aircraft to avoid radar detection.

Even when the target is not masked by clutter repetitive detection of individual targets may not be possible because detection is a function of the target effective area which, for wreckage with its irregular shape, is not constant but fluctuates wildly. These factors make it impossible to follow individual returns through successive sweeps of the radar head.

7.3 Analysis of the radar data

The detailed analysis of the radar information concentrated on the break-up of the aircraft. The Royal Signals and Radar Establishment (RSRE) corrected the radar returns for fixed errors and converted the SSR returns to latitude and longitude so that an accurate time and position for the aircraft could be determined. This information was correlated with the CVR and ATC times to establish a time and position for the aircraft at the initial disintegration.

For the purposes of this analysis the data from Great Dun Fell Radar has been presented. Figures C-14 to C-23 show a mosaic picture of the radar data i.e. each figure contains the information on the preceding figure together with more recently recorded information. Figure C-14 shows the radar returns from an aircraft tracking 321¡(Grid) with a calculated ground speed of 434 kts. Reading along track (towards the top left of Figure C-14) there are 6 SSR returns with the sixth and final SSR return shown decoded: squawk code 0357 (identifying the aircraft as N739PA); mode C indicating FL310; and the time in seconds (68566.9 seconds from 00:00, i.e. 19.02:46.9 hrs).

At the next radar return there is no SSR data, only 4 primary returns. One return is along track close to the expected position of the aircraft if it had continued at its previous speed and heading. There are 2 returns to the left of track and 1 to the right of track. Remembering the point made earlier about clutter, it is unlikely that each of these returns are real targets. It can, however, be concluded that the aircraft is no longer a single return and, considering the approximately 1 nautical mile spread of returns across track, that items have been ejected at high speed probably to both right and left of the aircraft. Figure C-15 shows the situation after the next head rotation. There is still a return along track but it has either slowed down or the slant range has decreased due to a loss of altitude.

Each rotation of the radar head thereafter shows the number of returns increasing with those first identified across track in Figure C-14 having slowed down very quickly and followed a track along the prevailing wind line. Figure C-20 shows clearly that there has been a further break-up of the aircraft and subsequent plots show a rapidly increasing number of returns, some following the wind direction and forming a wreckage trail parallel to and north of the original break-up debris. Additionally it is possible that there was some break-up between these points with a short trail being formed between the north and south trails. From the absence of any returns travelling along track it can be concluded that the main wreckage was travelling almost vertically downwards for much of the time.

The geographical position of the final secondary return at 19.02:46.9 hrs was calculated by RSRE to be OS Grid Reference 15257772, annotated Point A in Appendix B, Figure B-4, with an accuracy considered to be better than ±300 metres This return was received 3.1±1 seconds before the loud sound was recorded on the CVR at 19.02:50 hrs. By projecting from this position along the track of 321¡(Grid) for 3.1±1 seconds at the groundspeed of 434 kts, the position of the aircraft was calculated to be OS Grid Reference 14827826, annotated Point B in Appendix B, Figure B-4, within an accuracy of ±525 metres. Based on the evidence of recorded data only, Point B therefore represents the geographical position of the aircraft at the moment the loud sound was recorded on the CVR.

8. Conclusions

The almost instant destruction of Flight PA103 resulted in no direct evidence on the cause of the accident being preserved on the DFDR. The CVR CAM track contained a loud sound 170 milliseconds before recording ceased. Sixty milliseconds of this sound were while power was applied to the recorder; after this period the amplitude decreased. It cannot be determine whether the decrease was because of reducing recorder drive or if the sound itself decreased in amplitude. Analysis of both flight recorders shows that they stopped because the electrical supply was removed and that there were valid signals available to both recorders at that time.

The most important contribution to the investigation that the flight recorders could make was to pinpoint the time and position of the event. As the timescale involved was so small in relation to the resolution and accuracy of many of the recorded time sources it was necessary to analyse collectively all the available recordings. From the analysis of the CVR, DFDR, ATC tapes, radar data and the seismic records it was concluded that the loud sound on the CVR occurred at 19.02:50 hrs ±1 second and wreckage from the aircraft crashed on Lockerbie at 19.03:36.5 hrs

±1 second, giving a time interval of 46.5 ±2 seconds
between these two events. When the loud sound was recorded on the CVR, the geographical position of the aircraft, based on the evidence of recorded data, was calculated to be within 525 metres of OS Grid Reference 14827826.

Eight seconds after the sound on the CVR the Great Dun Fell radar showed 4 primary radar returns. The returns indicated a spread of wreckage in the order of 1 nautical mile across track. On successive returns of the radar, two parallel wreckage trails are seen to develop with the second trail, to the north, becoming evident 30 to 40 seconds after the first.

APPENDIX D

CRITICAL CRACK CALCULATIONS

It was assumed that the fuselage rupture and associated star-burst petalling process was driven by an expanding 'bubble' of high pressure gas, produced by the conversion of solid explosive material into gas products. As the explosive gas pressures reduced due to dissipation through the structure and external venting, the service differential pressure loading would have taken over from the explosive pressures as the principal force driving the skin fractures.

The high temperature gas would initially have been confined within the container where, because of the low volume, the pressure would have been extremely high (too high for containment) and the gas bubble would have expanded violently into the cavities of the fuselage between the outer skin and the container. This gas bubble would have continued to expand, with an accompanying fall in pressure due to the increasing volume combined with a corresponding drop in temperature.

The precise nature of the gas expansion process could not be determined directly from the evidence and it was therefore necessary to make a number of assumptions about its behaviour, based on the geometry of the hull and the area of fuselage skin which the high pressure bubble would have ruptured. Essentially, it was assumed that the gas bubble would expand freely in the circumferential direction, into the cavity between the fuselage skin and the container. In contrast, the freedom for the bubble to expand longitudinally would have been restricted by the presence of the fuselage frames, which would have partially blocked the passage of gas in the fore and aft directions. However, the pressures acting on the frames would have been such that they would have buckled and failed, allowing the gas to vent into the next 'bay', producing failure of the next frame. This sequential frame-failure process would have continued until the pressure had fallen to a level which the frames could withstand. During the period of frame failure and the associated longitudinal expansion of the gas bubble, this expansion rate was assumed to be half that of the circumferential rate.

It was assumed that venting would have taken place through the ruptured skin and that the boundary of the petalled hole followed behind the expanding gas bubble, just inside its outer boundary, i.e. the expanding gas bubble would have stretched and 'unzipped' the skins as it expanded. This process would have continued until the gas bubble had expanded/vented to a level where the pressure was no longer able to drive the petalling mechanism because the skin stresses had reduced to below the natural strength of the material.

The following structural model was assumed:

(i) The pressurised hull was considered to be a cylinder of radius 128 inches, divided into regular lengths by stiff frames.

(ii) The contributions of the stringers and frames beyond the petalled region were considered to be the equivalent of a reduction of stress in the skins by 20%, corresponding to an increase in skin thickness from 0.064 inches to 0.080 inches.

(iii) Standing skin loads were assumed to be present due to the service differential pressure, i.e.. it was assumed that no significant venting of internal cabin pressure occurred within the relevant timescale.

(iv) The mechanism of bubble pressure load transfer into the skins was:

a) Hoop direction -conventional membrance reaction into hoop stresses b)

Longitudinal direction - reaction of pressures locally by the frames, restrained by the skins.

The critical crack calculations were based upon the generalised model of a plate under biaxial loading in which there was an elliptical hole with sharp cracks emanating from it. This is a good approximation of the initial condition, i.e.. the shattered hole, and an adequate representation of the subsequent phase, when the hole was enlarging in its star-burst, petalling, mode.

The analyses of critical crack dimensions in the circumferential and longitudinal directions were based on established Fracture Resistance techniques. The method utilises fracture resistance data for the material in question to establish the critical condition at which the rate of energy released by the crack just balances the rate of energy absorbed by the material in the cracking process, i.e. the instantaneous value of the parameter Kr, commonly referred to as the fracture toughness Kc. From this, the relationship between critical stress and crack length can be determined.

Using conventional Linear Elastic Fracture Mechanics (LEFM) with fracture toughness data from RAE experimental work and published geometric factors relating to cracks emanating from elliptical holes, the stress levels required to drive cracks of increasing lengths in both circumferential and longitudinal directions were calculated. The skin stresses at sequential stages of the expanding gas bubble/skin petalling process were then calculated and compared with these data.

The results of the analysis indicated that, once the large petalled hole had been produced by explosive gas overpressure, the hoop stresses generated by fuselage pressurisation loads acting alone would have been sufficient to drive cracks longitudinally for large distances beyond the boundaries of the petalled hole. Thus, with residual gas overpressure acting as well, the 43 feet (total length) longitudinal fractures observed in the wreckage are entirely understandable. The calculations also suggested that the hoop fractures, due to longitudinal stresses in the skins, would have extended beyond the boundary of the petalled hole, though the excess stress driving the fractures in this direction would have been much smaller than for the longitudinal fractures, and the level of uncertainty was greater due to the difficulty of producing an accurate model reflecting the diffusion of longitudinal loads into the skins. Nevertheless, the results suggested that the circumferential cracks would extend downwards just beyond the keel, and upwards as far as the window belt - conclusions which accord reasonably well with the wreckage evidence.

APPENDIX E

POTENTIAL REMEDIAL MEASURES

1. Introduction

In the following discussion, those damage mechanisms which appear to have contributed to the catastrophic structural failure of Flight PA103 are identified and possible ways of reducing their damaging effects are suggested. These suggestions are intended to stimulate thought and discussion by manufacturers, airworthiness authorities, and others having an interest in finding solutions to the problem; they are intended to serve as a catalyst rather than to lay claim to a definitive solution. On the basis of the Flight PA103 investigation, damage is likely to fall into two categories: direct explosive damage, and indirect explosive damage.

2. Direct explosive damage

The most serious aspect of the direct explosive damage on the structure is the large, jagged aperture in the pressure hull, combined with frame and stringer break-up, which results from the star-burst rupture of the fuselage skin. Because of its uncontrolled size and position, and the naturally radiating cracks which form as part of the petalling process, the skin's critical crack length (under pressurisation loading) is likely to be exceeded, resulting in unstable crack propagation away from the boundary of the aperture. Such cracks can lead to a critical loss of structural integrity at a time when additional loads are likely to be imposed on the structure due to reflected blast pressure and/or aircraft aerodynamic and inertial loading.

A further complicating factor is that the size of this aperture is likely to be sufficiently large to allow complete cargo containers and other debris to be ejected into the airstream, with a high probability of causing catastrophic structural damage to the empennage.

3. Indirect explosive damage

Indirect explosive damage (channelling or ducting of explosive energy in the form of both shock waves and supersonic gas flows) is likely to occur because of the network of interlinked cavities which exist, in various forms, in all large commercial aircraft, particularly below cabin floor level. This channeling mechanism can produce critical damage at significant distances from the source of the explosion.

In addition to the structural damage, aircraft flight control and other critical systems will potentially be disrupted, both by the explosive forces and as a result of structural break-up and distortions. The discussion which follows focuses on possible means of limiting structural damage of the kind which occurred on Flight PA103. Undoubtedly, such measures will also have beneficial effects in limiting systems damage. However, system vulnerability can further be reduced by applying, wherever possible, those techniques used on military aircraft to reduce vulnerability to battle damage; multiplexed, multiply redundant systems using distributed hardware to minimise risk of a single area of damage producing major system disruption. Fly by wire flight control systems potentially offer considerable scope to achieve these goals, but the same distributed approach would also be required for the electronic and other equipment which, in current aircraft, tends to be concentrated into a small number of 'equipment centres'.

4. Remedial measures to reduce structural damage

Whilst pure containment of the explosive energy is theoretically possible, in an aviation context such a scheme would not be viable. Any unsuccessful attempt to contain the explosive will probably produce greater devastation than the original (uncontained) explosion since all the explosive energy would merely be stored until the containment finally ruptured, when the stored energy would be released together with massive fragmentation of the containment.

However, a mixed approach involving a combination of containment, venting, and energy absorption should provide useful gains provided that a systematic rather than piecemeal approach is adopted, and that the scheme also addresses blast channelling. The following scheme is put forward for discussion, primarily as means of identifying, by example, how the various elements of the problem might be approached at a conceptual level and to provide a stimulus for debate. No detailed engineering solutions are offered, but it is firmly believed that the requirements of such a scheme could be met from a technical standpoint. The proposed scheme is based on the need to counter a threat similar to that involving Flight PA103, i.e. a high explosive device placed within a baggage container, however, the principles should be applicable to other aircraft types.

Such a scheme might comprise several 'layers' of defence. The first two layers, one within the other, are essentially identical and provide partial containment of the explosive energy and the redirection of blast out from the compartment via pre-determined vent paths. Although the containment is temporary, it must provide an effective barrier to uncontrolled venting, preventing the escape of blast except via the pre-designated paths.

The third layer comprises a pre-determined area of fuselage skin, adjoining the outer end of the vent path, designed to rupture or burst in a controlled manner, providing a large vent aperture which will not tend to crack or rupture beyond the designated boundaries.

A fourth layer of protection has two elements, both intended to limit the propagation of shock waves through the internal cavities in the hull. The first element comprises the closure of any gaps between the vent apertures in the two innermost containment layers and the vent aperture in the outer skin. This effectively provides an exhaust duct connecting the inner and outer vent apertures to minimise leakage into the intervening structure and cavities around the cargo hold. The second element comprises the incorporation of an energy absorbing lining material within all the cavities in the lower hull, to absorb shock energy, limit shock reflection and limit the propagation of pressure waves which might enter the cavities, for example because of containment layer breakthrough.

5 Possible application to Boeing 747 type aircraft

5.1 Container Modification

The obvious candidates for the inner containment layer are the baggage containers themselves. Existing containers are of crude construction, typically comprising aluminium sheet sides and top attached to an aluminium frame with a fabric reinforced access curtain, or have sides and top of fibreglass laminate attached to a robust aluminium base section.

These containers are stacked in the aircraft in such a manner that on three sides (except for the endmost containers) the baggage within the adjoining containers provides an already highly effective energy absorbing barrier. If the container is modified so that loading access is via the outboard side of the container rather than at the end, i.e. the curtain is put on the faces shown in Figure E-1, then only the top and base are 'unbacked' by other containers, leaving the outboard face as a vent region.

The proposal is therefore that a modified container is developed in which the access is changed from the end to the outside face only, and which is modified to improve the resistance to internal pressures and thus encourage venting via the new access curtain only. How the container is actually modified to achieve the containment requirement is a matter of detail design, but two approaches suggest themselves, both involving the use of composite type materials. The first approach is to adopt a scheme for a rigid container which relies on a combination of energy absorption and burst strength to prevent uncontrolled breakout of explosive energy. The second approach is to use a 'flexible' container, i.e. rigid enough for normal use, but sufficiently flexible to allow gross deformation of shape without rupture. This, particularly if used with a backing blanket made from high performance material to resist fragmentation, could deform sufficiently to allow the container to bear against, and partially crush, adjoining containers. In this way, the shock energy transmission should be significantly reduced and the inherent energy absorption capability and mass of the baggage in adjoining containers could be utilised, whilst still retaining the high pressure gas for long enough to allow venting via the side face. Clearly, care would need to be taken to ensure that the container vent aperture remained as undistorted as possible, to ensure minimal leakage at the interface.

5.2 Cargo bay liner

The existing cargo bay liner is a thin fibreglass laminate which lines the roof and sidewalls of the cargo hold. There is no floor as such; instead, the containers are supported on rails running fore and aft on the tops of the fuselage frame lower segments. In a number of areas, there are zipped fabric panels let into the liner to provide access to equipment located behind. The liner 'ceiling' is suspended on plastic pillars approximately 2 centimeters below the bottom of the main cabin floor beams.

The purpose of the liner is solely to act as a general barrier to protect wiring looms and systems components.

The proposal is to produce a new liner designed to provide the second level of containment, essentially at 'floor' and 'roof' level only [Figure E-1]. The dimensional constraints are such that potentially quite thick material could be incorporated (leaving aside the weight problem), permitting not only a rigid liner design, but semi-rigid or flexible linings backed by energy absorbing blanket materials.

The liner would be designed to provide an additional barrier at the base and roof of the containers, which unlike the sides, are not protected by adjoining containers. The outside ends of these barrier elements must effectively seal against the vent apertures in the containers, to minimise leakage into the fuselage cavities.

5.3 Structural blow-out regions.

The final element in the containment/venting part of the scheme is a line of blow-out regions in the fuselage skins, coinciding exactly with the positions of the vent apertures in the cargo containers and cargo bay liner. These should extend along the length of the cargo hold, zoned in such a way that rupture due to rapid overpressure will occur in a controlled manner. The primary function of the blow-out regions would be to provide immediate pressure relief by allowing the inevitable skin rupture to take place only within pre-determined zones, limiting the extent of the skin tearing by means of careful stiffness control at the boundary of the blow-out regions.

The structural requirements of such panels are perhaps the most difficult challenge to meet, particularly for existing designs. However, it is believed that by giving appropriate consideration to the directionality of fastening strengths, and the use of external tear straps, it should be possible to design the structure to carry the normal service loads whilst creating a pre-disposition to rupturing in a controlled manner in response to gross pressure impulse loading.

The implementation of such features will need carefully balanced design in order to provide local stiffening, sufficient to control and direct the tear processes, without creating stiffness discontinuities which could lead to fatigue problems during extended service. However, the degree of reinforcement needed at the blow-out aperture need only be sufficient to limit tearing and to sustain the aircraft long enough to complete the flight unpressurised.

All aircraft have pre-existing strength discontinuities, despite the efforts of the designers to eliminate them. By choosing the positions of butt joints, lap joints, anti-tear straps and similar structural features in future designs, so as to incorporate them into the boundary of the blow-out panel region, the natural "tear here" tendencies of such features could possibly be turned to advantage. In the case of current generation aircraft, the positions of existing lines of weakness at such features will determine the optimum position for structural blow-out areas, and hence the positions of the container and cargo bay liner blow-out panels. A limited amount of local structural reinforcement (e.g. in the form of external anti-tear straps), carried out as part of a modification program, could perhaps fine tune the tearing properties of existing lines of weakness, potentially producing significant improvements.

5.4 Closure of cavities

There are four main classes of cavity which will need to be addressed on the Boeing 747, and most other modern aircraft. These are:

(i) The channels formed between fuselage frames

(ii) The cross-ship cavities between cabin floor beams

(iii) Longitudinal 'manifold' cavities on each side of the cargo deck, running fore and aft in the space behind the upper sidewall areas of the cargo bay liner.

(iv) Air conditioning vents along the bottom of the cabin side-liner panels, which connect the side cavities below cabin floor level with the main passenger cabin.

If the containment barriers (i.e. modified cargo containers and cargo hold liner) can be made to prevent blast breakthrough into these cavities directly, then the only area where transfer can occur is at the interface between the container/cargo hold liner vent apertures and the fuselage skins at the blow-out region. This short distance will need to be sealed in order to form a short 'exhaust duct' between the container vent aperture and the fuselage skin. Since the shock and general explosive pressure will act mainly along the vent-duct axis, the pressure loading on the vent duct walls should not be excessive.

5.5 Attenuation of shock waves in structural cavities

To prevent the 'ducting' of any blast which does enter the fuselage cavities, either because of partial penetration of the containment barriers or leakage at the vent duct interfaces, the scheme requires the provision of lightweight energy absorbing material within the cavities to limit reflection and propagation of pressure waves within the cavities, and radiation of shock waves into the cabin from the conditioning air vents. Materials such as vermiculite, which are of low density yet have excellent explosive energy absorption properties, may have application in this area, perhaps in lieu of the existing insulation material.

Since the existing cavities often serve as part of the air conditioning outflow circuit, some consideration will need to be given to finding an alternative route. However, the flow rates are small compared with the total cross-sectional flow potential of the cavities and this function could be served by separate air conditioning ducts, or perhaps by restricting access to one or two cavities only (thus limiting the risk), or by using some form of blast valve to close off the air conditioning vents. Similarly, the requirement to vent pressure from the cabin in the event of a cargo bay decompression would also need to be addressed.

APPENDIX F

BAGGAGE CONTAINER EXAMINATION, RECONSTRUCTION AND RELATIONSHIP TO THE AIRCRAFT STRUCTURE

1. Introduction

During the wreckage recovery operation it became apparent that some items, identified as parts of baggage containers, exhibited blast damage. It was confirmed by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE), after detailed physical and chemical examination, that these items showed conclusive evidence of a detonating high performance plastic explosive. It was therefore decided to segregate identifiable container parts and reconstruct any that showed evidence from the effect of Improvised Explosive Device (IED). It was evident, from the main wreckage layout that the IED had been located in the forward cargo hold and, although all baggage container wreckage was examined, only items from the forward hold showing the relevant characteristics were considered for the reconstruction. This Appendix documents the reconstruction of two particular containers and, from their position within the forward fuselage, defines the location of the IED.

2 Container Arrangement

Information supplied by Pan Am showed that this aircraft had been loaded with 12 baggage containers and two cargo pallets in the forward hold located as shown in Figure F-1. Three containers were recorded as being of the glass fibre reinforced plastic type (those at positions 11L, 13L and 21L) with the remaining 9 being of metal construction.

3. Container Description

All the baggage containers installed in the forward cargo hold were of the LD3 type (lower deck container, half width - cargo) and designated with the codes AVE, for those constructed from aluminum alloy, and AVA or AVN for those constructed from fibreglass. Each container was specifically identified with a four digit serial number followed by the letters PA and this nine digit identifier was present at the top of three sides of each container in black letters/numbers approximately 5 inches tall. Detail drawings and photographs of a typical metal container are shown in Figure F-2. Each container was essentially a 5 feet cube with a 17 inch extension over its full length to the left of the access aperture. In order to fit within the section of the lower fuselage this extension had a sloping face at its base joining the edge of the container floor to the left vertical sidewall at a position some 20 inches above the floor. The access aperture on the AVE type container was covered by a blue reinforced plastic curtain, fixed to the container at its top edge, braced by two wires and central and lower edge cross bars which engaged with the aperture structure. The strength of this type of container superstructure was provided by the various extruded section edge members, attached to a robust floor panel, with a thin aluminum skin providing baggage containment and weatherproofing.

4. Container Identification

Discrimination between forward and rear cargo hold containers was relatively straightforward as the rear cargo hold wreckage was almost entirely confined to the town of Lockerbie and was characteristically different from that from the forward hold, in that it was generally severely crushed and covered in mud. The forward hold debris, by comparison, was mostly recovered from the southern wreckage trail some distance from Lockerbie and had mainly been torn into relatively large sections.

All immediately identifiable parts of the forward cargo containers were segregated into areas designated by their serial numbers and items not identified at that stage were collected into piles of similar parts for later assessment. As a result of this two containers, one metal and one fibreglass, were identified as exhibiting damage likely to have been caused by the IED. From the Pan Am records the metal container of these two had been positioned at position 14L, and the fibreglass at position 21L (adjacent positions, 4th and 5th from the front of the forward cargo hold on the left side). The serial numbers of these containers were respectively AVE 4041 PA and AVN 7511 PA.

5. Container Reconstruction

Those parts which could be positively identified as being from containers AVE 4041 PA and AVN 7511 PA were assembled onto one of three wooden frameworks; one each for the floor and superstructure of container 4041, and one for the superstructure of container 7511. Figures F-3 to F-9 show the reconstruction of container 4041 and Figure F-10 shows the reconstructed forward face of container 7511.
Approximately 85% of container 4041 was identified, the main missing sections being the aft half of the sloping face skin and all of the curtain. Two items were included which could not be fracture or tear matched to container 4041, however, they showed the particular type of blast damage exhibited only by items from this container.

While this work was in progress a buckled section of skin from container 4041 was found by an AAIB Inspector to contain, trapped within its folds, an item which was subsequently identified by forensic scientists at the Royal Armaments Research and Development Establishment (RARDE) as belonging to a specific type of radio-cassette player and that this had been fitted with an improvised explosive device.

Examination of all other component parts of the remaining containers from the front and rear cargo holds did not reveal any evidence of blast damage similar to that found on containers 4041 and 7511.

6. Wreckage Distribution

Those items which were positively identified as parts of container 4041 or 7511, and for which a grid reference was available, were found to have fallen close to the southern edge of the southern wreckage trail. This indicated that one of the very early events in the aircraft break-up sequence was the blast damage to, and ejection of, parts of these two containers.

7. Fuselage Reconstruction

In order to gain a better understanding of the failure sequence, that part of the aircraft's fuselage encompassing the forward cargo hold was reconstructed at AAIB Farnborough. After all available blast damaged pieces of structure had been added, the floor of container 4041 was installed as near to its original position as the deformation of the wreckage would allow and this is shown in Figure F-11. The presence of this floor panel in the fuselage greatly assisted the three-dimensional assessment of the IED location. Witness marks between this floor and the aircraft structure, tie down rail, roller rail and relative areas of blast damage left no doubt that container 4041 had been located at position 14L at the time of detonation.

8. Analysis

The general character of damage that could be seen on the reconstructions of containers 4041 and 7511 was not of a type seen on the wreckage of any of the other containers examined. In particular, the reconstruction of the floor of container 4041 revealed an area of severe distortion, tearing and blackening localised in its aft outboard quarter which, together with the results of the forensic examination of items from this part of the container, left no doubt that the IED had detonated within this container.

Within container 4041 the lack of direct blast damage (of the type seen on the outboard floor edge member and lower portions of the aft face structural members) on most of the floor panel in the heavily distorted area suggested that this had been protected by, presumably, a piece of luggage. The downward heaving of the floor in this area was sufficient to stretch the floor material, far enough to be cut by cargo bay sub structure, and distort the adjacent fuselage frames. This supported the view that the item of baggage containing the IED had been positioned fairly close to the floor but not actually placed upon it. The installation of the floor of container 4041 into the fuselage reconstruction (Figure F-11) showed the blast to have been centered almost directly above frame 700 and that its main effects had not only been directed mostly downwards and outboard but also rearwards. The blast effects on the aircraft skin were onto stringer 39L but centered at station 710 (Figure F-12). Downwards crushing at the top, and rearwards distortion of frame 700 was apparent as well as rearwards distortion of frame 720.

With the two container reconstructions placed together it became apparent that a relatively mild blast had exited container 4041 through the rear lower face to the left of the curtain and impinged at an angle on the forward face of container 7511. This had punched a hole, Figure F-10, approximately 8 inches square some 10 inches up from its base and removed the surface of this face inboard from the hole for some 50 inches. Radiating out from the hole were areas of sooting, and other black deposits, extending to the top of the container. No signs were present of any similar damage on other external or internal faces of container 7511 or the immediately adjacent containers 14R and 21R.

The above assessment of the directions of distortion, comparison of damage to both containers, and the related airframe damage adjacent to the container position, enabled the most probable lateral and vertical location of the IED to be established as shown in Figure F-13, centered longitudinally on station 700.

9. Conclusions

Throughout the general examination of the aircraft wreckage, direct evidence of blast damage was exhibited on the airframe only in the area bounded, approximately, by stations 700 and 720 and stringers 38L and 40L. Blast damage was found only on pieces of containers 4042 and 7511, the relative location and character of which left no doubt that it was directly associated with airframe damage. Thus, these two containers had been loaded in positions 14L and 21L as recorded on the Pan Am cargo loading documents. There was also no doubt that the IED had been located within container 14L, specifically in its aft outboard quarter as indicated in Figure F-13, centered on station 700.

Blast damage to the forward face of container 7511 was as a direct result of hot gases/fragments escaping from the aft face of container 4041. No evidence was seen to suggest that more than one IED had detonated on Flight PA103.

APPENDIX G

MACH STEM SHOCK WAVE EFFECTS

1. Introduction

An explosive detonation within a fuselage, in reasonably close proximity to the skin, will produce a high intensity shock wave which will propagate outwards from the centre of detonation. On reaching the inner surface of the fuselage skin, energy will partially be absorbed in shattering, deforming and accelerating the skin and stringer material in its path. Much of the remaining energy will be transmitted, as a shock wave, through the skin and into the atmosphere but a significant amount of energy will be returned as a reflected shock wave, which will travel back into the fuselage interior where it will interact with the incident shock to produce Mach stem shocks - re-combination shock waves which can have pressures and velocities of propagation greater than the incident shock.

The Mach stem phenomenon is significant for two reasons. Firstly, it gives rise (for relatively small charge sizes) to a geometric limitation on the area of skin material which the incident shock wave can shatter. This geometric limitation occurs irrespective of charge size (within the range of charge sizes considered realistic for the Flight PA103 scenario), and thus provides a means of calculating the standoff distance of the explosive charge from the fuselage skin. Secondly, the Mach stem may have been a significant factor in transmitting explosive energy through the fuselage cavities, producing damage at a number of separate sites remote from the source of the explosion.

2. Mach stem shock wave formation

A Mach stem shock is formed by the interaction between the incident and reflected shock waves, resulting in a coalescing of the two waves to produce a new, single, shock wave. If an explosive charge is detonated in a free field at some standoff distance from a reflective surface, then the incident shock wave expands spherically until the wave front contacts the reflective surface, when that element of the wave surface will be reflected back (Figure G-1). The local angle between the spherical wave front and the reflecting surface is zero at the point where the reflecting surface intersects the normal axis, resulting in wave reflection directly back towards the source and maximum reflected overpressure at the reflective surface. The angle between the wave front and the reflecting surface at other locations increases with distance from the normal axis, producing a corresponding increase in the oblique angle of reflection of the wave element, with a corresponding reduction in the reflected overpressure. (To a first order of approximation, explosive shock waves can be considered to follow similar reflection and refraction paths to light waves, ref: "Geometric Shock Initiation of Pyrotechnics and Explosives", R Weinheimer, McDonnel Douglas Aerospace Co.) Beyond some critical (conical) angle about the normal axis, typically around 40 degrees, the reflected and incident waves coalesce to form Mach stem shock waves which, effectively, bisect the angle between the incident and reflected waves, and thus travel approximately at right angles to the normal axis, i.e.parallel with the reflective surface (detail "A", figure G-1).

3. Estimation of charge standoff distance from the fuselage skin

Within the constraint of the likely charge size used on Flight PA103, calculations suggested that the initial Mach stem shock wave pressure close to the region of Mach stem formation (i.e. the shock wave face-on pressure, acting at right angles to the skin), was likely to be more than twice that of the incident shock wave, with a velocity of propagation perhaps 25% greater. However, the Mach stem out-of-plane pressure, i.e.the pressure felt by the reflecting surface where the Mach stem touches it, would have been relatively low and insufficient to shatter the skin material. Therefore, provided that the charge had sufficient energy to produce skin shatter within the conical central region where no Mach stems form, the size of the shattered region would be a function mainly of charge standoff distance, and charge weight would have had little influence. Consequently, it was possible to calculate the charge standoff distance required to produce a given size of shattered skin from geometric considerations alone. On this basis, a charge standoff distance of approximately 25 to 27 inches would have resulted in a shattered region of some 18 to 20 inches in diameter, broadly comparable to the size of the shattered region evident on the three-dimensional wreckage reconstruction.

Whilst the analytical method makes no allowance for the effect of the IED casing, or any other baggage or container structure interposed between the charge and the fuselage skin, the presence of such a
barrier would have tended to absorb energy rather than re-direct the transmitted shock wave; therefore its presence would have been more critical in terms of charge size than of position. Certainly, the standoff
distance predicted by this method was strikingly similar to the figure of 25 inches derived independently from the container and fuselage reconstructions.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: Jaswindersingh <jaswinderp@hotmail.com>
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WASHINGTON, D.C. 20594
AIRCRAFT ACCIDENT REPORT
EXPLOSIVE DECOMPRESSION--
LOSS OF CARGO DOOR IN FLIGHT
UNITED AIRLINES FLIGHT 811
BOEING 747-122, N4713U
HONOLULU, HAWAII
FEBRUARY 24, 1989
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Adopted: March 18, 1992 Notation 5059C

Abstract: This report explains the explosive decompression resulting from the loss of a cargo door in flight on United Airlines flight 811, a Boeing 747-122, near Honolulu, Hawaii, on February 24, 1989. The safety issues discussed in the report are the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, and emergency response. Recommendations concerning these issues were made to the Federal Aviation Administration, the State of Hawaii, and the U.S. Department of Defense.

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EXECUTIVE SUMMARY

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.

The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.

A year after the accident, the Safety Board was uncertain that the cargo door would be located and recovered from the Pacific Ocean. The Safety Board decided to proceed with a final report based on the available evidence without the benefit of an actual examination of the door mechanism. The original report was adopted by the Safety Board on April 16, 1990, as NTSB/AAR-90/01.

Subsequently, on July 22, 1990, a search and recovery operation was begun by the U.S. Navy with the cost shared by the Safety Board, the Federal Aviation Administration, Boeing Aircraft Company, and United Airlines. The search and recovery effort was supported by Navy radar data on the separated cargo door, underwater sonar equipment, and a manned submersible vehicle. The effort was successful, and the cargo door was recovered in two pieces from the ocean floor at a depth of 14,200 feet on September 26 and October 1, 1990.

Before the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.

Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.

The issues in this investigation centered around the design and certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

As a result of this investigation, the Safety Board issued safety recommendations concerning cargo doors and other nonplug doors on pressurized transport category airplanes, cabin safety, and emergency response.

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1. FACTUAL INFORMATION

1.1 History of the Flight

On February 24, 1989, United Airlines (UAL) flight 811, a Boeing 747-122 (B-747), N4713U, was being operated as a regularly scheduled flight from Los Angeles, California (LAX) to Sydney, Australia (SYD), with intermediate stops in Honolulu, Hawaii (HNL) and Auckland, New Zealand (AKL).

The flightcrew assigned to the LAX/HNL route segment reported no difficulty during their flight.

A flightcrew change occurred when flight 811 arrived at HNL. The oncoming captain stated that he and his crew reported to UAL operations 1 hour and 15 minutes prior to the flight's scheduled departure time from HNL. The crew had completed a 34-hour layover (rest period) in HNL.

The captain reviewed the flight plan, the weather, pertinent NOTAMs, and maintenance records, and signed the Instrument Flight Rules (IFR) clearance before boarding the airplane.

Flight 811 departed HNL gate 10 at 0133 Honolulu Standard Time (HST), 3 minutes after the scheduled departure time, with 3 flight crewmembers, 15 cabin crewmembers, and 337 passengers. The flightcrew attributed the short delay to cabin crew problems with arming the 5L cabin door emergency exit slide and the normal securing of the 2L door after a somewhat extended passenger boarding process. The second officer stated that all cabin and cargo door warning lights were out prior to the airplane's departure from the gate. He said that he dimmed the annunciator panel lights at his station while the airplane was departing the gate area.

The captain was at the controls when the flight was cleared for takeoff on HNL runway 8R at 0152:49 HST. The auxiliary power unit (APU), which was used during the takeoff, was shutdown shortly after making the initial power reduction to climb thrust. The flightcrew reported the airplane's operation to be normal during the takeoff and during the initial and intermediate segments of the climb. The flightcrew observed en route thunderstorms both visually and on the airplane's weather radar, so they requested and received clearance for a deviation to the left of course from the HNL Combined Center Radar Approach

Control (CERAP). The captain elected to leave the passenger seat belt sign "on."

The flightcrew stated that the first indication of a problem occurred while the airplane was climbing between 22,000 and 23,000 feet at an indicated airspeed (IAS) of 300 knots. They heard a sound, described as a "thump," which shook the airplane. They said that this sound was followed immediately by a "tremendous explosion." The airplane had experienced an explosive decompression. They said that they donned their respective oxygen masks but found no oxygen available. The airplane cabin altitude horn sounded and the flightcrew believed the passenger oxygen masks had deployed automatically.

The captain immediately initiated an emergency descent, turned 180(to the left to avoid a thunderstorm, and proceeded toward HNL. The first officer informed CERAP that the airplane was in an emergency descent and appeared to have lost power in the No. 3 engine. The appropriate 7700 emergency code was placed in the airplane's radar beacon transponder and an emergency was declared with CERAP at approximately 0220 HST. The No. 3 engine was shut down shortly after commencing the descent because of heavy vibration, no N1 compressor indication, low exhaust gas temperature (EGT), and low engine pressure ratio (EPR).

The second officer then left the cockpit to inspect the cabin area and returned to inform the captain that a large portion of the forward right side of the cabin fuselage was missing. The captain subsequently shut down the No. 4 engine because of high EGT and no N1 compressor indication, accompanied by visible flashes of fire. The flightcrew initiated fuel dumping during the descent to reduce the airplane landing weight.

The airplane was cleared for an approach to HNL runway 8L. The final approach was flown at 190 to 200 knots with the No. 1 and No. 2 engines only. During flap extension, the flightcrew observed an indication of asymmetrical flaps as the flap position approached 5(. The flightcrew decided to extend inboard trailing edge flaps to 10(for the landing. The right outboard leading edge flaps did not extend during the flap lowering sequence. The airplane touched down on the runway, approximately 1,000 feet from the approach end, and came to a stop about 7,000 feet later. The captain applied idle reverse on the Nos. 1 and No. 2 engines and employed moderate to heavy braking to stop the airplane. At 0234 (HST), HNL tower was notified by the flightcrew that the airplane was stopped and an emergency evacuation had commenced on the runway.

After the accident, UAL ramp service personnel, who had been involved with the cargo loading and unloading of flight 811 before takeoff from HNL, stated that they had opened and closed the forward cargo door electrically. They said that they had observed no damage to the cargo door. The ramp service personnel said that they had verified that the forward cargo door was flush with the fuselage of the airplane, that the master door latch handle was stowed, and that the pressure relief doors were flush with the exterior skin of the cargo door.

The dispatch mechanic stated that, in accordance with UAL procedures, he had performed a "circle check" prior to the airplane's departure from the HNL gate. This check included verification that the cargo doors were flush with the fuselage of the airplane, that the master latch lock handles were stowed, and that the pressure relief doors were flush or within 1/2 inch of the cargo door's exterior skin. He said a flashlight was used during this inspection.

The second officer stated that, in accordance with UAL Standard Operating Procedures (SOP) he had performed an operational check of the door warning annunciator lights as part of his portion of the cockpit preparation. The second officer also stated that he used a flashlight while performing an exterior inspection, again in accordance with UAL procedures. The exterior inspection was conducted while ramp service personnel were performing cargo loading operations and the cargo doors were open. He stated that he had observed no abnormalities or damage.

1.2 Injuries to Persons

Injuries Flightcrew Cabincrew Passengers Others Serious *Lost in flight. An extensive air and sea search for the passengers was unsuccessful.

1.3 Damage to the Airplane

The primary damage to the airplane consisted of a hole on the right side in the area of the forward lower lobe cargo door, approximately 10 by 15 feet large. The cargo door fuselage cutout lower sill and side frames were intact but the door was missing (see figures 1 and 2). An area of fuselage skin measuring about 13 feet lengthwise by 15 feet vertically, and extending from the upper sill of the forward cargo door to the upper deck window belt, had separated from the airplane at a location above the cargo door extending to the upper deck windows. The floor beams adjacent to and inboard of the cargo door area had been fractured and buckled downward.

Examination of all structure around the area of primary damage disclosed no evidence of preexisting cracks or corrosion. All fractures were typical of fresh overstress breaks.

Debris had damaged portions of the right wing, the right horizontal stabilizer, the vertical stabilizer and engines Nos. 3 and 4. No damage was noted on the left side of the airplane, including engines Nos. 1 and 2.

The right wing had sustained impact damage along the leading edge between the No. 3 engine pylon and the No. 17 variable camber leading edge flap. Slight impact damage to the No. 18 leading edge flap was noted.

There was a break and scuff in the wing leading edge aft of engine No. 4 and a scuff in the wing leading edge outboard of engine No. 4. There was a large indentation (to a depth of nearly 8 inches) in the area just above the outboard landing light, and the landing light covers were broken. There was a small puncture in the upper surface of the No. 14 krueger flap and impact damage to the wing leading edge just aft of the No. 14 krueger flap. There was a gash on the upper wing surface aft of the No. 14 krueger flap and leading edge, as well as punctures to the wing leading edge aft of the number 16 krueger flap. The under wing surface aft of the krueger flaps also sustained impact damage.

The right wing also had sustained damage at the wing-to-body fairing and two flap track canoe fairings.1 Wing-to-body fairing damage was limited to surface scraping forward of and below the wing. The outboard surface of the No. 6 flap track canoe fairing revealed a slightly more significant gouge mark. The most severe damage was evident on the inboard surface of the No. 8 flap track canoe fairing, where three separate punctured areas were observed. The trailing edge flaps were not damaged.

The leading edge of the right horizontal stabilizer had several dents. The most severe dents, located 8 to 10 feet from the stabilizer root, were approximately 3 inches wide and 1 inch deep. No punctures were found. The vertical stabilizer had multiple small and elongated indentations with a maximum depth of 1/2 inch near the right base of the leading edge. A small gouge and two small scrapes were noted at midspan of the upper rudder.

A piece of cargo container was found lodged between the No. 3 engine pylon (inboard) and the wing underside. The piece of metal had severed the pneumatic duct for the leading edge flaps. Various nicks and punctures were evident on the inboard side of the No. 3 engine pylon. The No. 4 engine pylon had a small puncture near the leading edge of the wing.

The external surfaces of the No. 3 engine inlet cowl assembly exhibited foreign object damage including small tears, scuffs and a large outwardly directed hole. The entire circumference of all the acoustic (sound attenuator) panels installed on the inlet section of the cowl had been punctured, torn, or dented. None of the No. 3 engine cases were penetrated by objects, nor was there evidence of fire damage to any visible engine components and accessories. The

leading edges of all fan blade airfoils on the No. 3 engine exhibited extensive foreign object damage.

External damage to the No. 4 engine inlet and core cowls was confined to the inboard side of the inlet cowl assembly. The damage consisted of one major scuff mark, four lesser scuff marks and one crescent- shaped cut. The sound attenuator panels that were installed in the inlet area of the inlet cowl assembly had not been penetrated. The No. 4 engine fan blade airfoils had sustained both soft and hard object damage from foreign objects.

The cargo door separation resulted in the loss of fuselage shell structure above the cargo door, along with main cabin floor structure below seats 8GH through 12GH (see figure 3). The missing floor area extended inboard from the interior of the right side fuselage wall to the inboard seat track of seats 8GH through 12GH.

The supply and fill lines from the flightcrew oxygen bottle, and the supply line for the passenger oxygen system had been broken below the cabin floor inboard of the missing cargo door.

The two cabin pressurization out-flow valves, located on the underside of the fuselage, aft of the rear cargo compartment, were found fully open. The two over-pressure relief valves located on the forward left side of the airplane were found in the normal closed position. These valves were removed and bench tested. (See section 1.16.3, Pressurization System.) The majority of the cabin floor-to-cargo compartment blowout panels were found activated. The blowout panels are designed to relieve excess

pressure differential following an explosive decompression to prevent catastrophic damage to the cabin floor structures.
The estimated damage to the airplane was $14,000,000, based on UAL's costs to repair it.

1.4 Other Damage

No other property damage resulted from this accident.

1.5 Personnel Information

The crew consisted of 3 flight crewmembers (the captain, the first officer, and the second officer) and 15 cabin crewmembers. (See appendix B.)

1.6 Aircraft Information

1.6.1 General

On February 24, 1989, the United Airlines B-747 fleet consisted of 31 airplanes, including: 2 B-747-222B, 11 B-747-SP, 5 B-747-123, and 13 B-747-122 series airplanes. N4713U was equipped with four Pratt & Whitney model JT9D engines.
The accident airplane, serial No. 19875, registered in the United States as N4713U, was manufactured as a Boeing 747-122 transport category airplane by the Boeing Commercial Airplane Company (Boeing), Seattle, Washington, a Division of the Boeing Company. N4713U, the 89th B-747 built by Boeing, was manufactured in accordance with Federal Aviation Administration (FAA) type certificate No. A20WE, as approved on December 30, 1969. The airplane was certificated in accordance with the provisions of 14 CFR Part 25, effective February 1, 1965.
The maximum calculated takeoff weight for flight 811 was 706,000 pounds. The flight plan data showed an actual takeoff weight of 697,900 pounds. The center of gravity (CG) for takeoff was computed at 20.4 percent mean aerodynamic chord (MAC). The forward and aft CG limits were 12 and 29.7 percent MAC, respectively.
At the time of the accident, N4713U had accumulated 58,815 total flight hours and 15,028 flight cycles. N4713U had not been

involved in any previous accident. Records indicated that the airplane had been inspected and maintained in accordance with the General Maintenance Program as defined in UAL Operations Specifications and in accordance with the FAA approved Aircraft and Powerplants Reliability Program. The records indicated that all required inspection and maintenance actions had been completed within specified time limits and all applicable airworthiness directives (AD) had been accomplished or were in the process of being accomplished, with the exception of AD 88-12-04, which was applicable to the B-747 lower lobe cargo door, and which had only been complied with partially. (See section 1.6.8 for explanation).

1.6.2 Cargo Door Description and Operation

Both the forward and aft lower cargo doors are similar in appearance and operation. They are located on the lower right side of the fuselage and are outward-opening. The door opening is approximately 110 inches wide by 99 inches high, as measured along the fuselage.

Electrical power for operation of the cargo door switches and actuators is supplied from the ground handling bus, which is powered by either external power or the APU. See figure 17 for a diagram of the cargo door electrical circuitry. The engine generators cannot provide power to the ground handling bus. APU generator electrical power to the ground handling bus is interrupted when an engine generator is brought on line after engine start. The APU generator "field" switch can be reengaged by the flightcrew, if necessary on the ground, to power the ground handling bus. The air/ground safety relay automatically disconnects the APU generator from the ground handling bus, if it is energized, when the airplane becomes airborne and the air/ground relay senses that the airplane is off the ground.

The cargo door and its associated hardware are designed to carry circumferential (hoop) loads arising from pressurization of the airplane. These loads are transmitted from the piano hinge at the top of the door, through the door itself, and into the eight latches located along the bottom of the door. The eight latches consist of eight latch pins attached to the lower door sill and eight latch cams attached to the bottom of the door. The cargo door also has two midspan latches located along the fore and aft sides of the door. These midspan latches primarily serve to keep the sides of the door aligned with the fuselage. There are also four door stops which limit inward movement of the door. There are two pull-in hooks located on the fore and aft lower portion of the door, with pull-in hook pins on the sides of the door frame. (See figure 4 for cargo door components).

The cargo doors on the B-747 have a master latch lock handle installed on the exterior of the door. The handle is opened and closed manually. The master latch lock handle simultaneously controls the operation of the latch lock sectors, which act as locks for the latch cams, and the two pressure relief doors located on the door. Figure 5 depicts a lock sector and latch cam in an unlocked and locked condition.

Figure 4.--Boeing 747 lower lobe forward cargo door.

Figure 5.--Cargo door latch cam and lock sector in unlocked and locked ositions.

The door has three electrical actuators for opening/closing and latching of the door. One actuator (main actuator) moves the door from the fully open position to the near closed position, and vice versa. A second actuator (pull-in hook actuator) moves the pull-in hooks closed or open, and the third actuator (latch actuator) rotates the latch cams from the unlatched position to the latched position, and vice versa. The latch actuator has an internal clutch, which slips to limit the torque output of the actuator.

Normally, the cargo doors are operated electrically by means of a switch located on the exterior of the fuselage, just forward of the door opening. The switch controls the opening and closing and the latching of the door. If at any time the switch is released, the switch will return to a neutral position, power is removed from all actuators, and movement of the actuators ceases.

In order to close the cargo door, the door switch is held to the "closed" position, energizing the closing actuator, and the door moves toward the closed position. After the door has reached the near closed position, the hook position switch transfers the electrical control power to the pull- in hook actuator, and the cargo door is brought to the closed position by the pull-in hooks. When the pull-in hooks reach their fully closed position, the hook-closed switch transfers electrical power to the latch actuator. The latch actuator rotates the eight latch cams, mounted on the lower portion of the door, around the eight latch pins, attached to the lower door sill. At the same time, the two midspan latch cams, located on the sides of the door rotate around the two midspan latch pins located on the sides of the door frame. When the eight latch cams and the two mid-span cams reach their fully closed position, electrical power is removed from the latch actuator by the latch-closed switch. This completes the electrically powered portion of the door closing operation. The door can also be operated in the same manner electrically by a switch located inside the cargo compartment adjacent to the door.

The final securing operation is the movement of lock sectors across the latch cams. These are manually moved in place across the open mouth of each of the eight lower cams through mechanical linkages to the master latch lock handle. The position of the lock sectors is indicated indirectly by noting visually the closed position of the two pressure relief doors located on the upper section of each cargo door. The pressure relief doors are designed to relieve any residual pressure differential before the cargo doors are opened after landing, and to prevent pressurization of the airplane should the airplane depart with the cargo doors not properly secured. The pressure relief doors are mechanically linked to the movement of the lock sectors. This final procedure also actuates the master latch lock switch, removing electrical control power from the opening and closing control circuits, and also extinguishes the cockpit cargo door warning light through a switch located on one of the pressure relief doors. Opening the cargo door is accomplished by reversing the above procedure.

The B-747 cargo door has eight (8) view ports located beneath the latch cams for direct viewing of the position of the cams by means of alignment stripes. Procedures for using these view ports for verifying the position of the cams were not in place or required by Boeing, the FAA, or UAL (see 1.17.5 for additional information).

Closing the door manually is accomplished through the same sequence of actions without electrical power. The door actuator mechanisms are manually driven to a closed and latched position by the use of a one-half inch socket driver. The door can also be opened manually with the use of the socket driver. There are separate socket drives for the door raising/lowering mechanism, the pull-in hooks, and the latches.

Operating procedures for the normal electrical operation of the forward and aft cargo doors are outlined in the UAL Maintenance Manual (MM). Authorization for deferral of maintenance on the door power system is contained in the UAL B-747 Minimum Equipment List (MEL). In addition, operating procedures for dispatching aircraft with an inoperative door electrical power system (manual operation) are specified in the operator's MEL.

The UAL MM differs from Boeing's recommended MM. UAL had modified Boeing printed material or replaced pages with their own methods and procedures for conducting maintenance functions. The modifications to the manufacturer's MM were accepted by the FAA through "approval" by the FAA Principal Maintenance Inspector (PMI). Electrical cargo door open/close operations in the UAL and Boeing MM's are approximately the same, except the final "Caution" statement differs in methods to ensure that the latch cams are closed:

United Airlines Maintenance Manual

CAUTION DO NOT FORCE HANDLE. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

Boeing Airplane Company Maintenance Manual

CAUTION DO NOT FORCE HANDLE. IF RESISTANCE IS FELT, CHECK LATCH ALIGNMENT STRIPES THROUGH VIEWING PORTS IN DOOR. LATCH CAMS NOT FULLY CLOSED COULD CAUSE HANDLE MECHANISM SHEAR RIVET TO SHEAR.

The following step in Boeing's MM does not appear in the UAL MM: "Check that the Cargo Door Warning Light on flight engineer panel goes out." The UAL flightcrew checklist includes a check of the warning light as part of the cockpit procedures for dispatch.

Prior to the issuance of AD-88-12-04 (see 1.6.8), UAL ramp service personnel only operated the cargo doors electrically. Manual operation was accomplished only by maintenance personnel. AD-88-12-04 required the additional procedure of recycling the master latch lock handle following manual operation of the latch actuator.

1.6.3 UAL Boeing 747 Special Procedures--Doors

The Safety Board's investigation revealed that UAL had published a "special maintenance procedure" in the UAL MEL for manual operation of the cargo door. The Maintenance Manual Special Procedures, 5-8-2-52, dated January 1988, were incorporated into UAL's MEL for use by maintenance controllers and work foremen in issuing instructions or procedures to mechanics. The procedure allowed the use of a special 1/2-inch socket drive wrench as the primary tool for use in manually opening or closing the cargo door. The document further authorized, as an alternate tool, an air-driven torque-limiting screwdriver. UAL procedures required approval by San Francisco Line Maintenance and the station maintenance coordinator before an air-driven screwdriver could be used to operate the doors of a B-747 airplane with an inoperative cargo door power system.

At the Safety Board's public hearing, the FAA PMI and the FAA B-747 maintenance inspector for UAL testified that prior to the accident they were unaware of an FAA authorization for UAL's use of an air-driven torque-limiting screwdriver on B-747 cargo doors. However, the FAA's approval for the use of the tool was noted in the MEL section of the airline's maintenance manual. The original approval had occurred before the current inspectors assumed their respective positions. Both testified that they had not reviewed UAL's B-747 MEL because they assumed that the previous inspectors had reviewed it.

According to UAL, the calibration/adjustment for the torque-limited air-driven screwdrivers was tested every six months. Safety Board investigators found no records for the calibration/adjustment of the power tools used to manually open and close UAL B-747 cargo doors.

The Safety Board received statements from UAL supervisory maintenance personnel at all UAL stations and contract facilities for B-747 operations indicating that air-driven screwdrivers had not been used by maintenance personnel to open or close the forward cargo door on N4713U in the months prior to the accident.

1.6.4 UAL Maintenance Program

Airplanes operated by UAL are maintained under an FAA-approved continuous airworthiness maintenance program, as required by 14 CFR Part 121, Subpart L. The requirements of the UAL maintenance program are detailed in their Operations Specifications, dated November 21, 1988. Generally, UAL has an overall in-house capability to perform virtually all of the maintenance required on its own airframes and powerplants. All of the required major airframe and powerplant maintenance for N4713U had been performed at the UAL maintenance facility in San Francisco, California.

UAL's maintenance and inspection program is scheduled either at specific flight hour or calendar intervals. These maintenance and inspection programs are designated as: Service No. 1, Service No. 2, or A, B, C, MPV, and D Checks.

The work scope of Service Checks consists of a general inspection of the airplane and engines, including servicing of consumable fluids, oxygen, and tire pressures. The Service No. 1 check involves an inspection at each maintenance facility where the airplane lands. The Service No. 2 check is performed at a maintenance facility where the airplane is scheduled for at least 12 hours of ground time. The maximum time interval between Service No. 2 Checks is not to exceed 65 flight hours.

The "A" Check is performed at intervals not to exceed 350 flight hours. This check includes an extended inspection of the cockpit, cabin, cargo compartments, landing gear, tires, and brakes. It does not include a detailed inspection of the cargo doors.

The Phase Check ("B" Check) is scheduled on a calendar basis, not to exceed 131 days. The scope of the "B" Check contains items of inspection such as interior safety equipment and functional verification of various aircraft systems and components. It does not include a detailed inspection of the cargo doors.

The "C" Check is heavy maintenance oriented and is scheduled on a calendar basis, every 13 months. The "C" Check work scope is substantial and includes:

structural inspection items;

corrosion repair;

prevention and inspection of critical flight control systems; and,

a detailed inspection of the cargo doors.
The Mid-Period Visit (MPV) Check is a heavy maintenance inspection that is scheduled at intervals not to exceed 5 years. Items requiring scheduled overhaul are contained in the check as well as inspections of the airplane structure and interior.
The D Check, completes the routine scheduled B-747 maintenance plan and is scheduled at intervals not to exceed 9 years. The work scope is very similar to the MPV Check and consists of heavy maintenance to the airplane structure, landing gear, interior, and airplane systems, including the cargo doors.

1.6.5 Maintenance Records Review

A review of the airplane's history indicated that the forward and aft cargo doors were the original doors and neither had been removed for repair or replaced for cause. There was no record of major repair to either door or adjacent airplane structure.
The forward cargo door's forward mid-span latch pin had been removed because of gouging of the pin surface, during the last "C" check on
November 28, 1988. According to the available maintenance documents, including the most recent "D" check, a full cargo door rigging check had not been accomplished. UAL maintenance personnel indicated that no rigging of the forward or aft cargo doors was required during the following checks:

1. "D" check accomplished April 1984;
2. "C" checks accomplished November 11, 1987, and November 28, 1988; and,
3. "B" checks accomplished March 21, 1988 and July 27, 1988;

The records prior to the "D" check in 1984 and the "C" check accomplished in November 1987 were not required to be retained. This procedure complies with FAR 121.380.
The logbook of N4713U was reviewed and all numbered pages were in sequential order with none missing. The airplane had been released for flight by UAL, HNL Maintenance, in accordance

with UAL procedures. The Los Angeles to HNL segment of flight 811, on February 23, 1989, generated four logbook discrepancy entries. All items were cleared by HNL maintenance and none were related to the cargo door. No new deferred items were generated and no current deferred items were corrected. The Maintenance Release document for flight 811 indicated that all deferred items were in accordance with the UAL Minimum Equipment List (MEL) and none referenced the forward cargo door.

UAL stores its maintenance information in an "electronic logbook," entitled Aircraft Maintenance Information System (AMIS). This system tracks on a daily and worldwide basis the flightcrew defect reports, all nonroutine maintenance defects, and maintenance corrective actions for the UAL airplane fleet. The system follows an Airline Transport Association (ATA) chapter format. According to UAL, the AMIS information is used as part of UAL's FAA approved maintenance reliability program affording the capability to assess trends at any given time.

A complete history of N4713U was reviewed for the following ATA Chapters:

Chapter-00-Miscellaneous

No significant items associated with the cargo door systems.

Chapter-21-Air Conditioning and Pressurization

An entry, dated August 19, 1988, indicated "Auto and Standby pressure controllers were erratic." UAL maintenance cleared this item as "Checked per Maintenance Manual Chapter (MM) 21-31-00.

Chapter-31-Instruments (Not related to any specific system)

No significant items associated with the cargo door systems.

Chapter-52-Doors (Cargo door section only)

During the period September 7, 1988, through November 1, 1988, a series of five discrepancies on the forward cargo door's electrical opening and closing system were noted. Ground handling personnel were required to operate the door by the manual system. On November 1, 1988, UAL maintenance corrective action for this discrepancy was signed off as, "replaced power unit [lift mechanism] per Maintenance Manual Chapter 52-34-02.

An expanded AMIS history of the N4713U forward cargo door system was prepared beginning December 1, 1988, and continuing until the date of the accident. The history tracked the airplane by each flight and station transited.

During the period December 5, 1988, through December 23, 1988, eight defect reports regarding the opening and closing of the forward cargo door were entered into the system. The reported defects involved problems with the cargo door not always operating with the normal electrical system. Appendix E contains the details of the writeups and corrective actions.

During the period December 23, 1988, through February 23, 1989, two forward cargo door discrepancies were noted on N4713U. On January 3, 1989, the discrepancy was, "Manual lock seals broken." The corrective action was signed off as, "recycled [door] per placard on door and documented. No door problems." On January 15, 1989, the discrepancy was, "cargo door seal, lower aft corner is torn and loose from retainer." The corrective action was "repaired seal." There were no further recorded discrepancies.

On February 23, 1989, a written discrepancy noted "Aft cargo door damaged aft lower corner." The corrective action listed, "Interim repair per (EVA) LM-8-433. Accomplish permanent repair within 60 flight hours."

Chapter-53-Structures (Fuselage)

During the period March 1988, through February 24, 1989, one defect was noted for each of the forward and aft cargo doors on N4713U.

Forward Cargo Door.--On September 6, 1988, the discrepancy was, "Approximately six inches of forward cargo door jamb damaged center of lower side sealing surface." The corrective action was, "Installed doubler and sealed area."

Aft Cargo Door.--On April 22, 1988, the discrepancy was, "Aft cargo door rear sill latch does not spring up to lock." The corrective action was, "Replaced latch."

1.6.6 Service Difficulty Report Information

A review was made of the Service Difficulty Reports (SDRs) for ATA Chapter 52 for all UAL Boeing 747 airplanes. Thirty-nine SDRs were recorded over the period January 31, 1983, through March 21, 1989. The following summarizes data concerning the forward and aft cargo doors:

cases of corrosion;

cases of cracking;

cases of door open (false) indications;

cases where cabin did not pressurize;

cases of cabin pressure loss; and

case of dent caused by ground equipment.

None of the noted SDR cases were recorded for N4713U.

1.6.7 Service Letters and Service Bulletins

Boeing issues information to its customers via Service Letters (SL's) and Service Bulletins (SB's) to inform operators of reported and anticipated difficulties with various airplane models. Twelve SL's provided guidance for maintenance or information applicable to the B-747 cargo doors. Twenty-nine SB's provided guidance for maintenance or information applicable to the B-747 cargo door.

SB-747-52-2097, "Pressure Relief Door Shroud Installation--Lower Lobe and Side Cargo Doors," was issued on June 27, 1975. Revision 1 to SB-747-52-2097 was issued November 14, 1975. In general, the SB recommended the installation of shrouds on the inboard sides of the cargo door pressure relief door openings. The purpose of the shrouds was to prevent the possibility of the pressure relief doors being rotated (blown) to the closed position during the pressurization cycle. This condition could only occur if the master latch lock handle had been left open and the flightcrew failed to note the cargo door open warning before takeoff.

UAL records for N4713U indicated that SB-747-52-2097 had been complied with and the shrouds had been installed on the forward and aft cargo doors. However, examination of the aft cargo door on N4713U revealed that the shrouds were not in place. UAL could not find records to verify if the shrouds had been installed or if they had been removed from either door.

1.6.8 Airworthiness Directives

There had been 141 Airworthiness Directives (ADs) issued that were applicable to the accident airplane. Two ADs were pertinent to the cargo door. AD 79-17-02-R2 ("Inspection of Fore and Aft Lower Cargo Door Sill Latch Support Fittings,") required an inspection every 1,700 flight hours. The second, AD 88-12-04 ("To Insure That Inadvertent Opening Of The Lower Cargo Door Will Not Occur In Flight,") issued on May 13, 1988, required an initial one time inspection of the cargo door latch locking mechanisms within 30 days of issuance of the AD, and certain repetitive inspections until terminating action for the AD was taken.

The circumstances of a Pan American World Airways (Pan Am), Boeing 747-122 cargo door opening in flight (see 1.17.1 for details) led to the issuance of Boeing Alert Service Bulletins (ASB) 52A2206 on April 8, 1987, and 52A2209 on August 27, 1987, entitled, "Doors - Cargo Doors Lower Lobe Forward and Aft Cargo Doors, Latch Locking System Tests, Operation and Modification." Tests and investigation revealed that latch lock sectors would, in some instances, not restrain the latch cams from being driven open manually or electrically. Movement of the latch cams without first moving the lock sectors to the stowed [unlocked] position would cause bending, gouging, and breaking of the sectors. The FAA issued AD-88-12-04 to make the provisions of SB's 52A2206 and 52A2209 mandatory.

The terminating action for AD 88-12-04 called for installing steel doublers to add strength to the lock sectors to prevent the latch cams from being able to be driven to the open position manually or electrically with the sectors in the locked position. AD 88-12-04 also required that, if the door could not be operated normally (electrically), a trained and qualified mechanic was to open and close the door manually, rather than ramp service personnel. Further, the AD required an inspection of the lock sectors for damage once a cargo door was restored to electrical operation after any malfunction had required manual operation of the door. The amount of time allowed for completing the terminating action portion of AD 88-12-04 was either 18 months or 24 months, from the issue date of the AD, depending on the Boeing 747 model series. Terminating action for the AD had not been accomplished on N4713U prior to the accident, nor was it required since, for this airplane, the deadline for compliance with the terminating action was January 1990. According to UAL, N4713U was scheduled for completion of the terminating action in April 1989, when the airplane was scheduled for other heavy maintenance.

During the Safety Board's investigation it was determined that a clerical error was made by UAL personnel, while attempting to expedite the processing of an advanced copy of a Notice of Proposed Rulemaking (NPRM 87-NM-148-AD), preceding AD 88-12-04. The error involved the omission of one line of text during the typing of the document. Because of that error, the portion of the text of the NPRM (and the final text of the AD) was left out of UAL's maintenance procedures. The omitted text required an inspection of the B-747 cargo door lock sectors every time a cargo door was restored to normal (electrical) operation after manual operation was required.

The UAL maintenance internal auditing system, including quality assurance personnel, did not detect the omission until after the accident. UAL personnel stated that, for unknown reasons, no one within the maintenance or quality assurance programs had reviewed the final AD language for comparison with the UAL maintenance procedure.

A review by Safety Board investigators of forms used by UAL to verify compliance with applicable FAA AD's issued indicated that all of the applicable mandatory ADs were satisfied within their specified time limits. The list provided by UAL to the FAA as part of the FAA's oversight responsibilities showed compliance with AD-88-12-04, with the exception of the terminating action.

Section 1.17.3 contains information relevant to the B-747 cargo door corrective actions taken since the accident.

1.7 Meteorological Information

The accident occurred in night visual meteorological conditions. No adverse weather was experienced, although the flight did have to deviate around thunderstorms during the descent.

1.8 Aids to Navigation

There were no navigational problems.

1.9 Communications

There were no radio communication difficulties between flight 811 and air traffic control (ATC). Members of the flightcrew did not have any difficulty in verbally communicating with each other; however, attempts to communicate with the cabin crewmembers by interphone were unsuccessful following the explosive decompression.

1.10 Aerodrome Information

After the explosive decompression, the airplane returned to HNL, a 14 CFR Part 139 certificated airport on the island of Oahu, Hawaii. The airport is located about 4 miles west of Honolulu, Hawaii.

HNL is a "joint use" airport that is used by the State of Hawaii, the U.S. Air Force, general aviation, commercial, air carrier, air taxi, and military aircraft. Aircraft Rescue and Fire Fighting (ARFF) services are provided by State and Hickam Air Force Base ARFF units. Prior to the emergency landing at Honolulu, flight 811 requested that all available rescue and medical equipment to be on hand when they landed. When the crash alarm was broadcast, all civilian and military fire units responded and were in position in 1-minute at pre-designated stations at runway 8 left.

The Safety Board's investigation revealed that there was no direct radio communications between the State Airport vehicles and Hickam ARFF vehicles. Because there were no direct radio communications, the Chief of the airport's units had to drive his vehicle to the vehicle of the Chief of the Hickam units to coordinate the positioning of ARFF units prior to the landing of United 811.

The Hickam vehicles are painted olive drab camouflage. During the response, the Chief of the State ARFF vehicles observed a near collision between a State and a Hickam vehicle. He attributed this to the camouflaged Hickam vehicle not being visually conspicuous in spite of the fact that each of the vehicles had a red rotating beacon operating. The response took place on a moonless night and in light rain.

1.11 Flight Recorders

The airplane was equipped with a Sundstrand model 573 digital type Flight Data Recorder (DFDR) and a Sundstrand model AV557-B Cockpit Voice Recorder (CVR).

Examination of the data plotted from the DFDR indicated that the flight was normal from liftoff to the accident. The recorder operated normally during the period. However, the decompression event caused a data loss of approximately 2 1/2 seconds. When the data resumed being recorded, all values appeared valid with the exception of the pitch and roll parameters. Lateral acceleration showed a sharp increase immediately following the decompression. Vertical acceleration showed a sharp, rapid change just after the decompression and a slight increase as the airplane began its descent.

The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.

1.12 Wreckage and Impact Information

An extensive air and surface search of the ocean conducted immediately following the accident failed to locate the portions of the airplane lost during the explosive decompression. However, the Safety Board, as well as other parties to the investigation, pursued several avenues to search for and recover the cargo door. Navy radar near Honolulu tracked debris that fell from the airplane when the cargo door was lost. Refinement of the radar data led to a probable "splashdown" point in the ocean. Further assistance from the Navy regarding the ocean currents and drift information led to a probable location of the cargo door and associated debris on the ocean floor.

The undersea search operation was begun on July 22, 1990, using the Orion, a state-of-the-art Navy side-scanning sonar "fish." Searching in the area selected by analysis of radar data and undersea currents, the Orion located a debris field on its first pass over the 14,200-foot-deep ocean floor. The second pass located a significant sonar target, which later analysis indicated was probably the cargo door. Since the Orion is only capable of searching, the debris field was marked with transponders for use during the subsequent recovery phase.

On September 14, 1990, the recovery ship Laney Chouest sailed from Pearl Harbor with the manned, deep-sea submersible Sea Cliff. Safety Board, FAA, Boeing, and UAL engineering staff assisted the recovery team aboard the Laney Chouest. After four dives in the area previously identified as the debris field, only pieces of cargo container and other small debris from the airplane had been recovered. (It appears that the significant target identified by the Orion was a piece of cargo container rather than the cargo door.) On the following dive, however, the lower portion of the cargo door was located and recovered. The fuselage structure above the cargo door was located and raised to the surface on the sixth dive, but heavy seas prevented its recovery. The upper portion of the door was recovered during the Sea Cliff's seventh dive on October 1, 1990. Afterward, it was decided that no further effort could be justified to recover the fuselage structure above the cargo door, and the recovery mission was terminated.

Following recovery of the cargo door, each piece was sprayed with a corrosion inhibitor. The ship promptly returned to Pearl Harbor, and the retrieved door portions were removed and examined before being shipped to Seattle, Washington, for detailed examinations under the supervision of Safety Board staff.

Visual examinations on the recovery ship and in Pearl Harbor confirmed that the cargo door lock sectors were in the locked position and that the latch cams were in the nearly open position. Figure 6 depicts the position of the lock sectors and cams as recovered from the ocean. There was no evidence of progressive fractures in the door structure.

The cost for the search mission was $193,000, and the cost for the recovery mission was $250,000. These costs were shared by the Safety Board, the FAA, UAL, and Boeing. Section 1.16 contains information on the examination of the recovered wreckage.

1.13 Medical and Pathological Information

Appendix D contains a list of injuries.

1.14 Fire

There was no fire in the cabin or fuselage. The fires in engines No. 3 and 4 were extinguished after the engines were shut down.

1.15 Survival Aspects

The fatal injuries were the result of the explosive nature of the decompression, which swept nine of the passengers from the airplane.

At 0210, the FAA notified the U.S. Coast Guard that a United Airlines, Inc., B-747, with a possible bomb on board, had experienced an explosion and was returning to HNL. The Coast Guard Cutter, Cape Corwin, departed Maui at 0248 to search the area for debris and the missing passengers. Ultimately, 4 shore commands, 13 surface/air units, and approximately 1,000 persons took part in the combined search and rescue (SAR) operation. The search was t™ erminated at 1200 on February 26, 1989, without recovery of any passenger bodies.

The flight attendants had approximately 20 minutes to prepare the cabin and the passengers for an imminent ocean ditching, and subsequently, for an emergency evacuation. During the 20 minutes they attended to injured flight attendants and passengers, attached the face masks to their emergency oxygen bottles, helped each other don life preservers, helped numerous passengers don life preservers, held up safety cards and life vests to call attention to these items for passengers to use, briefed "helper" passengers to assist in the evacuation, cleared debris away from the exit doors and aisles, closed the doors of the storage compartment above doors 2 left and 2 right, prepared the cabin for an emergency evacuation, and told the passengers to brace for impact.

Several problems were experienced by the flight attendants and the passengers following the decompression, while preparing for a possible ditching, and preparing for the emergency evacuation.

These problems included difficulties encountered by flight attendants in connecting face masks to their portable oxygen bottles, the lack of a sufficient number of megaphones, limited visibility from a flight attendant seat, overhead storage compartment doors opening, and donning and fastening life preservers.

Federal Aviation Regulation 14 CFR 25.1447 (c)(4) requires that "portable oxygen equipment must be immediately available for each cabin attendant." Those portable oxygen bottles on N4713U, which were readily available, were not immediately usable because the masks were not attached to the regulators. The flight attendants reported difficulties in attaching the masks to the regulators.

The aft purser ran back to the flight attendant jumpseat at door 5-left for a portable oxygen bottle. However, she found no bottle at this location (none was installed). She then ran back to the 4-left jumpseat, by which time she was "light headed." After the aft purser reached jumpseat 4-left, flight attendant No. 14, who was already sitting there, placed an oxygen mask on her face. The aft purser further stated, "considering the fact that in this case there was no other available source of oxygen, you can't imagine how horrible I felt going back there needing oxygen but finding no oxygen bottle at 5-left. It was terrifying."

A portable emergency oxygen bottle was not required to be stowed at the flight attendant seat at exit 5-right; however, one was stowed in the right coat closet behind the flight attendant seat. In addition, the left side closet and rest rooms were physically separated from the right side closet and rest rooms. This arrangement requires a flight attendant, who was seated at exit 5-left to walk around to the right side of the cabin to obtain the oxygen bottle.

Communication between the flight attendants and passengers was very difficult because of the high ambient noise level in the cabin after the decompression, even though the public address (PA) system was operational. Flight attendants were located at each of the 10 exit doors, yet there were only two megaphones required to be on the airplane; one located at door 1-left and another located a 4-left.

The flight attendants, who were responsible for each of these two doors, used the megaphones to broadcast commands to passengers in their immediate areas and to other flight attendants in preparation for the landing and subsequent evacuation. The other 13 flight attendants (including the one deadheading flight attendant) had to shout, use hand signals, and show passengers how to prepare for the evacuation by holding up passenger safety cards, so passengers could review the information and also know how to put on their life preservers.

As soon as the decompression occurred, the flight attendant in the upper deck business class section went to her jumpseat and donned her oxygen mask, life preserver, and restraint system. While she waited for instructions, and because of intense cabin noise she had to communicate with passengers by holding up a safety card and a life preserver. Passengers sitting in the front rows, in turn, showed safety cards and life preservers to other passengers seated behind them. Eventually everyone understood that they were to read the safety card and put on their preservers. However, the 5 foot 3 1/2 inch flight attendant stated that her jumpseat was so low that she could not directly observe the passengers in the 4th row (last).

A two door overhead stowage compartment that had formerly stored a life raft was located above each exit door. These compartments contained blankets and passenger carry-on luggage. At doors 2-left and 2-right the doors of each compartment had opened downward and blocked each exit. Also the contents of the compartments fell to the floor at the exits. The doors had to be closed before the evacuation because they

partially blocked the exit.
The chief purser was not able to tighten the life preserver's two straps around her waist and needed the deadheading flight attendant to tighten them for her. Several flight attendants and passengers had difficulties connecting the two straps around their waists. One flight attendant helped about 36 passengers don their preservers.
Safety Board investigators and United Airlines personnel examined several life preservers from each of the types of preservers produced by five manufacturers. The strap of one manufacturer's preserver was very difficult to tighten around the waist while another from the same manufacturer was easy to tighten. The two vests had different strap material and strap adjustment fittings. Also, the straps are very difficult, if not impossible, to tighten when they are pulled at an acute angle from the wearer's body, i.e. from about 45 to 70 degrees. Holding the hands and straps closer to the waist facilitates easier adjustment of the straps.

1.16 Tests and Research

1.16.1 Cargo Door Hardware Examinations

1.16.1.1 Before Recovery of the Door

The following forward cargo door closing and latching components were returned to the Safety Board's Materials Laboratory for analysis after they were documented in place on the airplane:
Two pull-in hook pins, one from the lower end of the forward side of the door body cutout forward frame, and one from the lower end of the aft side of the body cutout aft frame, with housings;
Two mid-span pins, one from the forward side of the door body cutout forward frame, and one from the aft side of the door body cutout aft frame.
All components were initially examined while installed on the

airplane. All eight forward cargo door latch pins, with housings, were removed for further laboratory examination. Also, for comparison, one of the latch pins, with housing, from the aft cargo door was also removed. For orientation purposes, the eight lower latch pin assemblies are referred to by number, with the No. 1 latch pin being the most forward on the lower door sill, and the No. 8 pin being the most aft. When referencing a circumferential location on the latch pins or mid-span pins, a clock position was used. The clock code was oriented looking forward with 12 o'clock being straight up and 9 o'clock being directly inboard.

Based on the orientation of the latching mechanisms, the fully unlatched latching cams would first contact the latch pins from about the 1:15 o'clock position to the 7:15 position as the door was closed. As the cams are being latched around the pins, they would rotate approximately 80(, making contact with the pins from about the 4:15 position to the 10:15 position (See figure 7).

Detailed examination of the exposed surface of the pins (the portion of the pins extending from the housings) revealed various types of wear and damage. In general, all of the forward door cargo latch pins had smooth wear over the entire portion of the pin area contacted by the cams during normal closing and opening of the door. The pins also had distinct roughened (smeared) areas between the 6:15 and the 7:30 positions (See figure 8). The roughened areas had evidence of "heat tinting" and transfer of cam material to the surface of the pins. On pins 1 and 8 the roughened areas extended past the pin bottom to the 5:00 position. The 7:30 position approximately corresponds to the area on the pin where the lower surface of the cam would be relative to the pin when the latch cams are in the unlatched or nearly unlatched position.

The forward pull-in hook pin was not significantly bent, but the structure to which it was attached was deformed outward, so the hook pin was deflected significantly outward. Three of the four bolts holding the aft pull-in hook pin had sheared, so the hook pin was also deflected outward. Both hook pin ends were damaged, but neither pin was significantly deformed along its length. There was significant heat tinting on the damaged area of the forward hook pin. Boeing engineering calculations determined that the pull-in hook pins would fail at a 3.5 psi differential cabin pressure with the latch cams unlatched.

The forward mid-span latch pin was relatively undamaged. The aft mid-span latch pin had definite areas of damage. Both pins had wear areas where the cams would contact the pins during latching.

1.16.1.2 After Recovery of the Door

The documentation of the recovered cargo door was divided into four areas: 1) door structure, 2) master latch lock system, 3) latch system, and 4) hook system. A description of the recovered door follows.

1. Door Structure:

The cargo door had fractured longitudinally near the mid-span lap joint near stringer 34R, just beneath the mid-span torque tubes. Except for an area of missing skin between frames 2 and 3 and a portion of frame webs where the upper latch lock torque tube had torn out, the frames and skin of the upper door piece mated to the lower door piece.2 Several areas of the upper door skin along the longitudinal fracture were bent back. In addition, a large area of lower door skin between frame 6 and the aft door edge had peeled downward from the fracture line. The two door pieces are shown together in Figures 9 and 10.

Examinations of the fracture surfaces of the skin and frames revealed no evidence of pre-existing cracks. All fractures were typical of overstress separation.

Seven of the eight lock sector slots in the lower beam showed evidence of contact and scraping by the lock sectors. Only the No.

1 lock sector slot was undamaged, although the bracket forward and above the No. 1 slot did appear to have been damaged by contact from the lock sector (slots numbered 1-8, forward-aft). The direction of the scraping on the slots could not be determined conclusively.

The decal covering the latch actuator manual drive port was found broken circumferentially around the edge of the port cover, which was loose and rotated from its normal position (See figure 11). There was an impression in the decal similar to a Phillips-head screw slot in line with the center of the retainer screw securing the cover. There was also a 0.06-inch-long linear slit from 10 to 4 o'clock approximately centered over the retainer screw head (See figures 12 and 13). There was no rotational tearing and no loss of decal material in the area covering the screw head location. During examinations of the door at Boeing, it was noted that the retainer bracket on the inside of the latch actuator manual drive port cover was bowed outward; the port cover was not deformed. The retainer bracket on the inside of the hook actuator manual drive port cover was similarly bowed outward, and the port cover was bowed outward.

The hinge that attaches the cargo door to the fuselage is comprised of several hinge sections--those attached along the upper edge of the cargo door and those along the fuselage just above the cargo door cutout--interconnected with hinge pins. The hinge pins and all hinge sections from N4713U's forward cargo door were intact; all hinge sections rotated relatively easily. All attach bolts from the hinge sections on the door remained attached; conversely, no bolts remained attached to the hinge sections on the fuselage. Several areas on the hinge sections, such as the fuselage hinge sections, showed evidence of contact from the door during overtravel (See figure 14). In addition, the fuselage forward hinge sections

were slightly bent. The upper flange of the door, to which the door hinges are attached, was not deformed. The forward cargo door can rotate open 143 degrees before the hinge would deform, permitting the door to contact the fuselage above.

Examination of the outer skin contour of the upper door piece revealed that it had been crushed inward. There were also many areas on the outer skin where blue and red paint transfer marks could be seen. These marks were generally forward of the aft pressure-relief door, and the blue marks were located above the red marks. The UAL paint pattern incorporates red and blue stripes along the fuselage above the cargo door. Figure 15 is a plot of the documented paint marks on the upper door piece.

There was no evidence of the pressure relief door shrouds found on the forward door; however, most of the inner door lining to which the shrouds attach was missing.

2. Master Latch Lock System:

All eight lock sectors were found in the locked position--actually past the fully locked position. They had been pulled through the lock sector slots in the lower beam of the cargo door. (When they are fully locked, the lock sectors should be recessed in the lower beam approximately 3/8 inch). All lock sectors had deflected off the high shoulder of the latch cams due to interference with the partially unlatched cams. Prior to disassembly of the components, the interference between the cams and the lock sectors was removed by rotating the cams to the latched position.

Examination of the lock sectors disclosed that the bottom of the lower arm of each lock sector was gouged. For seven of the eight lock sectors, the distance from the main gouge area to the location of the interference between the latch cam and the lock sector was approximately 0.75 inch. (The No. 2 lock sector was corroded and had fractured at the location of the large gouge common to the other seven lock sectors. Consequently, it was not in contact with the No. 2 latch cam when the door was retrieved).

The master latch lock handle housing and trigger were found relatively flush with the door outer skin. The top of the handle was recessed approximately 0.50 inch inward from flush, and the bottom of the handle was protruding approximately 0.40 inch outward from flush (See figure 16). This

Figure 15.--Documented paint marks on outer skin of upper door piece. Dashed line is approximately 8 degrees from horizontal.

position of the handle indicates that the lock sectors were in a position past fully locked. The fuse pin was found in three pieces but was heavily corroded. The handle housing was undamaged. Two of the three connecting rods between the master latch lock handle and the lock sector torque tube were bowed slightly, but they were otherwise intact. No deformation was observed on any section of the lock sector torque tube, although one of the six bearings assembled on the torque tube had been damaged. The No. 3 bearing inner race and its torque tube locator sleeve were displaced forward approximately 0.20 inch from the bearing housing centerline. The outer race was broken and pushed forward out of the housing.

The lower two connecting rods between the lock sector torque tube and the torque tube below the pressure-relief doors were undamaged; however, the upper connecting rod had separated at the upper, tapered end. The torque tube below the pressure-relief doors were missing, and the pressure-relief door connecting rods had separated at the lower, tapered end. The remaining portion of each rod was undamaged, but the forward pressure-relief door was jammed open into the cutout.

3. Latch System:

All eight lower latch cams were found in a nearly unlatched position, and all of them were binding against the lock sectors except the No. 2 cam (lock sector No. 2 had broken). Latch cams 1-6 were approximately 62 degrees from the fully latched position, and cams 7 and 8 were approximately 70 degrees from fully latched. Full rotation of the latch cams is 80 degrees.

Several of the lower latch cams contained compression and smearing damage on the lower lip of the latch cam cavity ("lower" relative to an open cam). This damage is consistent with the forceful movement of the cams across the latch pins.

The four rods between the latch actuator torque tube and the four bellcranks containing the latch cams were attached and undamaged. No section of the latch actuator torque tube was damaged, and the bearings/supports along the tube were intact. The latch actuator was removed and later disassembled. No anomalies were found.

4. Pull-in Hook System:

The forward and aft pull-in hooks were found near the closed position. Both of them exhibited wear patterns consistent with contact with the pull-in hook pins during door operation. For both the forward and aft hooks, the inboard edge of the pull-in hook channel contained compression and smearing damage consistent with a forceful movement of the hooks over the pins while the hooks were in the closed or nearly closed position.

1.16.2 Forward Cargo Door Electrical Component Examinations

1.16.2.1 Before Recovery of the Door

Several electrical components associated with the operation of the forward cargo door were examined on the airplane and were then removed for further testing. These components included the No. 2 ground handling power bus relay, the air/ground safety relay, the No. 1 auxiliary power circuit breaker, and the outside and inside door control switches. All of these components were tested for both single faults and intermittent failures. The test results showed that all of the switches/relays were functional, although a loose wire connection was found on the outside door control switch. This loose wire connection showed evidence of overheated insulation on the two terminal lugs that attach to terminal No. 5, and there was evidence of a burn (arc point) on the top of the screw head for terminal No. 5. Terminal No. 5 is associated with power for the door "close" cycle, and not the door "open" cycle.

An electrical continuity check was performed on the cockpit cargo door warning light system components that remained with the airplane. This check confirmed the integrity of the circuit from the door area to the cockpit. The examination of the two bulbs that comprise the forward cargo door warning light revealed that one bulb was inoperative. The other bulb, which is in parallel with the inoperative bulb, was found operative. The illumination of the display legend, which reads "FWD CARGO DR" on the flight engineer's panel, was discernible with one bulb inoperative. A functional check of the circuit, which allows the cockpit warning lights to be dimmed during night operations, was also performed. The check consisted of removing the card containing this circuit and installing it in another B-747. The test was satisfactory in that the dim/bright circuit functioned properly.

1.16.2.2 After Recovery of the Door Switches--General

The cargo door was recovered with all of its position sensing switches installed in their proper locations. The electrical junction box was found attached to the door but damaged. The switches recovered and examined were: S2 Master Latch Lock; S3 Door Warning; S4 Latch Close; S5 Hook Position; S6 Fwd Mid-Span Latch Open; S7 Door Close; S8 Hook Close; and S9 Aft Mid-Span Latch Open. Figure 17 provides a diagram of the cargo door's electrical circuitry.

Five of the eight position-sensing switches installed on the door had evidence of external damage to the switch housing. The damage on four switches (S2,S3,S4,S8) consisted of primarily compression dimpling on the housing. The S5 switch exhibited mechanical impact damage on the switch housing and mounting bracket. The striker assembly for switch S8 was loose (2 of 3 rivet fasteners sheared). The electrical wiring recovered with the door exhibited signs of tensile separation from overload at all failure points examined.

Each switch was photographed and its installed position was documented. Electrical continuity readings were taken with an ohmmeter across the poles of each switch at the first point of wire separation as found on the door. After the readings were recorded, all switches were removed from the door so that photographs and x-rays of each switch could be taken. Electrical continuity readings were retaken.

Disassembly of each switch consisted of: (1) drilling two holes in the switch housing to release trapped water from the switch (2) cutting a small window in the switch housing to examine the internal basic switches (3) removing the housing, (4) removing the internal bracket, and (5) removing basic switch covers.

During the drilling step, water was released from every switch when the holes were drilled in the switch housing. The water was filtered into a glass container. The quantity was not measured but appeared to be less than 5 mL. The residue from the filtered water trapped on the filter media had a blue-green color.

After the switch housing was removed, an ohmmeter was connected across the 1-2 poles of the switches that would not transfer electrical continuity (S2,S3,S4,S6,S7) when actuated. The rivets were then drilled out of the internal bracket. After the last of the two rivets were drilled out, the switch contacts

Figure 17b.--Diagram of cargo door electrical circuitry.

transferred to the other pole on S2, S3, and S4. On S6, the used3 basic switch was held closed by its plunger. S7 transferred after the switch housing and water inside were removed.

During removal of the basic switch covers, a trend was noted in the discoloration of some of the basic switches. The used switch had a reddish-brown coloration. The unused switch was not discolored.

Each switch was found to be wired correctly to its poles and through its contacts within the basic switches. All contacts operated with light finger pressure after removal of the basic switch covers. There was no evidence of pitting, excessive corrosion, or heat distress in the contacts of any of the switches. The following sections detail pertinent observations concerning each switch.

The S2 master latch lock is given particular significance because of its function to protect against inadvertent door operation and is thus described in more detail. It is a single-pole double-throw (SPDT) switch used to sense the unlocked position of the door lock sectors. The switch is mounted in the aft lower corner of the door. A bracket attached to the No. 7 lock sector depresses the switch when the door lock sectors are rotated to their unlocked position. When the bracket attached to the lock sector contacts the switch plunger and depresses it, the circuit path through the switch is closed and 28VDC electrical control power to the door is established. When the force on the plunger is relaxed, the circuit is opened and 28VDC electrical control circuit is removed.

The wires leading to the S2 switch had been cut by the team after the recovery in an attempt to test continuity through the switch. The door recovery team reported that it found continuity through the 1-3 contacts but not through the 1-2 contacts. The switch plunger was actuated by the recovery team. The recovery team noted that the switch did not transfer continuity during these tests. The operation of the switch plunger would normally transfer continuity. Subsequent detailed examination of the S2 switch confirmed the findings of the recovery team.

The area around the upper face of the internal bracket was bent toward the basic switches and had evidence of corrosion residue. The bracket was found broken. The switch contacts transferred from the 1-3 actuated position to the 1-2 nonactuated position when the bracket was removed. Scanning electron

microscope examination of the fracture surfaces revealed evidence of overload and corrosion.
The external switch housing was dented. The final examination performed on the switch consisted of removing the plastic covers on the basic switches. Prior to removal of the basic switch covers, it was noted that the cover to the used basic switch was cracked. The contacts functioned normally when exercised by light finger pressure.
Microscopic examination revealed a black discoloration near one of the lower contact posts of the used basic switch. Energy dispersive spectrometric examination of the residue disclosed the presence of gold, iron, magnesium, sodium, and chlorine. No mechanical or electrical anomalies were detected with the basic switch contacts.
Additional testing was performed by Boeing on switches of a similar design to those used on the accident airplane's cargo door. The testing was conducted to identify conditions that would result from salt water immersion at a pressure depth of 14,200 feet for 18 months. The testing verified that external damage to the switch housing occurred at pressure depths of 7,000 feet and greater. Switch seal leakage and subsequent internal corrosion was also noted. None of the testing performed by Boeing duplicated internal switch damage that caused basic switch contact closure or internal damage to the switch support bracket.
Wiring:
The electrical wiring recovered with the cargo door was documented in place before being removed for further tests. About 40 percent or 112 feet of wire from the original length of approximately 274 feet was recovered and examined. Of this amount, about 46 feet of wire installed in the aircraft forward of the cargo door was not examined. Most of the wires leading from the door to the fuselage were not recovered. There was no visible external evidence of burning, arcing, or heat distress in any of the

wires removed. Several areas of wire insulation damage were found.

Thirty five wires were identified that could provide a possible short circuit path that could drive the latch actuator open with or without failures of other door electrical components if the ground handling bus was energized. The wires were schematically coded by function. Wires coded (-..-..-) were denoted for wiring that provides open command logic to the latch actuator. Wires coded (--.--.--.) were denoted for additional wiring enabled by an activated (failed) S2 switch. Wires coded (-o-o-o-o) were denoted for wiring providing 28VDC power from the C285 circuit.

Potential short circuit paths were identified for the cargo door that could provide 28VDC to the latch actuator control circuit relay. These potential short circuit paths can cause the latch actuator to drive the latches toward their open position if 115VAC power is available to the latch actuator motor. The potential short circuit paths include two bare wires shorting against each other, bare wire-to-metal structure-to-bare wire contact, wire to conductive fluid (such as water) to wire, or a combination of the aforementioned.

Conductive contact of (-o-o-o-o) or (--.--.--) coded wire with (-..-..-) coded wire could potentially result in providing a 28VDC circuit path to the latch actuator open circuit. Direct wire-to-wire paths are coded in Figure 17 as defined above. The two-wire short circuit paths are identified as wire pairs consisting of wire 101-20 shorting with any of the following wires; 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

If the S2 master latch lock switch fails in the "Not Locked" position, there are additional wire pairs that provide short circuit paths. These are coded in Figure 17 as (--.--.--) to (-..-..-..) wire pairs.

Short Circuit Wire Damage Simulation Tests:

Tests were conducted by Boeing and United to simulate typical examples of bare wire short circuiting to determine the extent of visible wire damage that would be expected in the 28VDC cargo door control circuit.

United performed tests on BMS 13-42 wire, the wire type used in the B-747 cargo door control circuit. Visible electrical short circuit damage on bare BMS 13-42 wire surfaces was difficult to create at 28VDC. Surface damage was considered visible when detected by microscopic examination at 15X magnification. United testing simulated the relay coil resistance variations that would be found during typical in-service conditions. A current of 1.0 A at 28VDC created visible surface damage on momentary bare wire-to-bare wire contact. Multiple contacts at 1.0 A provided a more positive indication. A single momentary contact between two bare BMS 13-42 wires with 0.160 A at 28VDC did not create visible surface damage. Contact between a BMS 13-42 bare wire and Alclad 2024-T3 metal (airplane and cargo door structure) with 0.160A at 28VDC did not create visible surface damage.

Boeing performed wire tests on BMS 13-48 20 gauge wire. The test setup used the MS27418-2B door latch actuator control relay in parallel with the 60B00311-2 door restraint solenoid, the actual electrical loads used in the B-747 cargo door latch actuator control circuit. A single momentary contact of a bare 28VDC power wire, with a bare wire connecting to the relay of the solenoid, showed small pithead area developed at the point of wire contact that was visible without magnification.

Wire Examination Procedure:

All of the recovered wires were examined in the Safety Board's Materials Laboratory on a mylar sheet to simulate their installed positions. Labels were used to identify the coded wires using the manufacturer's original wire identification numbers imprinted on each wire's insulation. Wire pairs for direct electrical short circuiting were located in two common wire bundles installed on the cargo door. One common wire bundle was associated with the

P3 plug connector, the other with the P4 plug junction box. The wire bundles were examined visually for areas of obvious insulation damage. Each individual wire was also examined with a stereo-microscope. Representative wire damage features were photographed.

Wire Damage Found:

Seven wires numbered 101-20, 102-20, 105-20, 107-20, 108-20, 122-20, and 135-20 had visible damage located near a 3.8 inch position as measured from the P3 plug pin tips. This common position on the wire corresponds to a 360-degree loop in the wire bundle, which is located immediately below the junction box. Figures 18 and 19 show typical wire damage. Wire 122-20 had an open insulation area approximately 0.25 inch long. The other four wires had flattened insulation damage areas.

In the P4 plug connector wire bundle, three wires displayed insulation damage. Wires 113-20, 121-20, and 124-20 had transverse insulation nicks, which exposed bare conductors. All three had insulation nicks 3 inches from the P4 plug pin tips; wires 121-20 and 124-20 had additional insulation nicks 34 inches from the plug pin tips. The two P4 insulation damage locations corresponded to wire bundle clamp positions.

1.16.3 Pressurization System

The pressure relief valves located on the left side of the fuselage in the forward cargo compartment were removed from the airplane and subjected to bench tests at the UAL maintenance facility in San Francisco, California. No significant anomalies were discovered and both valves performed within specified tolerances.

1.16.4 General Inspection of Other UAL Airplanes

During the on-scene phase of the investigation, the Safety Board investigators examined six other B-747 airplanes while they were on the ground at HNL (four UAL airplanes and two operated by other carriers) to observe routine cargo door operations and to assess the condition of latching components. Generally, the door operations were normal. During the examination of latch pins on these airplanes, it was noted that most had a smooth wear ridge at the 9:00 position (looking forward) or were undamaged. All wear areas on the pins were smooth.

During electrical operation of the aft cargo door on one of the other UAL B-747 airplanes (N4718U), the pull-in hooks did not pull the door fully closed and the latch cams completed the closure. During operation of the latch cams, the bottom of the door moved, first circumferentially downward and then inboard. This additional movement was approximately 1/4 inch. A definite "thunking" noise was discernible as the door moved to its closed position at the end of cam rotation. On one occasion, the door would not open under electrical power. The door was "kicked" by a UAL mechanic, power was reapplied, and the door opened properly. Examination of the door by UAL mechanics, disclosed that the riveted plate holding the aft pull-in hook switch striker was loose.

All eight lower latch pins for the forward cargo door on N4718U exhibited a smooth ridge near the 9:00 position. Pins No. 1 and 2 also showed a smooth ridge at the 6:30 position with a smooth wear area between the 6:30 and 9:00 position. The forward and aft midspan cams of both forward and aft cargo doors had a heavy gouge mark corresponding to the end of the midspan latch pin. N4718U was subsequently removed from service for repair of the aft cargo door latching mechanisms.

1.17 Additional Information

1.17.1 Previous Cargo Door Incident

On March 10, 1987, a Pan American Airways B-747-122, N740PA, operating as flight 125 from London to New York, experienced an incident involving the forward cargo door. According to Pan Am and Boeing officials who investigated this incident, the flightcrew experienced pressurization problems as the airplane was climbing through about 20,000 feet. The crew began a descent and the pressurization problem ceased about 15,000 feet. The crew began to climb again, but about 20,000 feet, the cabin altitude began to rise rapidly again. The flight returned to London.

When the airplane was examined on the ground, the forward cargo door was found open about 1 1/2 inches along the bottom with the latch cams unlatched and the master latch lock handle closed. The cockpit cargo door warning light was off.

According to the persons who examined the airplane, the cargo door had been closed manually and the manual master latch lock handle was stowed, in turn closing the pressure relief doors and extinguishing the cockpit cargo door warning light. Subsequent investigation on N740PA revealed that the latch lock sectors had been damaged and would not restrain the latch cams from being driven open electrically or manually. It was concluded by Boeing and Pan Am that the ground service person who closed the cargo door apparently had back-driven (opened) the latches manually after the door had been closed and locked. The damage to the sectors, and the absence of other mechanical or electrical failures supported this conclusion.

Further testing of the door components from N740PA and attempts to recreate the events that led to the door opening in flight revealed that the lock sectors, even in their damaged condition, prevented the master latch lock handle from being stowed, until the latch cams had been rotated to within 20 turns (using the manual 1/2 inch socket drive) of being fully closed. A full cycle, from closed to open, is about 95 turns with the manual drive system.

1.17.2 FAA Surveillance of UAL Maintenance

The Denver, Colorado, FAA Flight Standards District Office (FSDO) holds the operating certificate for United Airlines, Inc. The FAA FSDO in San Francisco, California, has the primary surveillance and oversight

responsibility for UAL maintenance.
The FAA's PMI has the responsibility to oversee an airline's compliance with Federal Regulations with respect to maintenance, preventive maintenance, and alteration programs. The PMI determines the need for, and then establishes work programs for, surveillance and inspection of the airline to assure adherence to the applicable regulations. A portion of the PMIs position description reads as follows:
Provides guidance to the assigned air carrier in the development of required maintenance manuals and recordkeeping systems. Reviews and determines adequacy of manuals associated with the air carrier's maintenance programs and revisions thereto. Assures that manuals and revisions comply with regulatory requirements, prescribe safe practices, and furnish clear and specific instructions governing maintenance programs. Approves operations specifications and amendments thereto.
Determines if overhaul and inspection time limitations warrant revision.
Determines if the air carrier's training program meets the requirements of the FARs, is compatible with the maintenance program, is properly organized and effectively conducted, and results in trained and competent personnel.
Directs the inspection and surveillance of the air carrier's continuous airworthiness maintenance program. Monitors all phases of the air carrier's maintenance operation, including the following: maintenance, engineering, quality control, production control, training, and reliability programs.
At the Safety Board's public hearing on this accident, the PMI for United Airlines at the time of the flight 811 accident stated that he was trained as an FAA air carrier inspector and had been assigned to United Airlines since November 25, 1985. In addition to attending the normal FAA indoctrination course, he had received training in accident investigation, compliance

enforcement, nondestructive testing, enforcement, and composite materials. To qualify for the position of PMI, he had completed a 3-week management training course at Lawton, Oklahoma. This was supplemented by a 2-week course on management training systems.

According to the PMI, FAA surveillance of UAL B-747 maintenance activities was organized around the daily work schedule of the FAA air safety inspector, specifically assigned to the UAL B-747 fleet by the PMI. The schedule for surveillance is normally prepared a year in advance by the FAA computerized Work Planning Management System (WPMS). Each FAA inspector is assigned specific responsibilities in the surveillance and monitoring of the airplane fleet to which he is assigned.

The PMI stated that assigned inspectors conducted surveillance of the UAL airplanes while they were in light or heavy maintenance and when they were released to service or in the process of preparing for a flight. Postflight surveillance was also performed. He said, as a routine, the inspectors visually inspected the airplanes and reviewed the airplane log records either during en route checks, while in flight, or upon termination of various flights. He said that inspectors conduct spot ramp inspections; however, they do not routinely observe ramp service operations as part of the surveillance program.

He said that FAA inspectors are not required to inspect the airplanes, but merely are to observe ramp service activities. Deficiencies or malfunctions were to be noted. The assigned inspector or the PMI would then report these observations to the UAL quality assurance liaison person or directly to UAL management.

The PMI stated that the FAA had conducted five special surveillance inspections of UAL in the previous 3 years and 5 months. The last special inspection, an MEL Survey Inspection, was completed in 1988. That inspection primarily addressed how many deferred maintenance items were being carried or deferred on each aircraft during a specified time period.

The PMI stated that his office does not approve the method by which the carrier complies with an AD, unless specified in the AD. However, a scheduled surveillance method was in place to review the carrier's AD compliance process and the ADs applicable to certain fleets. Each assigned inspector had a schedule for performing this oversight in his work program. The PMI or his staff review a monthly report from the carrier listing ADs applicable to a particular fleet and their compliance. The FAA's surveillance of the carrier's AD compliance process involved a review of this list, not actual shop visits to verify compliance.

The inspector assigned to the UAL B-747 fleet stated that approximately 30 percent of his time was spent on actual ramp maintenance surveillance. Other activities included: en route inspections, station inspections, meetings, classes and administrative paper work. Spot ramp inspections were scheduled as a normal routine, as well as by mandate in a particular AD.

The PMI stated that foreign contract maintenance bases were inspected once a year at a minimum. The PMI had the prerogative to use geographical surveillance inspectors (inspectors from other FAA offices), or inspectors from his office more familiar with UAL maintenance procedures to conduct inspections or investigations.

The PMI and the B-747 maintenance inspector assigned to UAL testified that, prior to this accident, they were not aware of any problems involving the operation of B-747 cargo doors, including the problems reported with N4713U during December 1988. The PMI testified that he could always use more inspectors to "conduct more in-depth surveillance and monitor UAL's fleet more adequately."

The extensive documentation of maintenance performed on UAL B-747 airplanes was forwarded to the PMI's official library by US mail. The data were ultimately channeled to the B-747 maintenance inspector. The PMI and maintenance inspector testified that the voluminous paperwork and work schedules precluded their monitoring the information to determine trends on problem areas.

1.17.3 Corrective Actions

On March 31, 1989, the FAA issued telegraphic (AD) ADT 89-05-54. This AD superseded AD 88-12-04 and required certain procedures to be accomplished when operating the cargo doors. These included: confidence checks of the door mechanical and electrical systems, inspections of the door locking mechanisms, and repairs if necessary. The AD also accelerated the schedule for terminating action to place steel doublers on the latch lock sectors, and it reinstituted the procedures for using the eight view ports to verify the position of the latch cams, after the door is latched and locked.

The FAA, in conjunction with the Air Transport Association, the manufacturers, and other interested parties, are collectively working to address the human factor issues in the readability and understandability of ADs and SBs by line maintenance personnel. They are also reviewing the entire range of design, maintenance, and operation of outward opening doors to develop advisory information for pertinent parties.

FAA representatives stated at the Safety Board's public hearing that the FAA is increasing their operations and airworthiness inspector staffing by approximately 1,000 new hires in the next 3 fiscal years.

The PMI for UAL at the time of the accident stated at the Safety Board's public hearing that, as a result of the accident, "we have intensified our surveillance on the cargo door activities to the point where the assigned inspectors and inspectors who are not assigned to that particular fleet, 747s, are doing night surveillance, early morning surveillance, and we have intensified our surveillance on the cargo door in watching the operation of the cargo door to comply with the Airworthiness Directive."

On August 23, 1989, the Safety Board issued three safety recommendations (A-89-92 through -94) to the FAA. The recommendations urged the FAA to:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams.

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently.

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions.

Section 4.0 contains the FAA's response to the recommendations and the status of the followup actions.

On October 12, 1989, the FAA issued NPRM 89-NM-148-AD, which proposed the amendment of ADT-89-05-54. The proposed revisions would require modification of the warning systems for the forward and aft cargo door, and the main deck cargo door, if installed. The modifications would provide visual warnings to flightcrew and ground crew when the doors are not fully closed, the latch cams are not rotated to the closed position, or the lock sectors are not in the locked position. Further, the source for the warning signal would monitor the position of the latch cams. Public comments for the NPRM were due by

December 27, 1989.

Boeing has completed tests that have verified the integrity of the upgraded latch lock sectors to prove that the latch cams cannot be back-driven through the lock sectors mechanically or electrically. Boeing also has been conducting tests on the B-747 cargo door to evaluate the effects of unrepaired damage and abuse on the latch/lock system. The tests, which determined the allowable damage limits on the latch lock system and mechanism support structures, were completed in March 1990. Additionally, Boeing conducted tests to evaluate any unlatching tendencies under cabin pressure loads. These tests were completed in November 1990 and included the measurement of loads in the latch system as the latch cams are rotated incrementally from the fully latched position to the unlatched position under pressurization loads.

The first series of tests included electrical backdriving of the latch cams into the lock sectors (both steel and steel reinforced were tested) with a modified latch actuator (the maximum output torque of the modified latch actuator was roughly twice that of a normal, torque-limiting latch actuator.) During these tests, the maximum cam rotation was 22.2 degrees against steel reinforced lock sectors and 18.8 degrees against the all-steel lock sectors.

During the second set of tests, which measured the effects of internal pressure loads on partially unlatched cams, it was discovered that pressurization did not create any significant loads in the latch mechanism with the door fully closed and the latch cams positioned up to 45 degrees from the fully latched position.

Both series of tests show that if the latch cams were somehow electrically backdriven by a latch actuator that had no torque-limiting ability, the steel or steel-reinforced lock sectors would limit the amount of cam rotation such that the partially unlatched cams would still prevent pressure loads from forcing the door open.

1.17.4 Boeing 747 Cargo Door Certification

Title 14 CFR 25.783, Amendment 25-15, effective October 24, 1967, was the original certification basis for Boeing 747 cargo doors. Specifically, Part 25.783(e) and (f) applied to doors for which the initial opening movement is outward (non-plug type doors). Those rules specified that:

(e) There must be a provision for direct visual inspection of the locking mechanism by crewmembers to determine whether external doors, for which the initial opening movement is outward (including passenger, crew, service, and cargo doors), are fully locked. In addition, there must be a visual means to signal to appropriate crewmembers when normally used external doors are closed and fully locked.

(f) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure.

Amendment 25-23, effective May 8, 1970, added the following text to paragraph (f): "...or failure of a single structural element." Amendment 25-23 did not apply to the initial certification basis for the B-747.

Amendment 25-54, effective October 14, 1980, expanded Part 25.783 (e), (f), and (g) to read:

(e) There must be a provision for direct visual inspection of the locking mechanism to determine if external doors, for which the initial opening movement is not inward (including passenger, crew, service and cargo doors), are fully closed and locked. The provision must be discernible under operational lighting conditions by appropriate crewmembers using a flashlight or equivalent lighting source. In addition, there must be a visual warning means to signal the appropriate flight crewmembers if any external door is not fully closed and locked. The means must be designed such that any failure or combination of failures that would result in an erroneous closed and locked indication is improbable for doors for which the initial opening movement is not inward.

(f) External doors must have provisions to prevent the initiation of pressurization of the airplane to an unsafe level if the door is not fully closed and locked. In addition, it must be shown by safety analysis that inadvertent opening is extremely improbable.

(g) Cargo and service doors not suitable for use as an exit in an emergency need only meet paragraph (e) of this section and be safeguarded against opening in flight as a result of mechanical failure or failure of a single structural element.

At the Safety Board's public hearing, the FAA and the Boeing representatives acknowledged that during certification of the Boeing 747 the loss of a lower lobe cargo door was not considered to be an "acceptable event." Therefore, redundant mechanical devices and operational procedures were incorporated to protect against loss of the door in flight. Initial FAA certification approval of the Boeing cargo door design and operation included the installation and use of eight view ports on the door for ground personnel to observe the alignment of paint stripes on the latch cams with arrows on the latch pin support fitting, thereby complying with the requirements of 14 CFR 25.783(e), which require a ". . . provision for direct visual inspection of the door locking mechanism ...," to determine if the door is closed and locked.

In correspondence dated November 24, 1969, and May 15, 1970, Boeing requested that the FAA approve the use of a visual inspection of the pressure relief doors of the cargo doors as an alternate method for determining the locked condition of the door. This design also provided a visual indication to the flightcrew via the cargo door warning light on the flight engineer's warning light annunciator panel. Boeing's request stated that this means of compliance "... provides a simpler check whereby only the pressure relief doors need to be checked ...," by

the ground crew, in lieu of actually observing the latch cams and alignment stripes through the eight view ports. Boeing also provided a Failure Analysis to support its request. The conclusion of the Failure Analysis reads: "Any failure, mechanical or electrical, within the latching system which results in open latches will always be indicated by open pressure relief doors." The FAA approved their alternate method on June 8, 1970. Subsequently, the procedures for maintaining the view ports and the alignment stripes in a serviceable condition,
which had been included in the UAL MM were removed. Also, the provision for observing the alignment stripes as part of the door closing procedure were not required for B-747 airline operators.

At the Safety Board's public hearing, a Boeing witness, in answer to a question relative to Boeing's possible consideration of modifications or design changes to the B-747 cargo door indication system to install a position switch directly on the latch cams, stated, "We are looking into the best possible designs that would provide indication on the cams and door closed, both exterior to the aircraft and in the flight deck. We are going to look into that.... However, we want to achieve the required indication in the most reliable method and we have not yet determined what that will be, or any changes (that) are necessary, or would make it more reliable than the way the system operates currently."

1.17.5 Advisory Circular AC 25.783-1

Advisory Circular (AC) 25.783-1 was issued December 10, 1986, on the subject, "Fuselage Doors, Hatches, and Exits." AC 25.783-1 set forth the acceptable means of compliance with the provisions of Part 25 of the FAR's dealing with the certification of fuselage doors. Specifically, it provides for an acceptable method for showing compliance with the provisions of Part 25.783, Amendment 25-54.

Neither the provisions of Part 25.783, Amendment 25-54, nor the guidelines of AC 25.783-1 were part of the certification basis of the Boeing 747.

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.

The airplane was being prepared for flight at the UAL maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.

The aft cargo door was cranked open manually, the C-288 circuit breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident. With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage. UAL personnel notified the Safety Board of the occurrence, and the airplane was examined at JFK by representatives of the Safety Board, United Airlines, and Boeing. After the wires in the damaged area were electrically isolated, electrical operation of the door was normal when the door was unlocked. When the door was locked (master latch lock handle closed), activation of the door control switches had no effect on the door. This indicated that the S2 master latch lock switch was operating as expected (removing power from the door when it was locked). After the on-site examinations, the wiring bundle was cut from the airplane and taken to the Safety Board's materials laboratory for further examination.

The wiring bundle with the damaged wires contained all electric control wires (28 volt DC) and power wires (115 volt AC) that pass between the fuselage and the aft cargo door. From the forward side of the J-4 junction box, the bundle progresses in the forward direction, just above the forward pressure relief door, then upward, following the forward lift actuator arms. The bundle then enters an empty space between two floor beams, where the bundle has an approximate 180-degree bend when the door is closed. From this location, the wiring bundle progresses inboard, through a fore-to-aft intercostal between two floor beams. The wiring bundle then splits, with wires going in several directions.

The bundle is covered by the flexible conduit approximately from the lower end of the lift actuator arms to the fore-to-aft intercostal between the floor beams.

The conduit covering the wiring bundle is intended to prevent the wire bundle from being damaged during opening and closing of the door and during cargo handling operations. The conduit is a sealed flexible interconnector consisting of a convoluted helical brass innercore covered by a bronze braid. The innercore is soldered at every other convolute, and should be capable of withstanding pressures exceeding 1,000 pounds per square inch (psi). Boeing has indicated that the conduit is an evolutionary improvement and that it has been installed on all B-747 airplanes produced since 1981 (from line number 489 on). Airplane N152UA was delivered in April 1987.

Airplanes produced prior to 1981, including N4713U, used a bungee retraction system, to retract the cargo door wire bundle. Guidelines for the replacement of the bungee sys tem with the flexible conduit were covered in Boeing Service Bulletin 747-752-2170, dated August 1981. The service bulletin was prompted by reports that the wire bundle bungee retraction system had not retracted the wire bundle sufficiently to prevent trapping the bundle between the cargo door and the door frame. UAL did not perform the retrofit on N4713U, which was line number 89, nor was the company required to do so.

Examination of the wires in the damaged area on the wiring bundle revealed that four of the wires were similar in appearance, with insulation breaches that progressed through to the underlying conductor. Adjacent to the breach on these four wires, the insulation was blackened, as if it had been burned. Another wire contained an extensive breach but no evidence of burned insulation. The damaged area was located on the bundle at a position approximately corresponding to a conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism. This support bracket was found bent in the forward direction. In addition, mechanical damage was noted on adjacent components in this area.

A second damaged area was noted on the wiring bundle at a position approximately corresponding to the conduit swivel clamp at the elbow between the two arms of the forward lift actuator mechanism. Wires in this area were missing portions of their exterior coating, but no breaches to the underlying conductors were noted.

The exterior braid on the conduit contained minor rub marks and was slightly kinked at a position corresponding to the area on the wires with breached insulation. Additional examinations revealed that the innercore of the conduit contained multiple circumferential cracks in the areas corresponding to the damage areas on the wires. The cracks were in the convoluted innercore directly adjacent to the inside diameter of the conduit.

The lock sectors, latch cams, and latch pins from the aft cargo door were examined on the incident airplane and were generally in excellent condition. There was no evidence to suggest that the cams had ever been electrically (or manually) driven into or through the lock sectors.

Boeing also informed the Safety Board that, in May of 1991, a B-747 operated by Quantas was found to have chafing of the wires in the wire bundle to the aft cargo door. This airplane also had a flexible conduit protecting the wires, and the chafing was located approximately at the standoff pin on the bracket at the upper arm of the forward lift actuator.

The Safety Board determined that the chafing of the wires on the airplane involved in the JFK occurrence was caused by, or was greatly accelerated by, the circumferential cracks in the conduit and that the cracks in the conduit were caused either by repeated flexing of the conduit as the cargo door opens and shuts or by unusual stresses on the conduit generated concurrently with damage to the conduit guide bracket and attached standoff pin on the upper end of the forward lift actuator upper arm.

A portion of the wire bundle for the forward cargo door on many B-747 airplanes is also covered by a flexible conduit that is very similar to the conduit for the aft cargo door. However, there are substantial differences between the orientation of the flexible conduits for the two doors, and the Safety Board has not become aware of problems associated with the flexible conduit for the forward door.

Nevertheless, because of the concerns about the chafed wires and possible electrical short circuits, on August 28, 1991, the Safety Board recommended that the FAA:

Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between the fuselage and aft cargo door to require an expedited inspection of:

(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test method or visual examination);

(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;

(3) the flexible conduit for the presence of cracking in the convoluted innercore.

Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an appropriate cyclic interval. (Class II, Priority Action) (A-91-83)

Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in A-91-83. (Class II, Priority Action) (A-91-84)

The FAA responded to these safety recommendations on November 1, 1991, stating that it agreed with the intent of the recommendations and that the issuance of an NPRM was being considered to address the issues in the safety recommendations. The Safety Board replied on November 27, 1991, classifying each of the recommendations as "Open--Acceptable Response," pending the completion of the rulemaking process. Since that exchange of correspondence, the FAA has published an NPRM which is now being reviewed by the Safety Board. Safety Recommendations A-91-83 and -84 will continue to be classified as "Open--Acceptable Response" until an acceptable final rule is published.

2. ANALYSIS

2.1 General

This analysis is based on the facts gathered during the initial investigation phase, without the benefit of the evidence from the cargo door, updated to include the findings from the subsequent examinations of the door after it was recovered.

The flightcrew and flight attendants were trained and qualified in accordance with the applicable Federal regulations and UAL standards and requirements. There were no air traffic control or weather factors related to the cause of this accident.

The airplane had been properly maintained, with the exception of certain requirements pertaining to the cargo doors. Those discrepancies will be discussed in detail in this analysis.

The evidence examined by the Safety Board during its investigation revealed conclusively that this accident was precipitated by the sudden loss of the forward lower lobe cargo door, which led to an explosive decompression. There was no evidence of preexisting metal fatigue or corrosion in the structure surrounding the cargo door. All breaks were the result of overload at the time of the loss of the door. There was no evidence of a bomb or similar device that caused an explosion on the airplane.

The explosive decompression of the cabin when the cargo door separated caused the nine fatalities. The floor structure and seats where the nine fatally injured passengers had been seated were subjected to the destructive forces of the decompression and the passengers were lost through the hole in the fuselage. Their remains were not recovered. Most of the injuries sustained by the survivors were caused by the events associated with the decompression, such as baro-trauma to ears, and cuts and abrasions from the flying debris in the cabin. Other injuries were incurred during the emergency evacuation.

The loss of power to the Nos. 3 and 4 engines was caused by foreign object damage when debris were ejected from the cargo compartment and cabin during the explosive decompression. The debris also caused damage to the right wing leading edge flap pneumatic ducting, and other areas along the right side and empennage of the airplane.

During the approach to HNL, all of the leading edge flaps had extended, except the outboard sections 22 through 26 on the right wing. The reason that they failed to extend probably was the damage to the pneumatic duct caused by the ejected debris. The pneumatic pressure probably was too low to actuate the most outboard flaps to the extended position.

The failure of the flightcrew and passenger oxygen systems was caused by structural deformation and damage to the supply lines in the area adjacent to the cargo door and failed fuselage structure.

The Safety Board's analysis of this accident concentrated on the reasons for the loss of the cargo door and the events that led to its loss in flight. The analysis included an evaluation of the design, certification, and approval processes for the B-747 cargo doors, and the operational, maintenance, and inspection processes for the doors. Also, the analysis included an evaluation of the historical events that had occurred over the past months and years that eventually led to this accident.

2.2 Loss of the Cargo Door

The calculated pressure differential at the time of the loss was about 6.5 psi, which would have exerted a load on a properly closed and locked door that was substantial, but well within design limits.

There was no evidence of a structural problem with the cargo door that could have caused it to fail from metal fatigue or corrosion. Although the cargo door was recovered in two pieces on the floor of the ocean, there was no evidence of a preseparation structural failure of the door. All fractures and damage found on the door were determined to be the result of the sudden opening of the door rather than the cause. The evidence showed that the door was intact when it flew open violently and that its integrity was compromised when it struck the upper fuselage structure and most likely when it struck the water. The fracture in the cargo door occurred just below the midspan latch cams. Paint marks on the outer surface of the door that matched upper fuselage structure paint pattern, damage to the latch pins, pull-in hooks and hook pins, as well as damage to the floor structure near the upper door hinge area were consistent evidence that the door was intact when it flew open.

The evidence was also conclusive that the failure of the door did not result from the failure of the structure surrounding the door. The damage to the cabin floor beam structure, adjacent to the cargo door hinge area, showed that decompression loads in the cabin broke the beams downward when pressure was released from the cargo compartment. The fuselage skin above the door was torn away during the decompression as the door separated violently from the airplane. Unfortunately, the upper skin structure was not recovered from the sea.

There are no reasonable means by which the door could open in flight with the cams properly closed and locked. If the lock sectors were in proper condition, and were properly situated over the closed latch cams, the lock sectors had sufficient strength to prevent the cams from vibrating to the open position during ground operation and flight. Thus, the only ways in which the cargo door could open while in flight involve the placement of the cams in a partially latched or unlatched position. Either the latching mechanisms were forced open electrically through the lock sectors after the door was secured, or the door was not properly latched and locked before departure. Then the door opened when the pressurization loads reached a point at which the latches could not hold.

2.3 Partially Closed Door

Examination of the eight latch pins that had been removed from the lower sill of the forward cargo door revealed smooth wear patterns where the latch cams had normally rotated around the pins. These wear patterns indicate that interference had existed during normal operation between the cams and the pins over an extended period of time. All eight pins also had roughened areas from approximately the 6:15 position to the 7:30 position (clock references are as looking forward, 9:00 being directly inboard). The 7:30 position corresponds closely to the area where the lower surface of the cam first contacts the pin as the door reaches the nearly closed position, before the cams are rotated to the latched position.

The hoop stresses generated by pressurization of the airplane create a bearing load against the cam/pin contacting points. Even if the cams are in the unlatched position, and the airplane is pressurized, this bearing load could act as a frictional latch between the cams and the pins and would tend to keep the door in the closed position.

Transferred cam material and heat tinting of the pin surface was found to extend from the point where the cam-to-pin interface at the near fully open position of the latch cams (7:30 position) to a position corresponding to the bottom of the pin (6:15 position).

This evidence was found on the roughened areas on all of the pins. The heat tinting and metal transfer are indicative of the high stress and rapid movement of the cam across the pin when the door separation occurred. Therefore, the location of this evidence indicates the probable location of the cams just before, and at the time of, separation of the door. The Safety Board concludes that these markings and their location on the pins resulted from a very fast, high bearing stress, separation of the cams across the pins, when the cams were in or very close to the unlatched position. Further, examination of the recovered cargo door confirmed that the latch cams were in a nearly unlatched position at the time the separation occurred. The lock sectors were found in the locked position jammed against the cams. Therefore, the cargo door latch cams had been closed, the master latch lock handle had been closed, and the lock sectors had moved to the locked position. Subsequently, the cams had been back-driven to the near-open position, deforming the lock sectors.

The pull-in hooks and pull-in hook pins would also counteract the pressurization loads in the outward direction, providing that the latch cams were not engaged on the latch pins and carrying the pressurization loads. However, Boeing studies showed that the pull-in hooks would fail at a pressure differential of about 3.5 psi, assuming that the cams are in the unlatched position and that there is no bearing load on the pins. Therefore, based on the probable pressure differential of about 6.5 psi just before the door separated, it is concluded that forces other than the pull-in hooks/pins were holding the door closed. Since the flightcrew and passengers reported no pressurization difficulties until the explosive decompression, it is reasonable to conclude that the door was being held closed by the bearing stresses of the cam-to-pin interfaces as well as by the pull-in hooks.

The Safety Board believes that the approximate 1.5 to 2.0 seconds between the first sound (a thump) and the second very loud noise recorded on the CVR at the time of the door separation was probably the time difference between the initial failure of the latches at the bottom of the door, and the subsequent separation of the door, explosive decompression, and destruction of the cabin floor and fuselage structure. The door did not fail and separate instantaneously; rather, it first opened at the bottom and then flew open violently. As the door separated, it tore away the hinge and surrounding structure as the pressure in the cabin forced the floor beams downward in the area of the door to equalize with the loss of pressure in the cargo compartment.

Three possible theories to explain why the latch cams could have been in a partially latched condition during flight are examined: (1) they were never closed fully before the door was "locked" before takeoff. (2) they were backdriven manually after the door had been fully latched and locked or (3) they were back-driven electrically after the door had been fully latched and locked.

2.4 Incomplete Latching of the Door During Closure

The Safety Board considered the possibility that the master latch lock handle had not been closed before the airplane departed the gate, and the possibility that the shrouds recommended by SB-747-52-2097 for the cargo door pressure relief doors were not installed on the forward door. If this were the case, it is possible that this condition allowed the pressure relief doors to be rotated closed when the airplane pressurized.

The Safety Board believes that these events were very unlikely based on the statements of the ramp personnel, line maintenance personnel, and the flightcrew. The ramp and maintenance personnel would have to have missed seeing the master latch lock handle in the unstowed position and the pressure relief doors open before departure. Also, the flightcrew would have to have missed seeing the cockpit cargo door warning light indication.

The examination of the recovered forward cargo door did not provide confirmation that the pressure relief door shrouds were actually installed on the forward door, although UAL records showed that they had been installed on both cargo doors of N4713U, in accordance with SB-747-52-2097. However, the shrouds were found not to be installed on the aft door, contrary to UAL records, and therefore may not have been installed on the forward door. Without the shrouds, the pressure relief doors could have rotated shut during the pressurization cycle. Because the closure of the pressure relief doors would back-drive the lock sectors, this scenario would presume previous damage to the sectors, which would permit the sectors to move over the unlatched cams.

Before recovery of the cargo door, the Safety Board believed that the lock sectors might have been damaged some time prior to the accident flight to the extent that they could have been moved to the locked position even though the latching cams were not fully closed.

During closure of the door, the latch actuator may not be able to rotate the cams to the fully closed position because of excessive binding forces between the latch cams and pins. This could occur if the cargo door is misaligned (out of rig) or if the pull-in hooks do not pull the door in far enough to properly engage the cams around the pins. There is sufficient evidence of wear on the pins and from the previous discrepancies with the door to indicate that the door was misaligned and not properly rigged.

The smooth wear areas found on the pins from N4713U are signs of heavy contact (interference) between the cams and pins during numerous past closings and openings of the door. This wear, other evidence from the door, and the maintenance history of the door, suggest strongly that the door was out of rig during the weeks and months before the accident.

The wear pattern damage to the pull-in hook pins also showed interference during the normal ground operations prior to the accident. This is further evidence of an out-of-rig door. It is also possible that the excessive binding force acting over a period of time precipitated a failure of the latch actuator. Regardless of the reason(s), the conditions of the latch pins and pull-in hook pins showed prolonged out-of-rig operation.

Most of the previous discrepancies with the forward cargo door on N4713U during December 1988 involved problems with closing the door electrically. These problems always occurred when the airplane was fully or nearly fully loaded, just before departure. The trouble-shooting and corrective actions by UAL maintenance, which on some occasions only involved cycling the door and finding it functional, were performed when the airplane was not fully loaded, during overnight maintenance inspections. The flexing of the fuselage with a full load of fuel, cargo, and passengers could have caused distortion of the door frame and resulted in misalignment between the cams and pins. In this case, the pull-in hooks may not have pulled the door fully in before the cam actuator attempted to latch the door. The wear evidence on the latch pins from N4713U suggests that this event had been occurring before the accident.

Safety Board investigators also witnessed this event during inspection and operation of the aft door on another UAL B-747, N4718U, in HNL. It was noted that the door on N4718U was not being pulled in fully by the pull-in hooks, so the latch cams completed the closing cycle with significant interference and "thunking" sounds. In fact, the out-of-rig door on N4718U failed to operate electrically at one point during its examination.

By design, any attempt to close the master latch lock handle and move undamaged lock sectors into place would not be successful unless the cams were rotated to near the fully latched position. This condition was substantiated by Boeing tests. Even with severely damaged lock sectors, as found on the Pan Am B-747, if the cams were more than 20 turns from the fully closed position on the Pan Am airplane, the master latch lock handle could not be stowed. Examination of the recovered N4713U door indicated that the door lock sectors were generally intact and jammed against the cams that had been back-driven into the lock sectors. Consequently, if the latch cams had been in the nearly unlatched position as found on the recovered door at the time the cargo handler attempted to move the master latch lock handle, the interference between the cams and the lock sectors would have prevented the master latch lock handle from moving to the closed position. Furthermore, this interference would have prevented the closure of the pressure relief doors as the airplane pressurized, irrespective of the possible absence of the pressure relief door shrouds. This conclusion is supported by extensive testing of the latch/lock mechanisms following the recovery of the door.

Therefore, based upon the examination of the lock sectors and the tests that were conducted, the Safety Board concludes that the latches were fully closed and that the locking handle was placed in the stowed position after the cargo was loaded.

2.5 Manual Unlatching of the Door Following Closure

It is possible that the cams could have been manually back-driven (about 95 turns) after the door had been secured; however, the UAL ramp personnel involved with dispatching the flight stated that the door was operated electrically. Furthermore, it seems unlikely that the ramp personnel would have driven the manual latch actuator 95 turns toward the open position after the door was fully latched.

The placard/seal located over the latch actuator manual drive on the recovered door was found with damage that initially suggested it had been previously compromised. If this were the case, it would indicate that someone may have used the manual drive to operate the door latches on an earlier flight or possibly immediately before the accident flight. However, the Safety Board

believes that an insertion of a screw driver and rotation of the plate retaining screw would have caused rotational tearing around the circumference of the screw head. There was no such tear. Rather, the damage to the placard/seal was more consistent with that which would occur from impact and underwater pressure
forces. Therefore, the evidence strongly suggests that manual operation of the latch actuator by ground service personnel after the door was properly closed is unlikely.

2.6 Electrical Unlatching of the Door Following Closure

2.6.1 Conditions or Malfunctions Required to Support Hypothesis

It was determined in 1987, after the Pan Am incident, that the locking sectors for B-747's, including those installed on N4713U, could be overcome by the force of the latch cam actuator, electrically or mechanically. If the latch cam actuator had been energized for some reason with the originally designed unstrengthened lock sectors installed, the latch actuator motor was capable of driving the latch cams open through properly positioned lock sectors, whether they were damaged or undamaged. Therefore, the locking sectors installed as original equipment for B-747's, and those installed on N4713U, would not perform the locking function as intended by the design. They would not "lock" the latches in place as implied by the name "lock sectors."

The investigation has shown that there are several conditions that must be met before the latch actuator will electrically drive the latch cams to the unlatched position on the B-747 after the door has been properly closed and locked. First, the ground handling power bus must be energized by having external power connected, or the APU must be operating and the APU generator field switch in the cockpit must be set to power the bus via the No. 2 ground handling power relay. Second, the air/ground relay must be in the "airplane on the ground" position. These two conditions are normally present when the airplane is on the ground before engine startup. Third, there must be a signal to the door open position in one of the two door open/close switches. Fourth, the S2 master latch lock switch, which cuts off power to the door actuators when the handle is stowed, must sense "not locked."

Therefore, it would take several independent conditions and some failures to provide for electrical power to be available to drive the door open electrically once it is closed and locked. The number of conditions and combinations depend upon the phase of operation of the airplane.

While the airplane was on the ground, before engine startup, with the master latch lock handle stowed, the external power connected (or with the APU running), and the ground handling bus powered, an "open" signal to the cargo door latch actuator would have occurred if any of the following combinations of conditions had been met: (1) a malfunction of the S2 master latch lock switch and the placement by someone of one of the door control switches to the "open" position; (2) a malfunction of the S2 master latch lock switch and certain short circuits; or (3) a two-wire short circuit path consisting of wire 101-20 shorting with any of the following wires: 108-20, 121-20, 122-20, 124-20, 135-20, or 136-20.

While the airplane was on the ground, after engine startup, and with the cargo door master latch lock handle stowed and the APU running, an "open" signal to the door latch actuator would have occurred if the following conditions had been met: (1) an energized ground handling bus resulting from the flightcrew reenergizing the APU generator field or failure of the No. 2 ground handling power relay; (2) a malfunction of the S2 master latch lock switch; (3) a malfunction of either of the door open/close switches or the placement of the switch in the "open" position by someone. An "open" signal would have also occurred had certain wire short circuits been present with condition (1) alone, or with conditions (1) and (2).

Regardless of the cause, electrical power to the latch actuator would have had to persist for the time necessary to rotate the cams to the nearly open position. If the electrical power had been applied for a longer time, the latch cams could have opened fully and caused the pull-in hooks to rotate open, a situation that would have prevented the airplane from pressurizing after takeoff. However, it is also possible that the latch actuator stalled before they opened fully because of the forces of the interference between the lock sectors and the cams as they were back-driven.

After takeoff, electrical operation of the door latch actuator would have required: (1) the APU to be running; (2) malfunction of the air/ground relay, (3) malfunction of the No. 2 ground handling power relay; and (4) malfunction of the S2 master latch lock switch and one of the cargo door open/close switches or a short circuit of the aforementioned wire pairs. Although the flightcrew could conceivably energize the ground handling bus from the APU by actuating the APU generator "field" switch, there was no evidence that they did so.

Thus, regardless of the phase of operation, either a wiring short circuit or a failure of the S2 master latch lock switch combined with some other anomaly or action would be required to cause the latches to move toward the open position. Before the recovery of the door, the Safety Board was able to examine two of the electrical relays and the door open/close switches from N4713U that would have to have failed to allow electrical operation of the cargo door in flight, with the APU running. These were the No. 2 ground handling power relay, the air/ground relay, and the internal and external door open/close switches. The examination of the relays and switches revealed no evidence of a single fault or conditions that might have caused an intermittent failure mode. The arcing noted on the No. 5 terminal of the outside door control switch was on the door "close" circuit and could not have been related to a short to the open mode. Further, because the flightcrew did not note a cargo door warning light, and the fact that the airplane was able to be pressurized, confirms that the master latch lock handle was in the closed position before takeoff. This position would actuate the master latch lock switch to disconnect power to the door opening actuators.

According to the flightcrew testimony and the pilots' comments recorded on the CVR during the flight, the APU was shut down shortly after takeoff and remained in that condition. Engine generators cannot power the ground handling bus from which the cargo door actuating mechanisms are powered. Once the APU was shut down, there was no power available to any of the cargo door electrical components. Therefore, an electrical actuation of the latch cam actuator at the time of the door loss was not possible.

The Safety Board believes that there is another reason why the opening of the door could not have been caused by electrical actuation shortly before the explosive decompression. Because the door carries the structural loads (hoop stresses) through its hinge and latches, the latch cams would be heavily loaded against the latch pins when the airplane was pressurized to the 6.5 psi differential pressure that was calculated to have been present at the time of the decompression. In that case, the torque limiter within the actuator would probably slip well before the actuator could achieve the torque necessary to drive the cams open against the frictional lock produced by the high bearing stresses resulting from pressurization.

2.6.2 Electrical Switches and Wiring Examinations--Recovered Door

All cargo door position sensing switches (S2 through S9) were found installed in their proper position. The cargo door recovery team found the S2 master latch lock switch in the "not-locked" position immediately after the door was aboard the recovery ship. This position would be consistent with the master latch lock handle being open. Further tests of the S2 switch revealed damage that probably resulted from the pressures under the sea. The only notable exception was a broken internal bracket that may have affected the operation of the switch prior to the accident. Other similar switches did not exhibit this failure. It is therefore possible that the S2 master latch lock switch failed prior to the accident, allowing more possibilities for electrical short circuits to power the latch actuator. Nevertheless, despite extensive testing, it could not be determined whether the S2 switch was functional before the accident.

The examination of 35 wires that remained with the recovered cargo door revealed several areas of damaged insulation that could have permitted an electrical short circuit to power the latch actuator. However, no evidence was noted of arcing that was indicative of short circuits. Furthermore, a significant number of the wires that had the potential for allowing for short circuits to power the latch actuator were not recovered. Testing conducted by Boeing and by UAL was inconclusive regarding whether a short circuit would have left detectable evidence of arcing. Therefore, the Safety Board was unable to determine whether the latch actuator was inadvertently powered by a short circuit in the cargo door wires.

The incident involving a UAL Boeing 747 at JFK Airport on June 13, 1991, confirmed that electrical short circuits in the cargo door wiring could cause the door to open. In this case, the short circuits were in the fuselage-to-cargo door wiring bundle where the bundle was covered by a flexible conduit. Although N4713U did not have a flexible conduit installed at the forward door position, its wiring was routed over the top of the door hinge where exposure to damage could occur. That portion of the wiring from N4713U was not recovered from the sea. The wires located at the door hinge area are more susceptible to in-service damage from movement during the open/close cycle, as compared with the wires mounted on the door that are normally static.

Following the incident at JFK, UAL directed that the circuit breaker that terminates power to the cargo doors be pulled after the door is closed and before departure of every B-747 flight. UAL obtained approval for this practice from the FAA and requested Boeing and the FAA to make such a practice part of the approved manual for the airplane. Neither Boeing nor the FAA acted on UAL's request.

Nevertheless, the Safety Board believes that the FAA should initiate rulemaking to include design considerations for nonplug transport category aircraft cargo doors that would deactivate the electrical circuitry to the door actuators after the doors are closed and locked. The catastrophic nature of the loss of a cargo door dictates the need to provide additional redundancies and fail-safe features in the door mechanisms to supplement the hardware safety features.

2.6.3 Possibility of Electrical Malfunction

Due to the lack of physical evidence, the Safety Board was unable to conclude that an electrical short caused the cargo door actuator to move the latch cams to the nearly open position, allowing the door to separate when the cabin pressure exceeded the load-carrying capability of the door latches. Neither could this possibility be eliminated. A momentary actuation of the door open switch by someone on the ground in the presence of a faulty S2 switch could also have caused the latches to open through the closed lock sectors. However, no evidence has been found that someone actuated the switch after the door was initially closed and locked.

The Safety Board concludes that it was not possible for the cargo door to have opened electrically at the time of the loss of the door. There was no power to the ground handling bus to power the actuator, even if there had been an electrical short. Further, the Safety Board concludes that it is highly improbable that an electrical short could have caused the latches to open after the airplane was airborne. Although the ground handling bus could conceivably have been powered, failures of other components that were tested as functional would also have been necessary.
The Safety Board believes that the electrical operation of the latch actuators from the fully closed and locked position most likely occurred before the engines were started when the ground handling bus was powered. The precise source of the electrical actuation could not be determined. Once the engines were started, the possibility of an electrical short decreases significantly because the ground handling bus is disengaged from the APU when the engines start. There was no evidence that the flightcrew reengaged the ground handling bus.
Because the preaccident condition of the S2 master latch lock switch could not be determined, it could also not be determined whether its proper functioning would have prevented the accident. The Safety Board did not determine whether damaged cargo door wires or a malfunctioning S2 switch could have been found by UAL maintenance had they been more aggressive in troubleshooting the cargo door problem in the weeks prior to the accident.

2.7 Design, Certification, and Continuing Airworthiness Issues

The Safety Board's analysis of this accident went beyond the conclusions about how the door failed. The Safety Board also examined the initial design and certification of the B-747 cargo door, and the continuing airworthiness system that should have prevented this accident, to identify the breakdowns in this system that led to the accident. As is the case with most aviation accidents, there are many factors that led up to the actual failure of the door on flight 811.

The Safety Board found that there were multiple opportunities during the design, certification, operation, and maintenance of the forward cargo door for N4713U for persons to have taken actions that could have precluded the accident involving flight 811. The circumstances that led to this accident exemplify the need for human factors considerations in the promulgation of regulations, the application of regulatory policies, the design of airplane systems, and the quality of airline operational and maintenance practices.

The first opportunity to prevent this accident occurred during the design and certification of the B-747 cargo door mechanical systems, when the design was chosen and approved, which allowed for the overriding of the lock sectors by either mechanical or electrical actuation. It is apparent that the original design was not tested sufficiently to verify that the locking sectors in fact "locked" the latch cams in the closed position. This shortcoming should have become apparent during the initial certification testing and approval process. Later, it should have become apparent when Boeing applied for, and the FAA granted, an alternative method of compliance with the certification regulations (25.783 [e]) that permitted the elimination of operational practices that included a visual verification of the cargo door latch positions via view ports in the doors.

The failure mode analysis performed by Boeing, and the FAA's acceptance of its content in granting the exemption, probably were based on the assumption that the lock sectors would always prevent the master latch lock handle from being in a stowed position when the latch cams were not fully closed. This assumption was not valid, as evidenced by the findings in 1987 following the Pan Am incident that the lock sectors could not prevent the latch cams from being driven from the fully latched position with the master latch lock handle stowed, while a false indication was provided to the flightcrew that the cargo door was properly latched and locked. At the time that Boeing sought approval of the alternative compliance, Boeing and the FAA should have reviewed the design and required testing of the door latch/lock mechanisms to verify their integrity. Thus, the procedure for direct viewing of the latches via the view ports before the airplane could be dispatched should not have been eliminated without adequate verification that the lock sectors were totally effective.

The next opportunity for the FAA and Boeing to have reexamined the original assumptions and conclusions about the B-747 cargo door design and certification was after the findings of the Turkish Airline DC-10 accident in 1974 near Paris, France. The concerns for the DC-10 cargo door latch/lock mechanisms and the human and mechanical failures, singularly and in combination, that led to that accident, should have prompted a review of the B-747 cargo door's continuing airworthiness. In the Turkish Airlines case, a single failure by a ramp service agent, who closed the door, in combination with a poorly designed latch/lock system, led to a catastrophic accident. The revisions to the DC-10 cargo door mechanisms mandated after that accident apparently were not examined and carried over to the design of the B-747 cargo doors.

Specifically, the mechanical retrofit of more positive locking mechanisms on the DC-10 cargo door to preclude an erroneous locked indication to the flightcrew, and the incorporation of redundant sensors to show the position of the latches/locks, were not required to be retrofitted at that time for the B-747. Of similar concern is the fact that the cargo doors for the L-1011 required redundant latch/lock indication sensors at initial certification, during the approximate same time frame the DC-10 and B-747

were certificated.
More recently, when Boeing and the FAA learned about the circumstances of the Pan Am cargo door opening incident in March 1987, more timely and positive corrective actions should have been taken. The Safety Board believes that the findings of that incident investigation should have called into question the assumptions and conclusions about the original design and certification of the B-747 cargo door, especially the alternative method for verifying that the door was latched and locked that was sought by Boeing and was granted by the FAA. Since a B-747 cargo door opening in flight was considered to be an "unacceptable event", once a door did come open in flight, the FAA and Boeing should have acted much quicker to prevent another failure.
It took nearly 16 months from the date of the Pan Am Incident (March 10, 1987) until the FAA issued AD-88-12-04 (July 1, 1988). And then, the AD allowed 18 or 24 months, depending on the model B-747, from the date of its issuance for compliance with the terminating actions of the AD. The fact that Boeing had issued an Alert SB as a result of the Pan Am incident is an indication of the apparent urgency with which Boeing treated this issue. Alert SB's are issued for "safety of flight" reasons, while regular SB's deal with "reliability" and not necessarily safety of flight items. Despite this, the terminating action, issued as
revision 3 to the Alert SB, on August 27, 1987, was not mandated by the FAA for 11 months.
The Safety Board found no evidence that the FAA or Boeing reassessed the original design and certification conclusions regarding the safety of the B-747 cargo door during this period.
Several opportunities for preventive action were also missed by UAL during this period. First, UAL delayed the completion of the terminating actions of Alert SB 52A2206 (Rev 3 and AD-88-12-04. In fact, there was no evidence that UAL had intended to comply

with the terminating action of the Alert SB, until it was mandated by the FAA.

It is understandable that an airline would not take its aircraft out of service to incorporate revisions that do not appear to be safety critical. Although by definition an Alert SB is safety related, there was no implication from Boeing's and FAA's actions regarding this matter that urgency was required. The airlines rely on the airframe manufacturers and the FAA to evaluate the need for urgent airworthiness actions that might take airplanes out of revenue service. In this case, UAL had scheduled completion of its B-747 fleet modifications in accordance with the terminating actions for AD-88-12-04 before the final allowable date; however, the schedule was based on other heavy maintenance schedules to prevent unnecessary down-time of its airplanes.

UAL personnel stated after the UAL 811 accident that its personnel did not fully appreciate the importance, or safety implications, of the terminating actions, or they would have incorporated the improvements much earlier. The usual difficulties in setting short suspense dates for performing terminating actions in AD's, such as parts availability, did not seem to exist in this case, because the parts were not complex components and probably could have been fabricated fairly quickly in-house by most airlines.

Human performance certainly contributed to UAL's failure to incorporate an important inspection step into its maintenance program as mandated by AD-88-12-04. When UAL obtained an advance draft copy of the forthcoming NPRM that eventually led to the AD, the airline began preparing its work orders to implement the forthcoming the AD requirements into its B-747 fleet (30 airplanes at the time). UAL developed its maintenance work sheets from the text of the draft NPRM, which was virtually identical to the text of the final rule. As a result of a clerical error, one of the important inspection steps required by the AD was omitted.

Apparently, UAL maintenance personnel never compared the work sheets they received with the actual requirements of the AD, or if they did, the omission was not detected. FAA inspectors responsible for oversight of UAL's maintenance program also did not detect this error because normal surveillance of AD compliance merely involved verifying the correctness of UAL's paperwork that listed the applicable AD's and compliance dates. The inspectors did not actually verify UAL's compliance action by shop visits, or by comparison of work sheets with AD provisions. These omissions by the UAL maintenance and quality assurance personnel, and the limitations of the FAA surveillance procedures were probably significant in setting the stage for the events that led to the actual cause of the door separation from N4713U.

Another matter of concern is the quality of UAL's trend analysis program. There was no indication that the repeated discrepancies with the forward cargo door on N4713U "raised a flag" within the UAL maintenance department. A quality assurance or trend analysis program should have detected an adverse trend and should have prompted efforts to resolve the repeated problems. If it had, any faults in the door electrical system or damage to mechanical components might have been detected.

In summary, the Safety Board concludes that there were several opportunities wherein Boeing, the FAA, and UAL could have taken action during the initial design and certification of the B-747 cargo door, as well as during the operation and maintenance of the cargo door installed on N4713U, to ensure the continuing airworthiness of the cargo door. The Safety Board further concludes that these deficiencies and oversights contributed to the cause of this accident.

2.8 Survival Aspects

The Hickam ARFF units and the airport's ARFF units operated on separate radio networks and thus they could not communicate directly on-scene by radio. This situation required them to communicate by voice. Although the two ARFF services had a common radio frequency (as per the Airport Emergency Plan), procedures for its use had not yet been developed. The Safety Board believes that such communication procedures should be expeditiously developed.

The use of camouflage paint schemes on military ARFF vehicles may be appropriate for military purposes; however, the Safety Board believes that camouflage is not appropriate for ARFF vehicles that are operated at a joint- use airport. It is obvious that these vehicles must be conspicuous to be seen by other responding vehicles and by persons who are involved in the accident, such as airport and airline personnel, crew and passengers, and off-airport firefighting and rescue vehicles.

The National Fire Protection Association Standards recommend for primary firefighting, rapid intervention and combined agent vehicles, that, "Paint finish shall be selected for maximum visibility and shall be resistant to damage from firefighting agents."4 Furthermore, Federal Aviation Regulation 14 CFR 139.319 (f) (2) requires emergency vehicles, "Be painted or marked in colors to enhance contrast with the background environment and optimize daytime and nighttime visibility and identification." Further guidance for the high visibility color of ARFF vehicles is provided in a Federal Aviation Administration Advisory Circular where the vehicle paint color is specified as, "lime yellow" Dupont No. 7744 UH or its equivalent.5

Because flight attendants are vital to the safety and survival of the passengers following a decompression, measures should be taken to prevent flight attendants from being incapacitated by hypoxia. The Safety Board believes that oxygen masks should be attached to the emergency oxygen bottles to avoid any delay in their use in order to be in compliance with the intent of 14 CFR 25.1447 (c)(4).

Therefore, the FAA should direct its inspector staff to survey B-747 airplanes for compliance with 14 CFR 25.1447(c)(4), and correct deficiencies found.

In this accident, the use of megaphones was vital because of the inability to be heard over the public address (PA) system. Title 14CFR 121.309 (f)(1) requires one megaphone on each airplane with a seating capacity of more that 60 and less that 100 passengers; 14 CFR 121.309 (f)(2) requires two megaphones in the cabins on each airplane with a seating capacity of more than 99 passengers. As this decompression demonstrated, additional megaphones are necessary on wide-body and large narrow-body airplanes to ensure communication in the cabin during emergencies when the PA system is inoperative.

Had there been a need for an immediate evacuation, or a water ditching, rapid egress would not have been possible at doors 2-left and 2-right because they were blocked by open storage compartments and spilled contents. The possibility also exists that a compartment door could release during a hard landing or turbulence and swing down and injure a flight attendant. Thus, the Safety Board believes that improved latches should be installed and the downward movement of stowage compartments doors should be restricted to prevent the doors from striking a seated flight attendant or block the exit door.

The Safety Board believes that the problems with life preserver donning and adjustment demonstrated in this accident should be addressed by the FAA. The straps and fittings on life preservers need to be evaluated to determine where improvements can be made, and clearer donning instructions should be developed.

TSO-C13d, Life Preservers 1/3/83 prescribes the minimum performance standards for life preservers. With regard to donning, the TSO requires:

Donning. It must be demonstrated that an adult, after receiving only the customary preflight briefing on the use of life preservers, can don the life preserver within 15 seconds unassisted while seated. It must be demonstrated that an adult can install the life preserver on another adult, a child, or an infant within 30 seconds unassisted. The donning demonstration is begun with the unpackaged life preserver in hand.

Based on flight attendant interviews and information obtained from passengers these donning times were exceeded in many instances.

The Safety Board has made numerous recommendations to the FAA in the past regarding needed improvements in life preserver donning instructions, donning procedures, and timing of donning.6 The FAA has adopted most of the Safety Board's recommendations in its April 23, 1986, revision to TSO-C13e, Life Preservers, which now requires the wearer to be able to secure the preserver with no more than one attachment and make no more than one adjustment for fit. Also, donning tests are required for age groups of users starting with 20-29 years and ending with 60-69 years. At least 60% of the test subjects in each age group must be able to don then life preserver within 25 seconds unassisted with their seatbelts fastened starting with the life preserver in its storage package. TSO-C13e contains requirements that would have eliminated some of the problems that passengers had in this accident in correctly donning and adjusting their life preservers.

The Safety Board has recommended (A-85-35 through-37) to the FAA to amend 14 CFR 121, 125, and 135 to require air carriers to install life preservers that meet TSO-C13e within a reasonable time. The FAA adopted TSO-C13e on April 23, 1986, and originally had specified an effective date of April 23, 1988, after which all newly manufactured life preservers approved under the TSO system would have to meet the requirements of TSO-C13e. The objective of the cut off date was to introduce life preservers into the fleets with the higher performance level as specified in

TSO-C13e by assuring that replacement articles met the higher standards. On March 3, 1988, the FAA rescinded the cut off date to seek further public comments of fleet retrofit in accord with the proposed rulemaking. See Section 4.0 for FAA action and status of the recommendations.

3. CONCLUSIONS

3.1 Findings

1. There were no flightcrew or cabincrew factors in the cause of the accident or injuries.
2. There were no air traffic control or weather factors in the cause of the accident.
3. The airplane had not been maintained in accordance with the provisions of AD-88-12-04 that required an inspection of the cargo door locking mechanisms after each time the door was operated manually and restored to electrical operation. However, this circumstance was determined not to be a factor in the accident.
4. All but one of the electrical components remaining with the airplane or found with the cargo door that were necessary to have malfunctioned in order to cause an inadvertent electrical opening of the cargo door after dispatch were found to function properly.
5. The forward cargo door lock sectors were found in the locked position (actually in an "over-locked" position) and jammed against the latch cams. The latch cams were found in the nearly open position.
6. The latch actuator manual drive port seal was found damaged from the forces involved in the separation of the door and did not indicate that the drive port had been used to open the door latches manually before the accident.
7. Electrical continuity tests indicated that the S2 master latch lock switch was in the "not locked" position when it was recovered with the cargo door. Because it had sustained damage from being submerged in the sea, its preaccident condition could not be determined.

8. An S2 switch functioning as found after recovery would permit electrical power to the door during ground operation so that additional failure modes or activation of the door control switch could result in movement of the latching cams.

9. All other switches associated with operation of the cargo door were found damaged from being submerged in the sea; however, they were determined to be properly installed and probably functional.

10. Short circuit paths in the cargo door circuit were identified that could have led to an uncommanded electrical actuation of the latch actuator; this situation occurred most likely before engine start, although limited possibilities for an uncommanded electrical actuation exist after engine start while an airplane is on the ground with the APU running.

11. It was not possible for electrical short circuits to command the cargo door to open at the time of the loss of the door, and it is highly improbable that such an event occurred when the airplane was airborne during the short period while the APU was running.

12. Insulation breaches were found on recovered portions of the cargo door wires that could have allowed short circuiting and power to the latch actuator, although no evidence of arcing was noted. All of the wires were not recovered, and tests showed that arcing evidence may not be detectable.

13. An uncommanded movement of cargo door latches that occurred on another UAL B-747 on June 13, 1991, was attributed to insulation damage and a consequent short between wires in the wiring bundle between the fuselage and the moveable door. Because the S2 switch functioned properly on that airplane, movement of the latches would not have occurred after the door was locked.

14. UAL's maintenance trend analysis program was inadequate to detect an adverse trend involving the cargo door on N4713U.

This circumstance was determined not to be a factor in the accident.
15. FAA oversight of the UAL maintenance and inspection program did not ensure adequate trend analysis and adherence to the provisions of airworthiness directives. This circumstance was determined not to be a factor in the accident.
16. The smooth wear patterns on the latch pins of the forward cargo door installed on N4713U were signs that the door was not properly aligned (out of rig) for an extended period of time, causing significant interference during the normal open/close cycle.
17. The rough heat-tinted wear areas on the latch pins of the forward cargo door installed on N4713U marked the positions of the cams at the time the door opened in flight.
18. The design of the B-747 cargo door locking mechanisms did not provide for the intended "fail-safe" provisions of the locking and indicating systems for the door.
19. Boeing's Failure Analysis, which was the basis upon which the FAA granted an alternative method of compliance with the provisions of 14 CFR 25.783(e), was not valid as evidenced by the findings of the Pan Am incident in 1987, and the accident involving flight 811.
20. Boeing and the FAA did not take immediate action to require the use of the cam position view ports following the Pan Am incident, and did not include this requirement in the provisions of the Alert Service Bulletins or AD-88-12-04.
21. There were several opportunities for the manufacturer and the FAA to have taken action during the service life of the Boeing 747 that might have prevented this accident.
22. The fact that the crash fire rescue vehicles responding to this accident did not use a common radio frequency led to problems in communication among the responding vehicles.
23. The camouflage paint scheme of the military fire rescue

units led to reduced visibility of these units and resulted in at least one near-collision.

24. Megaphones were used in flight to communicate with passengers because of the high ambient noise level. However, more megaphones would have afforded better communication in all parts of the cabin.

25. Some flight attendants and passengers had difficulties tightening straps of their life preservers around their waists because of the fabric used, the design of the adjustment fittings, and the angle the straps were pulled.

26. Articles that fell to the floor from stowage bins above the L-2 and R-2 exits and galley service items had to be cleared away from the exits before the emergency evacuation could be initiated.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.

4. RECOMMENDATIONS

As a result of the investigation, including evidence from the recovered cargo door and a June 13, 1991, incident involving the uncommanded electrical operation of a cargo door on a UAL Boeing 747 at JFK Airport, the National Transportation Safety

Board recommends that the FAA:

Require that the electrical actuating systems for nonplug cargo doors on transport-category aircraft provide for the removal of all electrical power from circuits on the door after closure (except for any indicating circuit power necessary to provide positive indication that the door is properly latched and locked) to eliminate the possibility of uncommanded actuator movements caused by wiring short circuits. (Class II, Priority Action) (A-92-21)

As a result of this investigation, on August 23, 1989, the Safety Board issued the following safety recommendations to the FAA:

Issue an Airworthiness Directive (AD) to require that the manual drive units and electrical actuators for Boeing 747 cargo doors have torque limiting devices to ensure that the lock sectors, modified per AD-88-12-04, cannot be overridden during mechanical or electrical operation of the latch cams. (Class II, Priority Action)(A-89-92)

Issue an Airworthiness Directive (AD) for non-plug cargo doors on all transport category airplanes requiring the installation of positive indicators to ground personnel and flightcrews confirming the actual position of both the latch cams and locks, independently. (Class II, Priority Action)(A-89-93)

Require that fail-safe design considerations for non-plug cargo doors on present and future transport category airplanes account for conceivable human errors in addition to electrical and mechanical malfunctions. (Class II, Priority Action)(A-89-94)

The FAA responded to Safety Recommendations A-89-92 through -94 on November 3, 1989. During its evaluation of Safety Recommendation A-89-92, the FAA determined that Boeing 747 cargo doors with lock sectors, modified in compliance with AD 88-12-04, cannot be overridden during mechanical or
least one torque-limiting device. The Safety Board has reviewed AD 88-12-04 and has confirmed the FAA's findings. Based on this,

Safety Recommendation A-89-92 has been classified as "Closed--Reconsidered."

The FAA responded to Safety Recommendations A-89-93 and -94 describing action to review all outward opening (nonplug) doors and all jetpowered transport-category airplanes to determine what, if any, modifications are needed to ensure that these doors will not open in flight. The FAA pointed out that the door latch indicating system is to be only part of the review and that door designs will be evaluated against criteria specified in 14 CFR 25.783 as amended by Amendment 25-54, and the policy material published in Advisory Circular 25.783.1, adopted in 1980 and will take into account human factors involved in the routine operation of closing and locking doors to ensure that the latch and lock systems are fail-safe. Further, to emphasize the importance of human factors, the FAA has developed a training program for FAA certification personnel to enhance their knowledge of human factors in aircraft design. This training program will be offered to approximately 100 certification personnel during the next year. Based on this response, Safety Recommendations A-89-93 and -94 have been classified as "Open--Acceptable Action." The Safety Board believes it necessary to point out that this hazard exists for any pressurized aircraft using nonplug doors and that the FAA should not be limiting this review to only those transports which are jetpowered.

On November 29, 1990, Boeing issued service bulletin number 747-52-2224 applicable to all 747-100, 747-200, and 747-300 airplanes to add a new "door latch" switch to all 747 cargo doors. In addition to the door warning switch that monitors the position of the pressure relief doors, the new door latch switch is activated by the latch cam bellcrank to separately sense the position of the latch cams. The existing "door closed" switch is also replaced with a double pole switch. The additional pole is used to separately sense the position of the door. Another single pole switch is also added to redundantly sense the position of the door. If any of these switches are not actuated, the warning light on the flight engineer's panel and a new light added to pilot's glareshield panel will be illuminated. The modification also requires installation of new cargo door control panels on the forward and aft lower cargo doors. The new panel incorporates an additional light to indicate proper door locking.

The FAA mandated the incorporation of this service bulletin within 18 months by AD 90-09-06, Amendment 39-6581, effective May 29, 1990.

Also, as a result of this accident, on May 4, 1990, the National Transportation Safety Board issued the following safety recommendations to the FAA:

Amend 14 CFR 25.1447(c)(4) to require that face masks be attached to the regulators of portable emergency oxygen bottles. (Class II, Priority Action) (A-90-54)

Require, in accordance with the requirements of 14 CFR 25.1447 (c)(4), that a portable oxygen bottle be located at the flight attendant stations at exit door 5 right and at exit door 5 left in B-747 airplanes. (Class II, Priority Action) (A-90-55)

Require that no articles be placed in storage compartments that are located over emergency exit doors. (Class II, Priority Action) (A-90-56)

Amend 14 CFR 121.309(f) to require a readily accessible megaphone at each seat row at which a flight attendant is stationed. (Class II, Priority Action) (A-90-57)

Take corrective action to improve direct visibility to passengers from the upper level flight attendant jumpseat in the B-747 airplanes using eye reference data contained in Federal Aviation Administration report FAA-AM-75-2 "Anthropometry of Airline Stewardesses." (Class II, Priority Action) (A-90-58)

Issue an Airworthiness Directive to require that stronger latches be installed in oversized storage compartments that formerly held liferafts on all B-747 airplanes and also limit the distance that these compartments can be opened. (Class II, Priority Action) (A-90-59)

Demonstrate for each make and model of life preserver that it can be donned, adjusted, and tightened within the elapsed time required by TSO-C13d. Direct particular attention to the ease with which straps pass through adjustment fittings when the straps are pulled at all possible angles. (Class II, Priority Action) (A-90-60)

Establish a cutoff date of [within 1 year of this recommendation letter] after which all life preservers manufactured for passengercarrying aircraft would be required to meet the specifications of TSO-C13e. (Class II, Priority Action) (A-90-61)

The FAA first responded to these safety recommendations in a July 26, 1990, letter. Further responses to various safety recommendations in the group came in letters dated October 26, 1990 (A-90-59); May 13, 1991 (A-90-58); September 23, 1991 (A-90-55, -56, and -59); and March 9, 1992 (A-90-59). The current status of each safety recommendation is:

A-90-54: "Open--Acceptable Response," pending outcome of potential rulemaking initiative by the FAA.

A-90-55: "Open--Unacceptable Response," pending a review by the FAA of B-747 airplanes for compliance with portable oxygen bottle placement and securement requirements and for modifications that do not meet the intent of the type certification.

A-90-56: "Open--Unacceptable Response," pending a reexamination by the FAA of the potential for contents of compartments spilling out during an emergency and obstructing passengers.

A-90-57: "Open--Unacceptable Response," pending the FAA's review of its position regarding a requirement for multiple megaphones on passenger airplanes.

A-90-58: "Closed--Reconsidered" as a result of the Safety Board's acceptance of the FAA position that the cabin jumpseat design on

B-747's does not constitute an unsafe condition.
A-90-59: "Open--Acceptable Response," pending the issuance of an Airworthiness Directive to require stronger latches on oversized storage compartments on B-747 airplanes.
A-90-60: "Open--Acceptable Response," pending the implementation of the latest iteration of TSO-C13.
A-90-61: "Open--Unacceptable Response," pending inclusion in TSO-C13 (latest iteration) of a cutoff date after which all life preservers manufactured for passenger-carrying aircraft would be required to meet the specifications of the TSO.
The FAA's March 9, 1992, response to Safety Recommendation A-90-59 included the final AD addressing this issue. The AD does meet the intent of the recommendation, which is now classified as "Closed--Acceptable Action."
Also as a result of this accident, on May 4, 1990, the Safety Board reiterated the following recommendations to the FAA:
A-85-35
Amend 14 CFR 121 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; ensure that 14 CFR 25 is consistent with the amendments to Part 121.
A-85-36
Amend 14 CFR 125 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; amend Part 125 to require approved flotation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR 25 is consistent with the amendments of Part 125.
A-85-37

Amend 14 CFR 135 to require that all passenger-carrying air carrier aircraft operating under this Part be equipped with approved life preservers meeting the requirements of the most current revision of TSO-C13 within a reasonable time after the adoption of the current revision of the TSO; Amend Part 135 to require approved floatation-type seat cushions (TSO-C72) on all such aircraft; ensure that 14 CFR SFAR No. 23 is consistent with the amendments to Part 135.

In a November 28, 1988, letter to the FAA, the Safety Board recommended that a cutoff date January 1, 1989, be reestablished. Based on this accident, the Safety Board's again urges the FAA to establish a cutoff date by which life preservers meeting TSO-C13e would be introduced into the fleets within a reasonable time (A-85-36). The Safety Board recognizes that the FAA has complied with the part of this recommendation pertaining to the flotation-type seat cushions.

Safety Recommendations A-85-35 and -37 are being held in an "Open--Acceptable Action" status pending the publication of the final rule. Safety Recommendation A-85-36 is being held in an "Open--Unacceptable Action" status because Part 125 operations were not included in the FAA rulemaking action.

As a result of its investigation, on May 4, 1990, the Safety Board also recommended that the State of Hawaii, Department of Transportation, Airports Division:

Develop, in cooperation with the Department of Defense, procedures for direct radio communication between aircraft rescue and fire fighting vehicles operated by the State of Hawaii and Hickam Air Force Base that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-62)

Additionally, as a result of its investigation, on May 4, 1990, the Safety Board recommended that the Department of Defense:

Develop, in cooperation with the State of Hawaii Department of

Transportation, procedures for direct radio communication between aircraft rescue and firefighting vehicles operated by Hickam Air Force Base and the State of Hawaii that would be used when responding to airport emergencies at Honolulu International Airport. (Class II, Priority Action) (A-90-63)

Comply with Federal Regulation 14 CFR 139.319(f)(2) and the guidance contained in Federal Aviation Administration Advisory Circular 150/5220-14 by using high visibility color for aircraft rescue and firefighting vehicles that operate at Honolulu International Airport. (Class II, Priority Action) (A-90-64)

The Department of Defense responded to Safety Recommendations A-90-63 and -64 on August 17, 1990, citing the establishment of emergency radio communication ability between ARFF vehicles operated by Hickam Air Force Base and the State of Hawaii at Honolulu International Airport. Based on this action, Safety Recommendation A-90-63 was classified as "Closed--Acceptable Action" on December 12, 1990. With the establishment of the communications system as recommended, the Safety Board now classifies Safety Recommendation A-90-62 as "Closed--Acceptable Action."

Also, with regard to Safety Recommendation A-90-64, the Department of Defense pointed out that the Air Force has initiated a program to rep™ aint the vehicles over a 3-year period to spread out funding concerns. This safety recommendation is being held as "Open--Acceptable Response," pending the completion of the repainting program in 1993.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Member
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Member
March 18, 1992

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Washington Headquarters of the National Transportation Safety Board was notified of the United Airlines accident within a short time after the occurrence. A full investigation team departed Washington, D.C. at 1400 eastern daylight time on the same day and arrived in Honolulu at 0030 Hawaiian standard time the next day.

The team was composed of the following investigation groups: Operations, Structures/Systems, Maintenance Records, Metallurgy, and Survival Factors. In addition, specialist reports were prepared relevant to the CVR, FDR and radar plots.

Parties to the field investigation were United Airlines, the FAA, the Boeing Commercial Airplane Company, the Air Line Pilots Association, the International Association of Machinists, and the Association of Flight Attendants.

2. Public Hearing

A 3-day public hearing was held in Seattle, Washington, beginning on April 25, 1989. Parties represented at the hearing were the FAA, United Airlines, the Boeing Commercial Airplanes Company, the Air Line Pilots Association, and the International Association of Machinists.

APPENDIX B

PERSONNEL INFORMATION

Captain David Cronin

Captain David Cronin, 59, was hired by UAL on December 10,

1954. The captain holds Airline Transport Pilot (ATP) Certificate No. 1268493 with airplane multiengine land ratings and commercial privileges in airplane single-engine land, sea and gliders. The captain is type rated in the B747, DC10, DC8, B727, Convair (CV) 440, CV340, CV240 and the learjet. The captain was issued a first class medical certificate on November 1, 1988, with no limitations.

The captain's initial operating experience (IOE) check out in the B747 occurred in December, 1985. The captain's latest line and proficiency checks in the B747 were completed in August and December, 1988, respectively. Training in ditching and evacuation was included with the proficiency check. The captain had flown a total of about 28,000 hours, 1,600 to 1,700 hours of which were in the B747. During the 24-hour, 72-hour and 30-day periods, prior to the accident, the captain had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 76 hours, 18 minutes, respectively.

First Officer Gregory Slader

First Officer Gregory Slader, 48, was hired by UAL on June 15, 1964. The first officer holds ATP Certificate No. 1528630 with airplane multiengine land ratings and commercial privileges in airplane single-engine land. The first officer is type rated in B747, DC10, B727, and B737. The first officer was issued a first class medical certificate on February 14, 1989, with no limitations.

The first officer's initial operating experience (IOE) check out in the B747 occurred in August, 1987. The first officer's latest proficiency check in the B747 was completed in October, 1988. Training on ditching and evacuation was included with the proficiency check. The first officer had flown a total of about 14,500 hours, 300 hours of which were in the B747. During the 24-hours, 72-hour and 30-day periods prior to the accident, the first officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Second Officer Randal Thomas

Second Officer Randal Thomas, 46, was hired by UAL on May 22, 1969. The second officer holds Flight Engineer Certificate No. 1947041 for turbo jet powered airplanes, issued July 18, 1969. The second officer holds commercial pilot certificate No. 1585899 with ratings and limitations of airplane single and multiengine land with instrument privileges. The second officer was issued a first class medical certificate on December 6, 1988, with no limitations. The second officer's IOE check out in the B747 occurred in March, 1987. The second officer's latest proficiency check in the B747 was completed in October, 1988. Training in ditching and evacuation was included with the proficiency check. He had flown a total of about 20,000 hours, about 1,200 hours of which were as second officer on the B747. During his 24-hour, 72-hour and 30 day-periods, prior to the accident, the second officer had flown: 1 hour, 5 minutes; 13 hours, 35 minutes; and 46 hours, 25 minutes, respectively.

Flight Attendant and Chief Purser Laura Brentlinger

Flight attendant Laura Brentlinger, 38, was employed by UAL in May 1982; and had completed B747 recurrent training on September 19, 1988.

Flight Attendant and AFT Purser Sarah Shanahan

Flight attendant Sarah Shanahan, 42, was employed by UAL in August 1967; and had completed B747 recurrent training on October 10, 1988.

Flight Attendant Richard Lam

Flight attendant Richard Lam, 41, was employed by UAL on April 1970; and had completed B747 recurrent training on September 16, 1988.

Flight Attendant John Horita

Flight attendant John Horita, 44, was employed by UAL in June 1970; and had completed B747 recurrent training on November 1, 1988.

Flight Attendant Curtis Christensen

Flight attendant Curtis Christensen, 34, was initially employed by PAA in May 1978. He was subsequently employed by UAL in February 1986 when UAL purchased PAA Pacific Division. Flight attendant Chrisensen had completed B747 recurrent training on December 12, 1988.

Flight Attendant Tina Blundy

Flight attendant Tina Blundy, 36, was employed by UAL in May 1973; and had completed B747 recurrent training on October 28, 1988.

Flight Attendant Jean Nakayama

Flight attendant Jane Nakayama, 37, was employed by UAL in August 1973; and had completed B747 recurrent training on December 6, 1988.

Flight Attendant Mae Sapolu

Flight attendant Mae Sapolu, 38, was initially employed by Pan American Airlines (PAA) in March 1973. She was subsequently employed by UAL in February 1986; when UAL purchased PAA Pacific Division. Flight attendant Sapolu completed B747 recurrent training on October 13, 1988.

Flight Attendant Robyn Nakamoto

Flight attendant Robyn Nakamoto, 26, was employed by UAL in April, 1986, and transferred to the Inflight Service Division in May, 1988. She was initially trained on the B747 in May 1988; and had not attended recurrent training.

Flight Attendant Edward Lythgoe

Flight attendant Edward Lythgoe, 37, was employed by UAL in December 1978; and had completed B747 recurrent training on October 21, 1988.

Flight Attendant Sharol Preston

Flight attendant Sharol Preston, 39, was employed by UAL in July 1970; and had completed B747 recurrent training on July 29, 1988.

Flight Attendant Ricky Umehira

Flight attendant Ricky Umehira, 35, was employed by UAL in

November 1983; and had completed B747 recurrent training on November 15, 1988.

Flight Attendant Darrell Blankenship

Flight attendant Darrell Blankenship, 28, was employed by UAL in February 1984; and had completed B747 recurrent training on February 10, 1988.

Flight Attendant Linda Shirley

Flight attendant Linda Shirley, 30, was employed by UAL in March 1979; and had completed B747 recurrent training on November 3, 1989.

Flight Attendant Ilona Benoit

Flight attendant Ilona Benoit, 48, was initially employed by PAA in November 1969. She was subsequently employed by UAL in February 1986; and had completed B747 recurrent training on November 17, 1988.

Lead Ramp Serviceman Paul Engalla

Lead ramp serviceman Paul Engalla was employed by UAL in 1959. Because of his extensive ramp service experience, Mr. Engalla was selected as a ramp service trainer in 1986.

Ramp Serviceman Daniel Sato

Ramp serviceman Daniel Sato was employed by UAL in May 1987. Company records indicate that his proficiency in the opening and closing of B747 cargo doors and the operation of container loads was attained in September 1988.

Ramp Serviceman Brian Kitaoka

Ramp serviceman Brian Kitaoka was employed by UAL in November 1986. Company records indicate that his proficiency in the operation of container loaders was attained in November 1987. His proficiency in the opening and closing of B747 cargo doors was attained in October 1988.

Dispatch Mechanic Steve Hajanos

Dispatch mechanic Steve Hajanos was employed as an airplane mechanic by UAL on October 30, 1986. He holds FAA Airplane and Powerplants Certificate No. 362583850, issued November 14, 1981. He was formerly employed by Aloha Airlines as a maintenance supervisor and by World Airways as a mechanic and maintenance supervisor. He began his aviation career as an airplane mechanic in the United States Air Force.

APPENDIX C

AIRPLANE INFORMATION

Type of Date of Maximum Inspection Inspection Cycles Interval Service No. 1 Current 02/23/89 58,814:24 15,027 Note 1 Previous 02/23/89 58,809:02 15,026 Service No. 2 Current 02/22/89 58,802:35 15,024 65 Hours Previous 02/18/89 58,747:12 15,016 Note 2 A Check Current 02/14/89 58,710:14 15,009 350 Hours Previous 01/16/89 58,368:57 14,947 B Check Current 11/28/88 57,751:44 14,839 131 Days Previous 07/28/88 56,635:36 14,632 C Check Current 11/28/88 57,751:44 14,839 393 Days Previous 11/19/87 53,789:00 14,146 MPV Check Current 04/30/84 43,731:0 11,857 5 Years Previous 01/30/80 30,906:0

D Check Current 04/30/84 43,731 19,237 9 Years Previous 09/09/76 19,237 Note 1: Service No. 1 to be accomplished on through flights or at trip termination whenever time is less than 12 hours per Maintenance Manual Procedures BX 12-0-1-1.

Note 2: Aircraft with layover of 12 hours or more will receive a Service No. 2 not to exceed 65 flight hours between checks.

APPENDIX D

INJURY INFORMATION

Flight Crewmember.--The second officer sustained minor superficial brush burns to both elbows and forearms, during the evacuation.

Cabin Crewmembers.--The cabin crewmembers sustained the following injuries during the evacuation:

Flight attendant No. 1 sustained a strained left shoulder;

Flight attendant No. 2 sustained acute thoracic and lumbosacral

strain;
Flight attendant No. 3 sustained a mild right bicep strain;
Flight attendant No. 4 sustained a left elbow contusion, left shoulder dislocation, and mild lumbosacral strain;
Flight attendant No. 5 sustained a left calf contusion;
Flight attendant No. 6 sustained a mild left elbow bruise;
Flight attendant No. 7 sustained mild left arm and lower back strain;
Flight attendant No. 8 sustained a soft tissue injury to the back;
Flight attendant No. 9 sustained abrasions to both palms and the left knee;
Flight attendant No. 10 sustained a fracture of the left tenth rib;
Flight attendant No. 11 sustained a minimal injury to the right middle finger PIP joint and left first MP joint;
Flight attendant No. 12 sustained a pulled muscle on the left side of the neck;
Flight attendant No. 13 sustained a comminuted fracture of the right ulna and radius;
Flight attendant No. 14 sustained a mild thoracic back strain;
Flight attendant No. 15 sustained a non-displaced fracture of C-6, a cerebral concussion, a fracture of the proximal right humerus, and multiple lacerations;
A flight attendant, flying as a passenger, sustained mild lumbosacral strain, a laceration of the right little finger, and a left elbow abrasion.
Passengers.--Nine Passengers who were seated in seats 8H, 9FGH, 10GH, 11GH, and 12H, were ejected from the fuselage and were not found; and thus, are assumed to have been fatally injured in the accident.
Passengers seated in the indicated seats sustained the following injuries:
Seat
7C - Barotrauma to both ears

9C - Half-inch laceration to the upper left arm, superficial abrasions to left arm and hand, barotrauma to both ears
9E - Superficial abrasions and contusions to the left hand, mild barotrauma to both ears
10B - Superficial abrasions to the left elbow and left middle finger
10E - Superficial abrasions to the torso and left forearm, bruising of the left hand and fingers
11E - Laceration on the right ankle tendon, multiple bruises
11F - Slight contusion of the right shoulder
13D - Barotrauma to both ears
13E - Bleeding in both ears
13H - Contusion to the left periorbital area
14A - Laceration in the parietal occipital area, barotrauma to both ears
15J - Comminuted fracture of the lateral epicondyle of the left distal humerus (about 5mm separation)
16B - Superficial abrasions to the right arm
16J - Barotrauma to both ears
16K - Right temporal abrasions
26A - Barotrauma to both ears
26B - barotrauma to both ears
26H - Barotitis to both ears, low back pain, irritation to the right eye due to foreign bodies
27A - Barotrauma to the right ear
28J - Superficial abrasions and a contusion to the left hand, mild barotrauma to both ears

1The flap track canoe fairings are numbered 1 through 8, from left outboard to right outboard.

2For ease in reference, the following numbering was used to relate forward cargo door frames to fuselage body stations (BS): frame 1--BS 567.10, frame 2--BS 580.95, frame 3--BS 596.75, frame 4--BS 608.15, frame 5--BS 623.96, frame 6--BS 636.02, frame 7--BS

651.50, frame 8--BS 662.90.
3 The "used" switch is the switch through which electricity passes; the "unused" switch does not have electricity pass through it.
4NFPA 414 - Aircraft Rescue and Fire Fighting Vehicles, National Fire Protection Association, 1984, Batterymarch Park, Quincy, MA 02269.
5Airport Fire and Rescue Vehicle Specification Guide, AC 150/5220-14, March 15, 1979, Federal Aviation Administration, Washington, D.C. 20591.
6 Air Carrier Overwater Emergency Equipment and Procedures" (NTSB/SS-85/02)

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: "Jaswinder Parmar" <jaswinderp@hotmail.com>
Subject: **AARs**

Dear Jaswinder,

The crown gave us 26 CD ROMs of information that they have gathered over the past 15 years. The CD's contain scanned images of documents they have collected. I am in the process of converting those images to text documents. Once this process is done the defence team will better be able to do searches using standard boolean expressions.

Terrific. I have the three AAR of AI 182, PA 103, and UAL 811 electronically and use the 'search' function all the time. The AAR of TWA 800 is very large and not suitable for emailing but is on

NTSB web site.

Let me send you the three AAR for reference, I'll use three separate email.

I am also in the process of creating a web site with forum that will alow us to communicate over the internet. I am looking into different ways to make sure the site is secure.

Well, sir, put in www.airindiaflight182.com into your browser and see where you go. Voila! Explosive decompression for AI 182. If you want to get rid of the banner ad on the bottom, just go direct to www.corazon.com

I own that domain and the defence can use it. Making it secure and creating the site would require professionals above my league.

I assume you got my pictures, I just want to confirm we can send and receive .jpg between us.

Narinder is coming down to my house tomorrow for another discussion about plans.

I really believe we are getting some where. It is time for the defence to take the initiative. Let the Crown disprove the wiring/cargo door/explosive decompression explanation (they can't) as we try to disprove the 'bomb' explanation, (we can).

Sincerely,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: "Aniljit Singh" <aniljitsingh@hotmail.com>
Subject: **Re: Morale booster, no bomb.**

Mr. Malik is not permitted to receive any food from the outside. His family
is vegetarian - so chocolates with no eggs please.

as

Got it, chocolate, no eggs is OK.

Is there anything official that Garstang changed to Aft instead of forward? Is that the point of view of Garstang or the TSB? Any reason for his changing. This is potentially very difficult. I can't rebut phantoms.

If it's aft, then the charges need to be refiled because the charges are based on the official report which says forward.

If forward, the charges need to be dismissed because all baggage from Vancouver, including the 'bomb', when into the aft compartment.

If aft, a new report by TSB needs to be written and approved explaining the new evidence which reverses the overwhelming evidence of explosion in forward compartment.

Sincerely,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: "??a ??h" <box2026@msn.com>
Subject: **Legally Blonde**

Thank you for the message regarding the appraisal. I forwarded your message on to Andy so he is current. I appreciate how you are handling all the various aspects of this transaction, and admire your calm manner after experiencing so much turbulence.

We mailed the contract to Mrs. Titus this afternoon, so that she will receive it on her return home.

Thanks for all your assistance and immediate response to these matters.

All the best, Randa

Dear Randa,

Message received. Standing by for email about deal.

Legally Blonde is good, very funny, not very true, but what the heck...

Needs a sequel, "Illegally Brunette."

Cheers,

Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: AHSWARTZ@aol.com
Subject: Shorted wiring/forward cargo door rupture/ explosive decompression/inflight breakup

Very intriguing Can you tell me more about it?????Andy Swartz

Well.....

Assume: that I believe my conclusions although they may be considered wrong by others; that if the discovery were easy, it would have been done long ago by others, that my conclusions are politically devastating to several countries, that I can document every statement I make, it's never been refuted, and you will not believe it at first blush.

I claim that four Boeing 747s have had fatal accidents caused by faulty wiring causing the forward cargo door to open in flight leading to explosive decompression. The state of the world today is that all four were thought to be bombs planted by terrorists. One accident was shown to be a cargo door event hours later, one accident had the bomb explanation ruled out 17 months later, and for the two remaining, the bomb explanation remains the official explanation. Conspiracy thinking rules, unfortunately.

I offer the mechanical explanation with no conspiracy involved and it's rejected as too weird.

The rewards come in when offered by governments and an individual for explanations for the fatal accidents. As it stands now, the rewards are offered for informants to give up terrorists who are assumed to be the culprits. I know the culprit and the explanation and it's wiring coupled with a design defect of outward opening non plug cargo doors. I have written thousands of pages about the events and contacted hundreds of persons in authority with mostly futile results.

There is an upcoming trial in February 02 in Vancouver BC for three accused of planting a bomb in Air India Flight 182. I know they did not do it, because nobody 'did it'. I've met two of the attorneys for one of the accused, Mr. Malik. They remain unconvinced. The evidence picks the flight numbers and they are all controversial of course, Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and Trans World Airlines Flight 800.

The trigger event for action is another fatal accident that fits the pattern. The event is almost inevitable and could happen anytime. We will both know it was a shorted wiring/forward cargo door rupture/explosive decompression/inflight breakup event when it is reported that a Boeing 747 came apart in the air suddenly and the explanation will be 'bomb'; the CVR will show a sudden loud sound followed by an abrupt power cut to the recorders; and engine number three will show foreign object damage plus much other significant matching evidence.

I've been at this for 12 years. It's a good story with life and death implications. When you consider it, consider this, I have been in a sudden night fiery fatal jet airplane crash and I am talking about sudden night fiery fatal jet airplane crashes. I've been there and I know what I'm talking about.

Details at www.corazon.com

Smith

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: AHSWARTZ@aol.com
Subject: **Re: Shorted wiring/forward cargo door rupture/ explosive decompression/infligh...**

Dear Mr. Smith Thank you for the description of your case. It is well
beyond our capabilities to handle such a case. I suggest the great airplane
crash specialist located in LA called Magana Cathcart (Bill Wimsatt) good
luck. Andy Swartz

Andy, Andy, Andy, still underestimating me.

I understand.

Cheers,
Barry

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: AHSWARTZ@aol.com
Subject: **Circuit breakers**

You are correct. I have no doubt you have the ability to prbably handle the
action by yourself. You certainly have the courage to do so. The problem is

the massive legal maneuvers to be expected by the other side. In any event
good luck and I sincerely thank you for considering me as your counsel. Andy
Swartz 9/1/01

Well, I did not mean to be arrogant and was later afraid my comment appeared to be so.

There would be no 'massive legal maneuvers' by either side until the next one explodes. I am looking ahead.

I would not be a party as victim or family member, Kriendler and Wolk and Granito III have that area sewed up.

It's even a stretch to claim a reward for explaining a crash when what the reward people want is the blood of a terrorist, not the red paint smears which shows the door opened up and outward and smashed against the fuselage transferring paint.

I've stayed away from the legal arena on this wiring/cargo door thing precisely for the reasons you state, massive maneuvers.

Well, thanks anyway and for at least considering it. If you will follow the upcoming trial of the three accused 'terrorists' for the 'bombing' of Air India Flight 182, you may see the wiring/cargo door explanation surface. One of the accused, Mr. Malik, is a millionaire businessman and has hired two attorneys, Crossin and Donaldson, who may know about crime and bank robberies, but nothing about why planes crash.

For information, if the below 10/11/00 event had happened in flight instead of on the ground, there would have been another inflight decompression leading to fatalities. The door stayed closed in flight because the circuit breakers had been pulled by the crew. The FAA specifically ordered crews to leave the CB in. The crew disobeyed the FAA and saved their lives.

My position based on facts, data, and evidence is the below sequence occurred for the other three controversial accidents which have been blamed on something not so damning for all concerned such as terrorists or mystery fuel tank explosions.

Well, maybe later. Life is so funny.

Cheers,
Barry

Difficulty Date : 10/11/00
Operator Type : Air Carrier
ATA Code : 5210
Part Name : CONTROLLER
Aircraft Manufacturer : BOEING
Aircraft Group : 747
Aircraft Model : 747422
Engine Manufacturer : PWA
Engine Group : 4056
Engine Model : PW4056
Part/Defect Location : CARGO DOOR
Part Condition : MALFUNCTIONED
Submitter Code : Carrier
Operator Desig. : UALA
Precautionary Procedure : NONE
Nature : OTHER

Stage of Flight : INSP/MAINT
District Office Region : Western/Pacific US office #29
A/C N Number : 199UA
Aircraft Serial No. : 28717
Discrepancy/Corrective Action:FWD CARGO DOOR OPENED BY ITSELF WHEN CB PUSHED IN. ON ARRIVAL, CIRCUIT BREAKERS WERE PUSHED IN, WHEN PRESSURE RELIEF DOOR HANDLE WAS OPENED THE DOOR LATCHES OPENED AND THEN THE DOOR OPENED ON ITS OWN. COULD NOT DUPLICATE PROBLEM AFTER INITIAL OPENING.

ORDER: 8300.10

APPENDIX: 4

BULLETIN TYPE: Flight Standards Information Bulletin (FSIB)
for Airworthiness (FSAW)

BULLETIN NUMBER: FSAW 93-50

BULLETIN TITLE: Inappropriate Use of Circuit Breakers
During B-747 Lower Lobe Cargo Door Operation

EFFECTIVE DATE: 06-02-94

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1. SUBJECT. This FSIB informs inspectors of unsafe procedures
being used by some operators to close and lock the lower lobe cargo doors of the Boeing 747 (B-747) series aircraft.

2. BACKGROUND.

A. This bulletin was developed after an inquiry by a foreign airworthiness authority into the special procedures used by a specific operator to close and lock the lower lobe cargo doors of B-747 series aircraft. The special procedure included in the operator's maintenance manual called for manual tripping of the cargo door control circuit breakers and the section 2 ground handling bus circuit breaker in order to further remove the possibility of power being applied accidentally to the cargo door control circuitry.

B. The manual tripping of the circuit breakers in special cargo door lock procedures is unnecessary and decreases the reliability of the circuit breakers to perform their intended function. Frequent switching of the breakers could cause them to trip before the point of rated voltage or not to trip at all. Both cases could have adverse effects (such as the following) in relation to the safe operation of the cargo doors:

(1) Circuit breakers that trip before the point of rated voltage would cause increased manual operation of the cargo doors.

(2) Manual operation could introduce additional failure conditions, such as out-of-sequence operation and overdriving of the cargo door mechanisms.

(3) Service history has shown that manual operation of the cargo doors is more prone to cause damage; for example, the failure of a breaker to trip at the point of rated voltage could lead to failed components and fire.

C. The revision to the B-747 cargo door lock sectors warning system, in airplanes compliant with Airworthiness Directive (AD)
90-09-06, provides an increased level of integrity so that manual tripping of the circuit breakers is not necessary to prevent the possibility of an uncommanded opening of the cargo doors. Furthermore, power to the cargo door is automatically removed by
the Master Latch Lock System upon first motion of the Master Latch Lock Switch away from the fully unlocked position.

3. ACTION. Principal maintenance inspectors (PMI) having certificate management responsibilities for operators of Boeing 747 series aircraft should ensure that this information is brought to the attention of their respective operators. Any operators using this procedure should be discouraged from its continued use.

4. INQUIRIES. This FSIB was developed by SEA.AEG. Any questions regarding this information should be directed to AFS-510 at (703) 661-0333, extension 5018.

5. EXPIRATION. This FSIB will expire on 05-31-95.

/s/
Edgar C. Fell

From AAR 92/02 United Airlines Flight 811

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053 hours and 1,547 cycles at the time of the occurrence.

The airplane was being prepared for flight at the UAL maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further

work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.

The aft cargo door was cranked open manually, the C-288 circuit breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident. With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage.

UAL personnel notified the Safety Board of the occurrence, and the airplane was examined at JFK by representatives of the Safety Board, United Airlines, and Boeing. After the wires in the damaged area were electrically isolated, electrical operation of the door was normal when the door was unlocked. When the door was locked (master latch lock handle closed), activation of the door control switches had no effect on the door. This indicated that the S2 master latch lock switch was operating as expected (removing power from the door when it was locked). After the on-site examinations, the wiring bundle was cut from the airplane and taken to the Safety Board's materials laboratory for further examination.

The wiring bundle with the damaged wires contained all electric control wires (28 volt DC) and power wires (115 volt AC) that pass between the fuselage and the aft cargo door. From the forward side of the J-4 junction box, the bundle progresses in the forward direction, just above the forward pressure relief door, then upward, following the forward lift actuator arms. The bundle then enters an empty space between two floor beams, where the bundle has an approximate 180-degree bend when the door is closed. From this location, the wiring bundle progresses inboard, through a fore-to-aft intercostal between two floor beams. The wiring bundle then splits, with wires going in several directions.

The bundle is covered by the flexible conduit approximately from the lower end of the lift actuator arms to the fore-to-aft intercostal between the floor beams.

The conduit covering the wiring bundle is intended to prevent the wire bundle from being damaged during opening and closing of the door and during cargo handling operations. The conduit is a sealed flexible interconnector consisting of a convoluted helical brass innercore covered by a bronze braid. The innercore is soldered at every other convolute, and should be capable of withstanding pressures exceeding 1,000 pounds per square inch (psi). Boeing has indicated that the conduit is an evolutionary improvement and that it has been installed on all B-747 airplanes produced since 1981 (from line number 489 on). Airplane N152UA was delivered in April 1987.

Airplanes produced prior to 1981, including N4713U, used a bungee retraction system, to retract the cargo door wire bundle. Guidelines for the replacement of the bungee system with the flexible conduit were covered in Boeing Service Bulletin 747-752-2170, dated August 1981. The service bulletin was prompted by reports that the wire bundle bungee retraction system had not retracted the wire bundle sufficiently to prevent trapping the bundle between the cargo door and the door frame. UAL did not perform the retrofit on N4713U, which was line number 89, nor was the company required to do so.

Examination of the wires in the damaged area on the wiring bundle revealed that four of the wires were similar in appearance, with insulation breaches that progressed through to the underlying conductor. Adjacent to the breach on these four wires, the insulation was blackened, as if it had been burned. Another wire contained an extensive breach but no evidence of burned insulation. The damaged area was located on the bundle at a position approximately corresponding to a conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism. This support bracket was found bent in the forward direction. In addition, mechanical damage was noted on adjacent components in this area.

A second damaged area was noted on the wiring bundle at a position approximately corresponding to the conduit swivel clamp at the elbow between the two arms of the forward lift actuator mechanism. Wires in this area were missing portions of their exterior coating, but no breaches to the underlying conductors were noted.

The exterior braid on the conduit contained minor rub marks and was slightly kinked at a position corresponding to the area on the wires with breached insulation. Additional examinations revealed that the innercore of the conduit contained multiple circumferential cracks in the areas corresponding to the damage areas on the wires. The cracks were in the convoluted innercore directly adjacent to the inside diameter of the conduit.

The lock sectors, latch cams, and latch pins from the aft cargo door were examined on the incident airplane and were generally in excellent condition. There was no evidence to suggest that the cams had ever been electrically (or manually) driven into or through the lock sectors.

Boeing also informed the Safety Board that, in May of 1991, a B-747 operated by Quantas was found to have chafing of the wires in the wire bundle to the aft cargo door. This airplane also had a flexible conduit protecting the wires, and the chafing was located approximately at the standoff pin on the bracket at the upper arm of the forward lift actuator.

The Safety Board determined that the chafing of the wires on the airplane involved in the JFK occurrence was caused by, or was greatly accelerated by, the circumferential cracks in the conduit and that the cracks in the conduit were caused either by repeated flexing of the conduit as the cargo door opens and shuts or by unusual stresses on the conduit generated concurrently with damage to the conduit guide bracket and attached standoff pin on the upper end of the forward lift actuator upper arm.

A portion of the wire bundle for the forward cargo door on many B-747 airplanes is also covered by a flexible conduit that is very similar to the conduit for the aft cargo door. However, there are substantial differences between the orientation of the flexible conduits for the two doors, and the Safety Board has not become aware of problems associated with the flexible conduit for the forward door.

Nevertheless, because of the concerns about the chafed wires and possible electrical short circuits, on August 28, 1991, the Safety Board recommended that the FAA:

Issue an Airworthiness Directive applicable to all Boeing 747 airplanes with a flexible conduit protecting the wiring bundle between the fuselage and aft cargo door to require an expedited inspection of:

(1) the wiring bundle in the area normally covered by the conduit for the presence of damaged insulation (using either an electrical test method or visual examination);

(2) the conduit support bracket and attached standoff pin on the upper arm of the forward lift actuator mechanism;

(3) the flexible conduit for the presence of cracking in the convoluted innercore.

Wires with damaged insulation should be repaired before further service. Damage to the flexible conduit, conduit support bracket and standoff pin should result in an immediate replacement of the conduit as well as the damaged parts. The inspection should be repeated at an appropriate cyclic interval. (Class II, Priority Action) (A-91-83)

Evaluate the design, installation, and operation of the forward cargo door flexible conduits on Boeing 747 airplanes so equipped and issue, if warranted, an Airworthiness Directive for inspection and repair of the flexible conduit and underlying wiring bundle, similar to the provisions recommended in A-91-83. (Class II, Priority Action) (A-91-84)

The FAA responded to these safety recommendations on November 1, 1991, stating that it agreed with the intent of the recommendations and that the issuance of an NPRM was being considered to address the issues in the safety recommendations.

The Safety Board replied on November 27, 1991, classifying each of the recommendations as "Open--Acceptable Response," pending the completion of the rulemaking process. Since that exchange of correspondence, the FAA has published an NPRM which is now being reviewed by the Safety Board. Safety Recommendations A-91-83 and -84 will continue to be classified as "Open--Acceptable Response" until an acceptable final rule is published.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: "Keith Hamilton" <keithrh@telus.net>
Subject: **Contact! Air India Flight 182**

Dear Mr. Hamilton, 15 October, 2001

Well, yours is an important email. Thanks for contact.

I have briefly reviewed your report, and it does raise several issues that do not appear to have been addressed in any of the other reports, and which I want to examine more closely.

Exactly right.

My report is dense because it is supposed to be, most scientific reports are when supported by documentation. For informal purposes, please email me with questions and I can answer them briefly without all the quotations. Or call by phone.

I know your clients are innocent because they did not do it, because nobody 'did it'. It was not evil persons but a mechanical event that has happened before and since. And it's all documented and available for inspection for those willing to be objective and scientific.

Just for openers:

The CASB says explosion of unknown type in forward cargo compartment of Air India Flight 182.
The Indians in the Kirpal report state explosion by bomb in the forward cargo compartment.
The RCMP with Garstang of TSB state explosion by bomb in aft cargo compartment.
AAIB opines explosion of unknown cause but not bomb, in the forward cargo compartment.
Smith, that's me, says explosion of explosive decompression when forward cargo door inadvertently opens inflight at the forward cargo compartment.
TSB is neutral.

All Vancouver baggage loaded in aft cargo compartment.
All Montreal baggage loaded into forward cargo compartment.

Can you see the problems for the prosecution? Where was exactly the explosion? What was the source? If in aft, how can CASB and Indians be so wrong? If forward, then Vancouver baggage could not have held bomb and accused are innocent.

TSB, CASB, Indians, RCMP, and this independent investigator all have conflicting answers.

I believe mine to be the most correct and invite rebuttal or questions.

From your point of view: Was it a bomb or not? If you believe a bomb then leave me out of it and continue on the conspiracy lunacy that sweeps the world.

If not a bomb, what was it? Then include me and we can go through the ways airplanes can come apart in the air as Air India Flight 182 did.

My model for the shorted wiring/forward cargo door rupture/ explosive decompression/inflight breakup explanation for Air India Flight 182 is United Airlines Flight 811, AAR available upon request. It's happened before, Mr. Hamilton.

Please keep in mind, Air India Flight 182 was an airplane crash, not a bank robbery. If we start with that premise, everything will make sense.

I await your enquiries. The sooner the better.

Cheers,
John Barry Smith
(831) 659 3552
541 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance bombardier navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.

Dear Mr. Smith:

I do not appear to have a mailing address for you, so I am sending you this email message instead.

I am one of the lawyers working on the defence team for Ajaib Singh Bagri, one of the three men charged with the Air India Flight 182 crash. Jaswinder Parmar suggested that I write to you, as I am reviewing the forensic evidence.

I have a copy of your report dated April 9, 2001, and the appendices. As you would expect, I have many reports that have been generated during the RCMP investigation and the various inquiries since 1985. I am working my way through them chronologically, and will be reading your's very closely within the next few weeks.

I have briefly reviewed your report, and it does raise several issues that do not appear to have been addressed in any of the other reports, and which I want to examine more closely.

When I have had an opportunity to read your report and appendices carefully, I expect that I will want to be in touch with you again, to discuss some specific issues.

Thank you for the interest you have expressed in our case. I will be in touch with you again, as my review of the reports continues.

Sincerely,

Keith Hamilton

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: keithrh@telus.net
Subject: **Forensics**

Dear Mr. Hamilton, 17 Oct 01

Forensics...forensics in an airplane crash. I interpret that to mean examination and evaluation of all physical evidence.

Well, there's not that much. 5% of the wreckage recovered. Lots of 35 MM film and video.

The most valuable of all the evidence is the rare direct testimony of the actual event on the CVR. That is gold. We can hear it but we can't see it. Then the FDR. The CVR and FDR are the heart of the physical evidence. They were put there to enable investigators to reconstruct what happened in the event of an accident. It happened and they did their job.

They state to the CASB, the AAIB and me that no bomb exploded anywhere on Air India Flight 182 and that the explosion that caused the inflight breakup was unknown or of a cause yet to be determined.

I have continued that out to determine the cause of the explosion in the forward cargo compartment was one of explosive decompression, just like as what happened four years later to United Airlines Flight 811.

No bomb, no bad guys, no crime, no criminals. Just a mechanical cause that is a probable cause that causes much grief among many powerful institutions that don't like being blamed for innocent deaths especially if the blame can be shifted. We might do the same if in their positions.

So, Mr. Hamilton, you are being compensated by the Crown? You are one side of the adversarial British type judicial system and being paid by the other side? Weird. Do you feel a conflict of interest?

What is your interest? Are you a neutral scientist? Strategy attorney? Spy for RCMP?

Ah, "Paranoia strikes deep, into your life it will creep."

Let's agree we are the good guys, I'm trying for aviation safety to get bad wiring and poor cargo doors fixed and you are trying to create justice by evaluating fairly and objectively real facts, data, and evidence.

I've been doing this persuasion thing for six years and I'm very poor at it. So, now I just say whatever I want assuming it makes no difference because the correct answer is in the twisted metal, bent plastic, crushed seats, dented panels, torn skin, magnetic tapes, and cargo manifests.

The answer is no bomb, no missile, no center tank explosion, no midair, but the same thing that did the Comet in, explosive decompression at high altitude. Ka-Boom! That is on the Air India Flight 182 CVR and the effect is immediately shown on the FDR.

The cause of the explosive decompression in the Comet was metal fatigue around a squarish window. The cause for Air India Flight 182, in my humble but expert opinion, was shorted wiring/ forward cargo door rupture/explosive decompression which caused the inflight breakup.

Wiring is the final culprit, then outward opening/non plug cargo doors, then the physical laws of pressure differential at altitude; 8.9 PSI for Air India Flight 182 at 35000 feet MSL at almost 300 Knots IAS.

So, choice for the public: Exciting story of agents and bombs, and timers, and terrorism here and there and politics everywhere; or boring mechanical problem that brought down an airliner and happened since, was supposed to have been fixed with stronger metal, but wasn't.

Of course the prevailing belief for Air India Flight 182 was bomb, bomb by terrorists, bomb by Sikh terrorists, bomb by Sikh terrorist Bagri. And even more so right now. Few will listen to a story about a plane crash that was not a terrorist act even though it was thought to be for 16 years.

But, the prevailing wisdom is wrong and time showed it to be so when four years after Air India Flight 182, another similar event in a Boeing 747 occurred that did not come apart but almost, but was able to land with its CVR and FDR intact which matched Air India Flight 182.

The CVR and FDR for Air India Flight 182 and United Airlines Flight 811 match in many significant points and those are the heart of any aviation accident investigation.

I have had email correspondence with Mr. Bill Tucker of TSB, Director General of Investigations. Would you like to see those? He is an ally, I believe. He may correspond with you, I've asked him to conduct a supplemental AAR from the TSB for Air India Flight 182 since it is prudent to have an official version ready during a trial. He has declined so far giving budget and staff overload reasons.

I've put a recent uncommanded cargo door opening on a Boeing 747 below. It's still happening as it did on June 23, 1985 with Air India Flight 182 and February 23, 1989 with United Airlines Flight 811. (I also contend it happened for two other controversial Boeing 747 crashes.) So, there is an urgency from my point of view of preventing future catastrophic events since there are about 1000 Boeing 747s in active service that are affected.

If you rule out circumstantial evidence such as Narita and try to find any direct evidence of bomb, there is none.

If you rule out circumstantial evidence of a bomb, there is much evidence to explain the mechanical alternative, the shorted wiring/forward cargo door rupture/explosive decompression/ inflight breakup explanation.

If the defense team believes it was a bomb that broke apart Air India Flight 182 and are looking for ways to squabble about were it was, how big, how did it get there, who put it, and why, please tell me. You will do what the PA 103 team did, agree it was a bomb but their clients did not put it there. One of the three Sikhs will be convicted in the political judgment such as PA 103.

If you submit that there was no bomb and no crime and no criminals, the Crown must establish a crime has been committed and they can't do that if you offer a plausible mechanical explanation with precedent that makes more sense and has more evidence.

Cross examine me if you wish, Mr. Hamilton. My explanation stands firm. It can not be shaken although I encourage attempts at rebuttal or refutation. It's not because of me and my charm, it's because of the facts, data, evidence, forensic evidence.

I'll be glad to go over any of the forensic evidence with you, Mr. Hamilton, and the sooner the better.

Sincerely,
Barry
John Barry Smith
(831) 659 3552
541 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com
Survivor of sudden night fiery fatal jet plane crash in RA-5C

Cargo Door Uncommanded Openings 1991 and 2000 Nonfatal (First instance on -400)

Difficulty Date : 10/11/00
Operator Type : Air Carrier
ATA Code : 5210
Part Name : CONTROLLER
Aircraft Manufacturer : BOEING
Aircraft Group : 747
Aircraft Model : 747422

Engine Manufacturer : PWA
Engine Group : 4056
Engine Model : PW4056
Part/Defect Location : CARGO DOOR
Part Condition : MALFUNCTIONED
Submitter Code : Carrier
Operator Desig. : UALA
Precautionary Procedure : NONE
Nature : OTHER
Stage of Flight : INSP/MAINT
District Office Region : Western/Pacific US office #29
A/C N Number : 199UA
Aircraft Serial No. : 28717

Discrepancy/Corrective Action:FWD CARGO DOOR OPENED BY ITSELF WHEN CB PUSHED IN. ON ARRIVAL, CIRCUIT BREAKERS WERE PUSHED IN, WHEN PRESSURE RELIEF DOOR HANDLE WAS OPENED THE DOOR LATCHES OPENED AND THEN THE DOOR OPENED ON ITS OWN. COULD NOT DUPLICATE PROBLEM AFTER INITIAL OPENING.

From NTSB AAR 92/02 United Airlines Flight 811

1.17.6 Uncommanded Cargo Door Opening--UAL B-747, JFK Airport

On June 13, 1991, UAL maintenance personnel were unable to electrically open the aft cargo door on a Boeing 747-222B, N152UA, at JFK Airport, Jamaica, New York. The airplane was one of two used exclusively on nonstop flights between Narita, Japan, and JFK. This particular airplane had accumulated 19,053

hours and 1,547 cycles at the time of the occurrence.
The airplane was being prepared for flight at the UAL maintenance hangar when an inspection of the circuit breaker panel revealed that the C-288 (aft cargo door) circuit breaker had popped. The circuit breaker, located in the electrical equipment bay just forward of the forward cargo compartment, was reset, and it popped again a few seconds later. A decision was made to defer further work until the airplane was repositioned at the gate for the flight. The airplane was then taxied to the gate, and work on the door resumed.
The aft cargo door was cranked open manually, the C-288 circuit breaker was reset, and it stayed in place. The door was then closed electrically and cycled a couple of times without incident. With the door closed, one of the two "cannon plug" (multiple pin) connectors was removed from the J-4 junction box located on the upper portion of the interior of the door. The wiring bundle from the junction box to the fuselage was then manipulated while readings were taken on the cannon plug pins using a volt/ohmmeter. Fluctuations in electrical resistance were noted. When the plug was reattached to the J-4 junction box, the door began to open with no activation of the electrical door open switches. The C-288 circuit breaker was pulled, and the door operation ceased. When the circuit breaker was reset, the door continued to the full open position, and the lift actuator motor continued to run for several seconds until the circuit breaker was again pulled. At this time, a flexible conduit, which covered a portion of the wiring bundle, was slid along the bundle toward the J-4 junction box, revealing several wires with insulation breaches and damage.

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT

To: keithrh@telus.net
Subject: Request from RCMP AITF

Keith Hamilton,
Defence Counsel

Dear Mr. Hamilton, 14 Nov 01

Below is a request from RCMP AITF Sgt Blachford to come to California to meet and discuss my report in some detail, taking at least a day to do so. He is asking when and where I would prefer to meet and states it will take at least a day to review my report.

I am going to reply back soon that in my home office is a good place and the sooner the better. Would you like to join us for a discussion of the shorted wiring/forward cargo door rupture/ explosive decompression/inflight breakup for Air India Flight 182? I think you should. What times and dates or places are convenient for you? I've notified Jaswinder of my offer to you.

I'll meet you at the Monterey Airport, or, if you drive, as I did in March to Vancouver, call me and I'll set you up with lodging. An alternative meeting place is possible.

I've also invited a representative of TSB to join us.

It seems the mood has changed in the past few days and now the first speculation of a cause of an airliner crash is mechanical failure instead of a terrorist act (such as believed in 1985). It looks like facts, data, and evidence, are taking priority now and that is good. There are lots of those for support of a mechanical cause for Air India Flight 182 and would look forward to laying them out for you.

Cheers,

John Barry Smith
(831) 659 3552
541 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Below from Oct 15 2001

Dear Mr. Smith:

I do not appear to have a mailing address for you, so I am sending you this email message instead.

I am one of the lawyers working on the defence team for Ajaib Singh Bagri, one of the three men charged with the Air India Flight 182 crash. Jaswinder Parmar suggested that I write to you, as I am reviewing the forensic evidence.

I have a copy of your report dated April 9, 2001, and the appendices. As you would expect, I have many reports that have been generated during the RCMP investigation and the various inquiries since 1985. I am working my way through them chronologically, and will be reading your's very closely within the next few weeks.

I have briefly reviewed your report, and it does raise several issues that do not appear to have been addressed in any of the other reports, and which I want to examine more closely.

When I have had an opportunity to read your report and appendices carefully, I expect that I will want to be in touch with you again, to discuss some specific issues.

Thank you for the interest you have expressed in our case. I will be in touch with you again, as my review of the reports continues.

Sincerely,

Keith Hamilton

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: keithrh@telus.net
Subject: **More info for meeting**

Dear Mr. Hamilton, 14 Nov 01

Below are email and snail mail addresses should you wish to consult with the gentlemen prior to any meeting.

Cheers,

John Barry Smith
(831) 659 3552
541 Country Club Drive,
Carmel Valley, CA 93924
www.corazon.com
barry@corazon.com

Email for Mr. Tucker:

Bill.Tucker@tsb.gc.ca

W.T. (Bill) Tucker
Director General,
Investigation Operations
TSB

Address and phone for Sgt Blachford:

Sgt. B. Blachford
Air India Task Force
5255 Heather St.
Vancouver, B. C.
V5Z 1K6
604 264 2249

From: John Barry Smith <barry@corazon.com>
Date: September 5, 2009 11:46:50 PM PDT
To: chaggar@aol.com
Subject: **So close, have the other attorneys contact me, I can prove no bomb anywhere, forward or aft.**

Reyat defence was to argue against blast
Thursday, February 27, 2003
By Robert Matas

VANCOUVER -- If his trial had gone ahead, Inderjit Singh Reyat was preparing to challenge the widely held assumption that Air-India Flight 182 was destroyed by a bomb at the rear of the aircraft.

Under a plea-bargain deal with the prosecution, Mr. Reyat was sentenced to five years in prison for manslaughter. The deal was announced shortly before John Garstang, an expert on analyzing wreckage scatter, was to be questioned at a pretrial hearing.

Court documents that now can be reported show that Mr. Reyat's lawyers had told the court as early as November, 2001, that they were reviewing several contradictory reports on the cause of the disaster and the location of the bomb.

Most of the Boeing 747 wreckage remains on the ocean floor, despite two RCMP dives. By weight, only 3 to 4 per cent of the aircraft has been retrieved.

An aggressive effort failed to find the remains of many of the 329 people on the flight. Only 131 bodies, including 30 children, were recovered and taken to Cork, Ireland, for autopsies.

An insurance-arbitration report for Lloyd's of London on a civil dispute over the cause of the crash notes that neither the bodies nor the wreckage provided clues to the cause of the crash.

"None of the recovered parts of the aircraft showed any sign whatsoever of damage from explosives," Lord Roskill wrote in a report dated March 21, 1988. "None of the 131 bodies . . . showed any sign of death having been caused by explosive injuries or by shrapnel."

Lord Roskill said he was faced with a situation in which neither side in the dispute could point to a recovered part of the aircraft or a body to establish conclusively whether the plane was brought down by a bomb blast or structural failure.

Lord Roskill, after noting that the suitcase believed to be housing a bomb was placed in the aft cargo compartment, concluded that a bomb exploded in the cargo hold at the back of the plane.

His findings contradict the conclusions of Canadian experts and a judicial inquiry in India.

The Canadian Aviation Safety Board found that an "explosion" occurred in the plane's forward cargo compartment. "This evidence is not conclusive. However, the evidence does not support any other conclusion," the agency stated in a submission to the judicial inquiry in India.

Mr. Justice B. N. Kirpal of the High Court of Delhi was more direct. Circumstantial and direct evidence directly points to "an explosion of a bomb in the forward cargo hold" as the cause of the incident, he wrote in a February, 1986, report.

At the Air-India trial in Vancouver, documents show that the prosecution preferred Lord Roskill's analysis to those of the Canadian experts and the Kirpal Commission's.

The prosecution was prepared to show at trial that a bomb exploded at the rear, in the cargo compartment where a suitcase from Vancouver was placed.

The court heard that the prosecution had a list of 49 potential witnesses to testify about the wreckage and 39 potential witnesses to testify about the analysis of injuries to the passengers.

At least 16 forensic experts were available to present evidence on the characteristics of a bomb, and 86 potential witnesses could be called to explain how the bomb was placed at the rear.

Mr. Reyat's lawyers told the court that conflicting opinions about whether the crash could be conclusively attributed to a bomb in the rear of the aircraft was "a very live issue" for the trial. "Although many murder cases involve one, two or perhaps more competing expert battles, a case involving scores of such experts is virtually unknown," the defence counsel said.

From: John Barry Smith <barry@qp6.com>
Date: September 5, 2009 11:46:50 PM PDT
To: Ian Donaldson@qp6.com
Subject: **Regarding Mr. Reyat and AI 182.**

Ian Donaldson, QC
Vancouver County
Donaldson Jett⁄
490 - 1090 Homer Street
Vancouver, BC V6B 2W9
Tel. 604 681-5232
Fax: 604 681-1331

Dear Mr. Donaldson, Sunday, February 19, 2006 at 8:54 AM

John Barry Smith here, the formerly long haired American who sat in your office in December 2001 with model airplanes and talked about the shorted wiring/ruptured open cargo door/ explosive decompression/inflight breakup explanation for Air

India Flight 182 and Pan Am 103.

You asked intelligent questions until Mr. Dave Crossin came in, took over the meeting, and then proceeded to tell me all about it, giving his best courtroom charm. I sensed an open mind in your questions although the premise was startling: No bomb for Pan Am 103.

Mr. Crossin was lucky and charming, he ran into an honest judge; his clients walked and more power to him. He never disputed a bomb brought down the plane, just that his clients did not do it. He was right about that, they did not do it, nobody did.

Well, I'm still here and the evidence still stands. Nobody bombed AI 182, it was a mechanical problem. In the upside down world of today, when an experienced pilot who has survived a fatal jet airplane crash reports that a fatal jet airplane crash was caused by a mechanical problem with precedent, he is labeled weird and his explanation unworthy of evaluation.

I still trust in the hard evidence and its ability to speak for me....eventually.

Mr. Reyat is now being tossed about. I can't really address the Narita event or any other involvement he had with whomever, but.....I do know that no bomb brought down AI 182 and that has to mean something to his case since he is alleged to have provided the bomb.

If you would like to chat about AI 182 and its reasonable and plausible explanation for the explosive decompression, I'm here where I've always been with a new email address, barry@qp6.com. I'll be glad to answer any questions you might have and let's leave the conspiracy nonsense for the conspiracy experts, the police and the media.

I would add that for PA 103 there has been a startling development: The police chief said the evidence was faked. PDF attached.

Regardless of the prosecutorial misconduct or the ineptness of the investigations, the evidence in the CVR and twisted metal for these crashes is what counts since it is immune from emotional interpretations and political considerations.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, CA, 93924
831 659 3552
barry@qp6.com
http://www.montereypeninsulaairport.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

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Tel. 604 681-5232
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Regards,

John Barry Smith
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Carmel Valley, CA, 93924
831 659 3552
barry@qp6.com

http://www.montereypeninsulaairport.com
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5C

From: John Barry Smith <barry@qp6.com>
Date: September 5, 2009 11:46:50 PM PDT
To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **Re: Refer John Hill to me, please**

Dear Sundeep, Wednesday, February 22, 2006 at 10:17 PM

Look at that, exactly five years to the day you emailed me, coincidence!

I understand why you would wish to avoid any dealings with Reyat, but I was asking for a referral to a fellow attorney to me regarding a case he has undertaken. I assume you made attorney in the past five years and if so, congratulations. Well done.

A Sikh friend sent the below to me recently:

3. A Sikh is prohibited from arguing with people who believe in foolish dogma and who insist on making ridiculous arguments. For example, some people insist that a prophet must perform miracles. People have turned sticks into snakes, heal the sick, walk through fire, etc., routinely on the stage everyday. The Gurus did not believe in engaging in such circus show just to

make people believe in them. People attracted in this manner will follow someone out of fear of punishment or, hope of a reward. Such people can not endure the rigors of the actual practice of God's Love, which should endure even in the face of adversity. Such people cannot understand why anyone would love God even if there were no reward forthcoming at all.

Sundeep, I do not believe in foolish dogma. I believe in facts, data and evidence plus my experience of flying airplanes for forty five years. AI 182 was not bombed by anybody, it was a mechanical problem. The problem of faulty wiring leading to a cargo door opening flight exists today and puts all passengers in Boeing 747s at risk. I am trying to get the wiring replaced and the doors fixed.

Just because Mr. Malik was set free after being unjustly held in prison for four years does not mean that the case is closed. The mystery remains for the police and the victim's families. Until that mystery in their minds is resolved, the press, the police, and the population will continue to believe that some Sikhs unknown committed a horrendous crime against innocents. That terrible reputation is a heavy burden to bear for a religion of twenty million.

I tried again and again on the web to find John Hill's number or email address to no avail. I've mailed a letter to Ian Donaldson.

I'll keep on trying. Any suggestions or advice would be welcomed.

Regards,

John Barry Smith

541 Country Club Drive
Carmel Valley, CA, 93924
831 659 3552
barry@qp6.com

X-From_: khalsaq@yahoo.com Thu Feb 22 16:53:06 2001
Date: Thu, 22 Feb 2001 16:53:34 -0800 (PST)
From: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: AI 182
To: barry@corazon.com

Hi Barry!

My name is Sundeep Kaur, I am helping Aniljit Singh and Mr. Malik with legal research, etc.

YOu sent three reports to Aniljit Singh and he has asked me to print them up, I was wondering if you could send those reports to me as attachments so that i can do that. It is easier for us to review hard copies of reports than on the computer. This would be much appreciated.

Thanks in advance.

Sundeep Kaur

At 7:45 PM -0800 2/22/06, Sundeep Dhaliwal wrote:
I do not have any of his information. We have no

dealings with the Reyat Family. Please contact Mr. Hill directly by looking his number up on the web.

Thank you

--- John Barry Smith <barry@qp6.com> wrote:

> Could you ask John Hill who represents Mr. Reyat, to
> contact me at
> barry@qp6.com?
>
> Regards,
>
> John Barry Smith
> 541 Country Club Drive
> Carmel Valley, CA, 93924
> 831 659 3552
> barry@qp6.com
>

Sundeep K. Dhaliwal
Yaletown Law Corporation
Barristers & Solicitors
Suite 403 - 1028 Hamilton Street
Vancouver, BC V6B 2R9
Ph: 604-684-8898 Fax: 604-684-8608
skdhaliwal@yaletownlaw.com

From: John Barry Smith <barry@qp6.com>
Date: September 5, 2009 11:46:50 PM PDT
To: barry@qp6.com
Subject: **d3 final final sunday**

Ian Donaldson, QC
Vancouver County
Donaldson Jett⁄
490 - 1090 Homer Street
Vancouver, BC V6B 2W9

Dear Mr. Donaldson, Saturday, June 10, 2006

Thank you for your letter of 5 June 2006 replying to my previous letter and enclosing the Acte D'Accusation of Mr. Inderjit Singh Reyat for twenty seven acts of "...swearing falsely and attempt to mislead the Court that he did not know or recall any details of the alleged conspiracy..."

At first blush, I ask, what conspiracy? Oh, that conspiracy, the one that culminated in the successful blowing up of Air India Flight 182...by a bomb...by bombers that Reyat knew...and Reyat supplied materials for the bomb....that successfully blew up Air India Flight 182...after an alleged conspiracy (but lied about knowing in court...under oath!).. (This alleged conspiracy was not the one to blow up Parliament, that was Guy Fawkes and Reyat is no Fawkes.)

At second blush, I note that every one of the twenty seven charges listed by the Crown has the 'alleged conspiracy' words included as an integral part of the charge. Specifically Mr. Reyat is accused of lying about the bombing of Air India Flight 182, lying about the bomb parts, lying about the bombers, and lying about the plot to blow it up. I would forcibly argue that Mr. Reyat and Air India Flight 182 are inextricably entwined and any information/analysis/conclusion about that airplane crash is relevant to his defence. The Crown prosecution certainly thinks that the details of Air India Flight 182 are relevant to his prosecution for perjury since they include the basic reference to it in every charge against him.

But let's get organized, first, the past, then a short detour to the present, then an analogy, then the future and lastly the present again.

As I reflected on the tone of my previous letter I hoped I did not appear petulant when complaining about manners in our relationship and I hoped that I was not upsetting by appearing to be arrogant when discussing legalities. I should have added then but state now that we are on the same side in that we are allies. Not friends or business partners but allies with common causes: Justice and citizen safety. Well, allies sometimes squabble, it's natural in grasping for the same plums on the tree.

Regarding the coffee incident. It was not you but Mr. Crossin who had the coffee, a thermos or pot as I recall. Aniljit was sitting on my right, you were opposite me at your desk and Mr. Crossin was on your right in a chair. After an hour Mr. Crossin got up and came back with some coffee and offered it to you but none to Aniljit or me. You accepted and the conversation (actually mostly Mr. Crossin talking) continued. I remember because I was thirsty after an hour or so. It is also at that moment when I knew my case was lost. I had driven twenty hours non stop from Carmel Valley to Vancouver the day before just to meet "Malik's attorneys" and it was all for naught, very deflating. The questions that were asked of me and my shorted wiring/ruptured open forward cargo door/explosive decompression/inflight breakup explanation that indicate an open mind of the listener were not being asked. Statements were made that indicated a closed mind, mainly about bomb, bomb, bomb, and bombers.

Regarding your correspondence as an 'indignity': I'm sorry, I was being selfish. To be brief is fair when the clock is ticking for billing and also a good habit, one I have not yet acquired.

Short detour to the present of your letter:

ID>It is not a central point, nor indeed is it any part, of the current prosecution against Mr. Reyat that there was a bomb on the airplane.

JBS>Polite response with respect disagreement, sir: I gainsay it is not a central point. Rude reply: Hell yes it is! Central. Right in the middle. Essential. Important so much so it is listed on the first page in the first paragraph of the Indictment and included in every single one of the charges, "...alleged conspiracy...". What exactly is the 'alleged conspiracy? It was to put a 'bomb on the airplane.' The central point of the current prosecution is there was a 'bomb on the airplane' based upon a conspiracy to put it there, a conspiracy Mr. Reyat is accused of lying about.

If no 'alleged conspiracy' to bomb Air India Flight 182 because there was no bomb then he could not lie when 'he did not know or recall details...' of it (Quadruple negative, whew). If no bomb, then no bombers; if no bombers, then no alleged conspiracy. If no alleged conspiracy, then no one can lie about it (or tell the truth about it). If no lies about it, then no perjury about the conspiracy. (There might be lies by Mr. Reyat about other matters, but he is not charged with those, only about the 'alleged conspiracy." Charges dropped...but first, no bomb? That's a tough nut to crack. I can do that, I have done that, I can show you how.

But more on those charges later; now I would like to give an analogy to avoid the emotional buzz words of bombs and Sikhs and flight numbers and mass murder of 329.

A man is walking along a street as he usually does every day. During his walk he falls down on the ground. The police and a physician arrive on the scene. The physician examines the prostrate man and declares he's dead but the physician doesn't know why. The police investigate and conclude he is dead because he was shot in the head by a rifle shot from two men seeking revenge. The press reports the man was murdered by rifle shot by terrorist thugs involved in a conspiracy.

The medical team that had the responsibility to keep the victim alive is relieved it was a murder and not health related implying negligence. The family of the dead man is relieved that it was not some genetic fault in the family that would shame them. The media is relieved the victim's death is interesting as a murder conspiracy and not a boring normal death. The government is relieved that they are not at fault for negligent oversight of his medical care and can now blame political enemies for the murder. The victim's friends are relieved because now they have someone to vent their anger at to assuage their grief.

The two accused terrorist men go on trial for murder and conspiracy. Another man accused of being in the conspiracy is separated out and accepts a deal for a lesser sentence and understands he may be called as a witness against the other two. This third man agrees to the lesser charge and goes on the witness stand but gives confusing, contradictory, misleading, evasive and nonsense statements about the conspiracy to murder the dead man. There is never any discussion by the defence for the two men that the victim was not murdered, just that he was murdered but not by the two accused.

The two accused of the murder and conspiracy are acquitted. The family, media, government, and friends are outraged that the killers go free. They all demand a government inquiry into how the case was bungled. The loser prosecution team submits that it was because of the perjured testimony of a witness who betrayed them and lied about the murder conspiracy under oath, implying that if the witness had spoken the truth, a conviction of the two murderers was assured. The witness is now accused of perjury by the prosecutors for his confusing, evasive, and misleading statements about that murder conspiracy.

And then, and then, the defence attorney for the accused witness is made aware by a correspondent (who, while not a physician, is well informed about medical matters) that there may in fact have been no murder and thus no murder conspiracy. An alternative explanation for the demise of the victim is offered: The death of the man was in fact a heart attack based on genetic defects in the family line and poor living habits. Proof is offered; precedents are cited.

The attorney replies that the cause of death for the victim is irrelevant; his client is not charged with the murder, just swearing falsely under oath about the conspiracy to murder.

The correspondent replies that if there is no conspiracy, then any accusations regarding it are of no practical importance or moot. The attorney deliberates.

The correspondent responds with advice to look at the victim. Check out the victim. Who was he? Was he a crime figure who might likely be murdered? Was he in a bad neighborhood and might be shot? Was he having an affair, was he in debt, what was his history?

And then the attorney finds out that in fact the victim was an old man with a history of heart problems and had three identical brothers fall down on the same road about the same time of day with the same weather conditions with two twins dying and one twin surviving although requiring a long recuperation period.

The one brother who lived through the heart attack had the same bruises, scrapes, and tears on him as the dead victims who were thought to have been murdered. The same sounds came out of all four brothers' mouths as they suffered the injury and fell down. All four brothers' injuries were initially thought to have been murders by rifle by terrorists. One brother's death remains officially cause unknown, one death a murder by rifle, one death was changed to brain stroke and the injury of the one brother who lived was caused by partial heart failure by natural causes of aging and genetics.

The possibility then exists that the victim was not murdered but was in fact a health related issue and plausible, it has precedent, and there is ample proof it was a heart attack. There was no murder, nor murder conspiracy, nor witness to lie about a non existent crime. His client is innocent. No one murdered the victim, he died from a natural internal problem called a heart attack.

The physicians are asked again for an opinion on their previous evaluation which stated the victim was dead of unknown causes and now can use the benefit of hindsight and the subsequent deaths of the victims' brothers under similar circumstances for a valid update.

The police are asked to provide all the photographs of the death scene for evaluation of bruises, blood, and scrapes on the victim.

And then...

My analogy skips to the imagined wishful thinking future and substitutes actual details:

After the Transportation Safety Board of Canada examines the previous accident reports and matches them to United Airlines Flight 811, they report internally that their initial assessment in 1986 was correct that an explosive decompression in the forward cargo compartment occurred in Air India Flight 182 but the unknown probable cause can now be updated as a mechanical electrical event, and that a bomb explosion therefore was ruled out.

The Crown Prosecutors and the Gendarmerie royale du Canada (GRC), after getting together with the TSB investigators, decide that based upon this new evaluation of excluded bomb and likely mechanical caused event, now based upon incontrovertible matching facts of a similar accident, to drop perjury charges against a witness. The reason given will be that the expense of a new trial does not warrant the punishment of a man who has already spent fifteen years in jail. The Crown would rather face the wrath of the victims' families than the unraveling of their entire case which would show they have been chasing ghosts for twenty one years at great expense in time and manpower.

Charges of perjury involving a conspiracy to bomb an airliner are dropped: The accused witness Reyat is happy, his attorney is happy, I am not happy. I'm happy that justice is done but the main goal was missed, aviation safety with the repair of faulty wiring and the correction of the design defect in the cargo doors of early model Boeing 747s. The hazards remain in the five hundred plus type airliners in service carrying and exposing hundreds of thousands of passengers and crew to a life and death hazard; explosive decompression in flight when the shorted wiring ruptures open the cargo door inflight at high altitude.

I would then ask you, Mr. Donaldson, after you write to TSB requesting an update to a twenty year old accident report on an airplane crash your client is accused of lying under oath about an 'alleged conspiracy' to blow up; after you request all the evidence of the airplane crash now held by RCMP, after the officials of those agencies get together and decide their case for a bombing and thus a conspiracy to bomb is weak and probably not provable, after they decide it is in the best interests (sic) of justice to drop the perjury charges against Reyat, that you go further with three possible actions.

1. I ask that you represent Mr. Malik for damages against him by the Crown for malicious prosecution since I know that the RCMP Air India Task Force representative Sgt Bart Blatchford knew about the shorted wiring/ruptured open forward cargo door/explosive decompression/ inflight breakup explanation before his trial and did not pursue the investigation; or:

2. You represent the families of the victims who died in Air India Flight 182 since they received a fraction of the money due them in a mechanically caused accident; or:

3. You arrange to get me into the John Major Commission of Inquiry into Air India Flight 182 now going on. I would use the opportunity to explain the shorted wiring/ruptured open forward cargo door/explosive decompression/inflight breakup explanation and answer any questions.

I ask these actions in order to get the official updated version of the probable cause of Air India Flight 182 by TSB into the record, into the public mind, into the government safety organizations around the world that monitor their airlines that fly early model Boeing 747s in order to get the manufacturer to repair the defects.

In my future predictions, one man was set free from risk of prison while I am trying to free literally hundreds of thousands from risk of death.

And then my crystal ball becomes cloudy and I revert back to the present, your 5 June 2006 letter to me.

The Crown>Indictment "...Reyat did commit perjury...by swearing falsely and attempt to mislead the Court that he did not know or recall any details of the alleged conspiracy...that:"

JBS>Note that all of the charges start out in lower case as they are the suffixes to the preliminary statement ending in '...alleged conspiracy...that:" The key to the successful defence of Mr. Reyat is in Count 1 as quoted above. "...of the alleged conspiracy..." It is their undoing. The Crown went a prosecution too far. Why include the words, "alleged conspiracy" for all the charges? It was to make the charges have practical importance. Without those conspiracy words, the charges are petty but the conspiracy allegation brings in mass murder, terror, and horrible evil thereby elevating the charges to important. Note also the mismatch of tense of 'swearing' and 'attempt'. This indictment is poorly written, the grammar has errors, the charges are confusing, the meanings are ambiguous, and one charge is downright nonsense.

ID>During his testimony, the Crown says that some of the statements {of the alleged conspiracy} made by Mr. Reyat were untrue. (Inserts of {of the alleged conspiracy} clarify your word "statements" and are quoted exactly from the Indictment. I will add further clarifying words in parenthesis as we go on.)

JBS>He may have made untrue statements but they were not about a conspiracy since there was none. No bomb, no bombers, no conspiracy, and no lying statement about it. If Reyat lied about his memories of the names of his friends from years ago, then let the Crown accuse him of that. They have not done that; they have accused him of misleading and making false statements of the 'alleged conspiracy' which included names of friends. Get rid of the conspiracy and it will get rid of the accusation of perjury about it.

ID>Whether the airplane crashed due to mechanical error or not, the issues at his trial will be whether the statements {of the alleged conspiracy} (to successfully blow up an airliner) that he made were true or false, or more particularly, whether the Crown can prove his statements {of the alleged conspiracy} (to successfully blow up an airliner) were false.

JBS>The Crown can never prove anybody made misleading statements about a conspiracy when there was no conspiracy. There are millions of Canadians out there who had nothing to do with Air India Flight 182 and dozens who have lied in court, why is it that Mr. Reyat is on trial if he had nothing to do with it? He is on trial because he is accused of having a lot to do with it. Regarding your phrase, "...or more particularly, whether the Crown can prove his statements {of the alleged conspiracy} were false", that refers to a strategy I call the Crossin Defence.

The Crossin Defence: It's where you do not prove your client is innocent. It's where you do not present an alternative culprit that could have committed the crime for which your client is accused. It's where you just poke holes in the Crown's case enough so that reasonable doubt is created in the mind of the judge or jury. It's a full defensive posture with no offence. The Crossin Defence is based upon the belief that the defence is more cunning and can avoid, deflect, or repel any offensive action by the clumsy Crown without fatal injury. In the current system of British based law and poorly worded indictments, that's good enough...for a not guilty verdict. It also requires an honest judge or impartial jury.

It's also the best type of defence to defend the guilty. The innocent deserve better. They deserve to be exonerated of the false charges. They need to be shown to be innocent which is a higher quality vindication than 'not guilty'. But if the accused did not do the crime, then who did it? And was it a crime after all? The innocent deserve to have the true culprit identified or to show the charges lacked merit since no crime occurred.

Mr. Reyat is innocent of perjury of a conspiracy and also innocent in any assistance in the bombing of Air India Flight 182. I know that and he deserves the exoneration of the accusations. That exoneration can be achieved by showing there was no bombing and also revealing the true culprit, in this case a manufacturing defect of faulty wiring and a design defect of a non plug cargo door. One byproduct of this exoneration will be the resurrection of the honor of a religion of twenty million world wide. Another consequence will be improved safety in current and future airliners.

ID>You will note from the indictment that the Crown does not allege anything to do with the cause of that event.

JBS>Whaaa? The Crown alleges that Reyat had everything to do with that event, the successful bombing of Air India Flight 182 because of a conspiracy. The Crown alleges he knew the conspirators, he provided the materials for the bomb, he practiced with the bomb, he harbored the conspirators; (and he lied about all of it!) The only thing he didn't do was put the bomb in the suitcase. If the Crown suspected that, they would not have severed him from Misters Malik and Bagri.

ID>Even if a witness's false statements {of the alleged conspiracy} (to successfully blow up an airliner which killed 329 passengers and crew) under oath are "not of any practical importance", and the Crown can prove beyond reasonable doubt that they are false then a perjury charge may be maintained.

JBS>Maintained but not convicted by a jury that says "What's the big deal, he protected his buddies who were acquitted of a crime and it turns out no crime anyway. Not guilty and stop wasting our time." The worst case guilty scenario would be a vastly reduced sentence for lying about what his friends' names were, his friends that were not part of an alleged conspiracy to blow up an airliner since there was no bomb, bombers, or conspiracy.

ID>Our client is not charged with assisting in the deaths of any person, but simply with giving false statements {of the alleged conspiracy} (to successfully blow up an airliner which killed 329 passengers and crew, including many women and children) under oath when called as a witness.

JBS> He certainly is accused, possibly indirectly, with assisting in the death of a person, in fact, 329 persons. He was asked at trial to effectively admit he was a co-conspirator. He declined. The Crown says he lied. Your client is charged simply with giving false statements of the alleged conspiracy to successfully blow up an airliner which killed 329 persons and refusing to admit he was part of the plot.

The Crown asserts in so many words: If he had not provided the materials for the bomb and practiced with it with Mr. X (those conspiracy boys do love their Mr. Xs, who always seem to die or remain missing) then there would have been no bombing and thus no deaths. If he had gone to the police and informed on his mates, the airliner would not have blown up. If he had not lied about his involvement in the alleged conspiracy to blow up an airliner or two, his guilty friends would have been convicted. Because he lied, two mass murderers of passengers in an airliner went free. He must be punished for those lies about the alleged conspiracy (to successfully blow up an airliner which killed 329 passengers and crew, including many women and children). The perjury charges are vindictive harassment by sore loser prosecutors. The prosecutors don't realize they lost convictions of bombers because no bombers exist to convict.

Again I say, no bomb, no bombers, no conspiracy, no perjury about the alleged conspiracy, no conviction, no punishment.

If there were no bomb, bombers or conspiracy, it is impossible to give false statements about the alleged conspiracy. He is innocent...but first it needs to be proved there was no bomb, bombers and thus no conspiracy. I can do that to your satisfaction. For the satisfaction of the RCMP and Crown, the TSB opinion is probably required. TSB must be asked for the updated opinion by you.

ID>You will see the statements {of the alleged conspiracy} (to successfully blow up an airliner which killed 329 passengers and crew, including many women and children making it the worst mass murder in Canadian history) alleged to be false.

JBS>Let's look at them all. But first, another analogy: If a man is accused of adultery by having an affair with a woman and I, as a witness, testify he was with me one assignation night and I'm lying (he was somewhere else) and thus accused of perjury about the adultery, if there were no affair in truth then there was no perjury about the adultery because I did not lie about an event that did not take place. If the Crown wants to accuse me of lying about where my friend was one night, then let them charge me for that. I am innocent about lying about an alleged adulterous affair since there was none.

JBS>Facts:

1. Talwinder Singh Parmar is dead and Mr. X is nowhere to be found and thus, fortunately for the defence and unfortunately for the prosecution, they are unable to be cross examined.

2. Air India Flight 182 crashed on June 23, 1985.

Assumptions:

A. The Babbar Khalsa is a terrorist group of Sikh extremists banned by the Canadian government.

B. Mr. Parmar was chief of the Babbar Khalsa, an organization of Sikh separatists.

C. Investigators believe the Air India bombing was masterminded by Talwinder Singh Parmar, leader of the extremist Babbar Khalsa group that advocates creating a Sikh state called Khalistan in India's Punjab region. Parmar was killed by Indian police in 1992.

JBS> All of the twenty seven charges of perjury against Mr. Reyat are prefaced in Count 1 by this edited statement: "...Reyat did commit perjury...by swearing falsely and attempt to mislead the Court that he did not know or recall any details of the alleged conspiracy...that:"

All of the twenty seven charges then start out in lower case as they are the suffixes to the preliminary statement ending in '...alleged conspiracy...that:"

Every complete charge thus includes the words 'alleged conspiracy". The conspiracy referenced in the Indictment is the one to successfully blow up an airliner which killed 329 passengers and crew, including many women and children making it the worst mass murder in Canadian history.

For example: Charge 5 would read in its entirety if standing alone: "...Reyat did commit perjury...by swearing falsely and attempt to mislead the Court that he did not know or recall any details of the alleged conspiracy...that Parmar asked him to make one explosive device."

The words "know" and "recall' appear to be redundant with the proper one word being 'recall'. A clearer accusation might read: Charge 5: "Reyat did commit perjury by swearing falsely and attempting to mislead the Court by stating he did not recall any details of the alleged conspiracy that resulted in the bombing of Air India Flight 182, for example, that Parmar asked him to make one explosive device."

Charge 1. he (Reyat) did not know....

Charge 2. he did not know...

Charge 3. he had no idea...

Charge 4. he could not recall what Parmar..

Charge 5. Parmar asked him...

Charge 6. the only reason Parmar...

Charge 7. Parmar did not say...

Charge 8. most of his conversations with Parmar...

Charge 9. Parmar never asked...

Charge 10. the two test devices that he built and tested for Parmar...

Charge 11. during the two tests...

Charge 12. after Parmar asked him...

Charge 13. before the second test, an associate of Parmar ("Mr. X")...

Charge 14. he never learned Mr. Xs name...

Charge 15. after the second test, neither Mr. X nor Parmar...

Charge 16. after the second test, Parmar returned to the ferry in Nanaimo but Mr. X...

Charge 17. he gave Mr. X... and had 'no idea' why Mr. X...

Charge 18. ...he never discussed doing so with Parmar or Mr. X;

Charge 19. although he believed at the time that Mr. X intended....he did not know why Mr. X intended...

Charge 20. Mr. X asked him....

Charge 21. while Mr. X and he ... Mr. X spent...but Mr. X did not say why....

Charge 22. he gave Mr. X...anticipating that Mr. X may want...

Charge 23. Mr. X never discussed...

Charge 24. before Mr. X left his home, Mr. X's phone number...

Charge 25. he introduced Mr. X...

Charge 26. he never asked Parmar...

Charge 27. he told either Parmar or Mr. X that....he never asked Parmar or Mr. X....

Perjury: (For the USA) In order for a person to be found guilty of perjury the government must prove: the person testified under oath before; at least one particular statement was false; and the person knew at the time the testimony was false.

The three elements of a perjury charge: 1: Testify under oath. 2. Statement was false to start with. 3. The person knew at the time of testimony the statement was false.

The first element is proven, Mr. Reyat testified under oath. The third element may or may not be true since Mr. Reyat may have known to himself he was lying.

But...the second of three elements of the perjury charges is impossible to fulfill for all charges related to Parmar or Mr. X (4 through 10, 12 through 27, total 23 charges) because the statement has to be false to fulfill element two and the only persons to confirm the falsehood are dead or missing. Charges relating to the state of mind of Parmar or Mr. X can only be confirmed by them thus it is impossible to confirm a statement about their state of mind being false or true. For instance, if Reyat were asked under oath what was Parmar's favorite color of turban and Reyat replies white when in fact Reyat knows he is lying because Parmar stated one time how he loves his black turban, there is no way to prove Reyat is lying if Parmar, the only authoritative source of his state of mind, is dead. If there is other supporting evidence of a Reyat lie, then present it, such as tape recordings or videotapes. Any other evidence is probably hearsay and inadmissible anyway.

For instance, Charge 20 essentially states that "Reyat did commit perjury by swearing falsely and attempt to mislead the Court by stating he did not recall any details of the alleged conspiracy that resulted in the bombing of Air India Flight 182 such that Mr. X asked him for a Micronta clock after seeing one installed in Reyat's car." The only person who could confirm that Reyat made a false statement that he could not recall the conversation is Mr. X who could contradict Mr.

Reyat and testify he did indeed ask Mr. Reyat for a Micronta clock... Without Mr. X, there is no proof that Mr. Reyat made a false statement about a clock and thus no perjury charge is proven. Twenty three charges are thus bogus and not provable without the testimony of the only persons who can prove they were false to start with, Parmar and Mr. X.

I once had a Superior Court judge tell me why murder charges are so hard to prove, it's because the victim was not there to rebut the exculpatory testimony of the accused. In Mr. Reyat's case, let the Crown produce Parmar or Mr. X and prove the second element in the twenty three charges that the statements by Mr. Reyat are false. And if they can't produce the rebutting evidence, then the assumption is that the statements by Mr. Reyat are not false.

(Mr. X is alleged to be a terrorist. It can be assumed he would not give his real name or details on his identity, habits, or location to strangers or fellow conspirators. To charge somebody for perjury for not revealing a name which is probably false anyway is unreasonable.)

Regarding charges 1 through 3: These are mind reading charges, thought crimes against a thoughtful person made by the Thought Police. The Crown assumes it knows what Mr. Reyat knows or should know, what he thinks or should remember. Many supposedly educated citizens are woefully ignorant about basic knowledge that is required for daily living. For Mr. Reyat to claim he did not know about a political splinter group or its leader is reasonable and to claim he should have known is doubtful. For Mr. Reyat to claim he had no idea what was going on politically in a country six thousand miles away which undergoes political change weekly is certainly plausible. To claim Mr. Reyat, a mill worker, is assumed to know the internal politics of a foreign country is doubtful. The Crown can never prove the statement that "Mr. Reyat did not know the name of a leader of a political splinter group" is false because the only one who knows what goes on in Mr. Reyat's mind is Mr. Reyat. Are there witnesses who can rebut Mr. Reyat's claimed ignorance of Indian politics? Bring them on. There is none. What is Mr. Reyat's IQ? What is his reading level? Is he a political science professor at McGill? Did Mr. Reyat lead seminars on Sikh separatist movements?

Are his students available for testimony as to Mr. Reyat's political knowledge? Can the average juror even name the previous four opposition leaders in Canadian government starting from twenty years ago?

Charges 1 through 3 are not provable for element two because only Mr. Reyat knows what Mr. Reyat knows and if he says he didn't know this or that, then it has to be assumed he did not know this or that. If Mr. Reyat says his favorite color is red, then it's red if there is no one to contradict him even if there is no red in his wardrobe, his car is not red, his house is not red, and his wife is not a redhead. And tomorrow if he says he hates red, then he hates red even though he wears red pants, his car is red, his house is red and his wife is...still blond.

Charges 4 through 10, 12 through 27 are not provable for element two because the only two persons who could confirm or discredit Reyat statements about the alleged conspiracy being false are dead or missing. And of course, Mr. Reyat can change his mind about what his mind remembers. If he made previous incriminating statements and then remembers differently under oath on the witness stand, well, that's what goes on inside people's heads all the time, selective memory and reinterpretations of history. Many eyewitnesses make false statements under oath while believing them to be true.

Charge 11: "during the two tests he used gunpowder rather than dynamite to ensure that no one got hurt."
What is the false statement? There was only one test? He was not present at the test? He did use dynamite after all? Someone got hurt? He couldn't remember what he used as the explosive? Regardless, since Mr. Reyat is the only one available about what did or did not happen on that day, his testimony can not be reliably discredited.

Charge number 8: It's interesting as it makes no sense. "most of his conversation with Parmar in the weeks prior to the June 22, 1985 concerned the conversion of Parmar's car to propane." What is the word 'the' doing in the sentence? It's as if the writer meant, "... most of his conversation with Parmar in the weeks prior to the June 22, 1985 (sic) bombing of Air India Flight 182 concerned the conversion..."

Regardless, this charge is a direct reference to Air India Flight 182 and determines the end date of any interest in Mr. Reyat's contacts with the parties named in the other charges.

To conclude:

1. All of the perjury charges against Mr. Reyat include the phrase 'alleged conspiracy' which directly refers to the alleged conspiracy of bombers to successfully bomb Air India Flight 182 on February 23, 1985.

2. Any information, data, or evidence about Air India Flight 182 is thus directly relevant to the perjury charges. Any request for such evidence or information for disclosure is justified. Acquiring that evidence is warranted for a comprehensive defence.

3. All of the perjury charges are not provable for the second element required: a statement was false to start with. The only persons who can prove the statements were false to start with are dead or missing or Mr. Reyat himself. (Perjury is hard to prove, if it were easy, prosecutors would be charging it often.)

4. If the 'alleged' conspiracy were shown to be not proven, then all the charges are not proven because each charge includes reference to the alleged conspiracy. Note the second dictionary meaning of 'alleged', doubtful plot indeed.

alleged [adj.]
PRON: /&'lΔjd/
1. Declared but not proved; "alleged abuses of housing benefits" --Wall Street Journal.
2. Doubtful or suspect; "these alleged experts are no help"; SYN. so-called, supposed.

conspiracy [n.]
PRON: /k&n'spir&sE/
FORMS: conspiracies
1. A group of conspirators banded together to achieve some harmful or illegal purpose; SYN. confederacy.

2. A plot to carry out some harmful or illegal act (especially a political plot); SYN. cabal.
3. A secret agreement between two or more people to perform an unlawful act; SYN. confederacy.

Recommendations:

1. Requests for all relevant data and evidence about Air India Flight 182 such as conspiracy related interviews, photographs of twisted metal, and cockpit voice recorder transcripts should be made to those agencies by an authorized attorney.

2. The request to the TSB should request an updated investigation by an objective official. Any TSB official seconded to the Air India Task Force should be excluded as he represented the Crown prosecution and has been biased.

3. The request to RCMP for photographic evidence and videos might indicate that Mr. Malik and Mr. Bagri were acquitted as well as stating the physical condition of the decades old evidence is irrelevant.

Mr. Donaldson, this winding long trail has ended, I hope you ended up here with me, even through the backtracks. There are shortcuts in there someplace, I imagine. Please request TSB and RCMP to provide disclosure about Air India Flight 182 to you, please ask me about the crash, you should know why airplanes crash sooner or later or at least one big one.

Best Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
barry@qp6.com

From: John Barry Smith <barry@qp6.com>
Date: September 5, 2009 11:46:50 PM PDT
To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **Commission of Inquiry**

Sundeep K. Dhaliwal
Yaletown Law Corporation
Barristers & Solicitors
Suite 403 - 1028 Hamilton Street
Vancouver, BC V6B 2R9
Ph: 604-684-8898 Fax: 604-684-8608
skdhaliwal@yaletownlaw.com

Dear Sundeep, Wednesday, June 21, 2006

Do you have any information on how I can contact Air-India inquiry administrator Sheila-Marie Cook? I want to apply for standing so I can appear before the Commission of Inquiry.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
barry@qp6.com

At 11:37 AM -0700 6/21/06,
She said she expects to hear from interested parties after June 21.
The first three hearing dates are July 18, 19 and 20, which will be to hear from people who would like standing at the inquiry and who would like to have funded legal representation.
Judge Major said he will begin putting other witnesses on notice in July that they are going to be subpoenaed to testify after the inquiry formally begins hearing evidence in late September.

Air India inquiry begins this week

Kim Bolan, CanWest News Service
Published: Monday, June 19, 2006

VANCOUVER - The judicial inquiry into the Air-India bombing will have done its job if victims' families feel like they are real Canadians despite the fact that many immigrated to Canada from India, retired Supreme Court Justice John Major says.

Close to 80 relatives are expected in Ottawa on Wednesday when Judge Major officially opens the long-awaited inquiry into the June, 1985, terrorist bombings with a brief statement outlining the terms of reference.

Judge Major said in an interview this week he is looking forward to helping bring resolutions to outstanding questions related to the unprecedented terrorist attack that was plotted and hatched in British Columbia and left 331 people dead.

Judge Major has held meetings across the country with victims' families -- many of whom have lobbied for 20 years for a public inquiry into Canada's worst mass murder.

Their lobby only picked up steam when two B.C. Sikh separatists -- Ripudaman Singh Malik and Ajaib Singh Bagri -- were acquitted in March, 2005, of all charges related to the bombings after a 19-month trial.

"If this commission can give them a sense that they are really Canadians despite the colour of their skin and that mistakes were made but they won't be made a second time, most of them -- from what they have said -- would feel that something's been accomplished," Judge Major said. "Accomplishing the second is easier than the first."

Judge Major said the simple act of then-prime minister Brian Mulroney sending a letter of condolence to Indian prime minister Rajiv Gandhi after the bombings pained family members, who were almost entirely Canadians or living in Canada. "They are owed some form of explanation for a letter of condolence going to India," he said.

But the bigger issue for Judge Major, who retired last year as chief justice of the Supreme Court of Canada, is reassuring Canadians such an act of terror could not be carried out again.

"The big interest is, 'could this happen again?' and I think that brings some public interest to the inquiry beyond what the tragedy is. Where are we with security?" he said. "I don't know how forthcoming the CSIS and the RCMP will be because they generally feel they are prejudicing the safety if they disclose too much, but we will see."

Part of his mandate -- as outlined when the inquiry was formally announced by Prime Minister Stephen Harper on May 1 -- is to look at whether a lack of information-sharing between agencies hampered the investigation into Sikh extremists prior to the bombing and during the subsequent bombing probe.

Judge Major said both the RCMP and CSIS "have expressed the willingness to co-operate fully."

"We will want to hear from the Department of Transport and they are doing their report. So, so far, there seems to be a willingness to see this thing through and hopefully reach some sensible conclusions," Judge Major said. "The mandate says that we are not to find fault and we don't make any awards."

Corporal Tom Seaman said the RCMP does not yet know who will be called as a witness. But he said the force is on board with the inquiry, even though the criminal investigation into the bombings continues.

Air India inquiry begins this week

Kim Bolan, CanWest News Service
Published: Monday, June 19, 2006

Judge Major said he has not heard from either of the two men acquitted about wanting to appear before the inquiry. Mr. Malik recently told journalists he was prepared to participate if asked to do so.
But then, nobody has yet made their intentions known, Air-India inquiry administrator Sheila-Marie Cook said on Friday.
She said she expects to hear from interested parties after June 21.
The first three hearing dates are July 18, 19 and 20, which will be to hear from people who would like standing at the inquiry and who would like to have funded legal representation.
Judge Major said he will begin putting other witnesses on notice in July that they are going to be subpoenaed to

testify after the inquiry formally begins hearing evidence in late September.

"If the witnesses volunteer, they don't have to be subpoenaed," he said.

Mr. Major said most of the staff is already in place.

The lead counsel is Mark Freiman, a partner with McCarthy Tetrault in Toronto and a former deputy attorney-general of Ontario.

Lata Pada, a Mississauga, Ont. dancer, who lost her husband and two teenage daughters in the 1985 terrorist attack, will be in Ottawa as the inquiry is officially launched. It is the same day the only man convicted in the bombing -- Inderjit Singh Reyat -- is to make another court appearance after being charged with perjury for his testimony at the Air-India trial.

Ms. Pada said she thinks the inquiry is particularly timely given the recent arrests in Ontario of suspected Islamic terrorists.

"I think the Air-India inquiry can certainly be a watershed moment in assessing Canada's preparedness for terrorist attacks," she said. "Air-India was really the precursor to everything we are seeing today with terrorism."

Ideally, whatever comes out at the inquiry should "serve to inform policy changes," Ms. Pada said. "We'll be watching it with keen interest."

Ms. Pada wants to make sure victims' families get independent counsel financed by the inquiry to represent their interests.

"There is a commitment and we hope that they keep that commitment," she said.

Dave Hayer, Surrey's Liberal Member of the Legislative Assembly, will also be in Ottawa, representing his late father Tara, who had agreed to be a witness in the Air-India case when he was assassinated in November, 1998.

Dave Hayer has been an advocate for victims' rights ever since, and has strong opinions about what more could be done to deal with terrorism cases and protect witnesses who risk a lot to testify.

"There should be some justice done for all the people killed in the Air-India bombing. Most of them -- 280 -- were Canadians. There were 20 Americans on the plane. We want to make sure that something like this never happens again," Mr. Hayer said. "And we want to make sure our judicial system has the tools to deal with cases like this."
CanWest News Service 2006

From: John Barry Smith <barry@qp6.com>
Date: September 5, 2009 11:46:50 PM PDT
To: Sundeep Dhaliwal <khalsaq@yahoo.com>
Subject: **Re: Commission of Inquiry**

At 10:59 PM -0700 6/23/06, Sundeep Dhaliwal wrote:

Take care and good luck! Thanks for your committtment to this cause.
Sundeep

I found the URL and am working on acquiring standing.

http://www.majorcomm.ca/en/index.asp

Mr. Malik may be called as witness.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
barry@qp6.com

From: John Barry Smith <barry@qp6.com>
Date: September 5, 2009 11:46:50 PM PDT
To: barry@qp6.com
Subject: **Donaldson5**

Ian Donaldson, QC
Vancouver County
Donaldson Jett⁄
490 - 1090 Homer Street
Vancouver, BC V6B 2W9
Dear Mr. Donaldson, Wednesday, June 21, 2006

Mr. Reyat may be called/subpoenaed to the Commission of Inquiry into the Investigation of the Bombing (sic)
of Air India Flight 182.

http://www.majorcomm.ca/en/index.asp

The URL above gives details on representation but it appears to be down as I type. Therefore I have included at the end of this letter excerpts from the website that I copied a few days ago.

Below is the letter I sent to the Commission requesting standing as a person.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
barry@qp6.com

Commission of Inquiry into the Investigation of the Bombing
of Air India Flight 182
Honourable John C. Major, Q.C. Commissioner
Sheila-Marie Cook, Executive Director and Commission Secretary
Mark J. Freiman, Commission's Lead Counsel
Michel Dorval, Commission's Co-Counsel

P.O. Box 1298, Station B
Ottawa, Ontario K1P 5R3
CANADA

Dear Commissioner Honourable John C. Major, Q.C. and esteemed Staff, Sunday, June 25, 2006

As required by the Rules of Procedure and Practice I hereby apply for standing as a 'person' by way of this motion supported by affidavit.

1. John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552

barry@ntsb.org
http://www.montereypeninsulaairport.com

2. I seek standing as a person for a portion of the mandate of the Inquiry.

3. The areas in which I have a clearly ascertainable interest and perspective which would enhance the work of the Commissioner and the reasons in support thereof are:

a. Aviation Safety in general. I am a survivor of a sudden fiery fatal jet airplane crash which has motivated me to become an independent aviation accident investigator to prevent similar accidents. In that role I have reviewed over a thousand aviation accident reports and hundreds in detail. My perspective is that of one who has been on scene before, during, and after the event, heard the explosions, felt the fires, suffered the injury, witnessed the fatality, smelled the ashes, and experienced the emotions caused by a sudden fiery fatal jet airplane crash.

b. Air India Flight 182 in specific. My ascertainable interest is demonstrated by my Smith AAR (Aviation Accident Report) for Air India Flight 182, a 249 page exhaustive evaluation of the facts, data, and evidence regarding that event. The AAR is a result of ten years of research and will be presented, if standing is granted, at Stage 2 of the inquiry. (Available upon request)

4. If required, I will make an oral submission in mid July in Ottawa.

Dear Commission Members, please permit me at this time to direct you to a significant error in the basic premise for the establishment of the Commission of Inquiry which, if I may be so bold to suggest, should be corrected as soon as possible to prevent undermining the credibility of your Commission.

1. Please note that the Prime Minister states that the public inquiry is a route to obtain answers to the tragedy of Air India Flight 182. He does not limit the inquiry to investigating any one cause, such as a bombing, but rightfully calls it a tragedy and implies any reasonable explanation will be considered as there are several non-bombing reasons for an aircraft to explode in flight.

From the Commission website: "Opening Statement" June 21, 2006, Background,
"In announcing the launch of this Inquiry, the Prime Minister, the Right Honourable Stephen Harper, stated that a public inquiry is the only route left to obtaining answers to how the tragedy of June 23, 1985 occurred when Air India Flight 182 exploded over the Atlantic Ocean."

2. The above is correct and yet several sentences later the grievous error is stated:
"Opening Statement" June 21, 2006, Background,
"Yet, it was not until the following January that the Canadian Aviation Safety Board concluded that the destruction of this aircraft was caused by a bomb."

Not so. Absolutely incorrect. Terribly misleading. The Canadian Aviation Safety Board made no such conclusion. The below is the actual conclusion in 4.1.5.

Aviation Occurrence Report of the Canadian Aviation Safety Board for Air India Flight 182 of January 22, 1986

"4.0 CONCLUSIONS
The Canadian Aviation Safety Board respectfully submits as follows:
4.1 Cause-Related Findings
1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion."

Dear Commission Members, the above Canadian accident expert opinion is correct. There was an explosion in the forward cargo compartment. The cause is left unstated and, in fact, the internal text of the report generally rules out a bomb as the cause of the explosion and suggests a mechanically caused explosive decompression.

The Indian Report, on the other hand:
Report of the Honourable Mr. Justice B.N. Kirpal of the High Court of Delhi of February 26, 1986:
"Analysis and Conclusions
4.1 From the evidence which is available what has now to be determined is as to what caused the accident.
4.5 It is evident that an event had occurred at 31,000 feet which had brought down 'Kanishka'. What could have possibly happened to it? The aircraft was apparently incapacitated and this was due either to it having been hit from outside; or due to some structural failure; or due to the detonation of an explosive device within the aircraft.
4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.
4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure."

Dear Commission Members, a Canadian Commission of Inquiry should use the Canadian aviation accident experts' opinions as a starting frame of reference, not that of an Indian Judge's opinion, (a criminal judge with no aviation accident investigation experience.) To claim that the Canadian Aviation Safety Board concluded that the destruction of this aircraft was caused by a bomb is absolutely incorrect and injects a dangerous bias into the supposedly objective proceedings so much so that the title is even incorrect: "Commission of Inquiry into the Investigation of the Bombing of Air India Flight 182". The title could be corrected to "Commission of Inquiry into the Investigation of the Tragedy of Air India Flight 182".

(The bombing statement error is understandable after twenty years of constant media and police opinions about terrorists everywhere and desires for grieving family members for revenge. However, there are no conspiracies to hide any truths, just passionate persons acting in their own perceived best interests.)

Please note that both of the quotes from the documents referenced above are specifically allowed by the Commission's Terms of Reference:

Terms of Reference: "...the Commissioner to conduct the Inquiry as he considers appropriate with respect to accepting as conclusive or giving weight to the findings of other examinations of the circumstances surrounding the bombing of Air India Flight 182, including
the report of the Honourable Mr. Justice B.N. Kirpal of the High Court of Delhi of February 26, 1986,
the Aviation Occurrence Report of the Canadian Aviation Safety Board into the crash involving Air India Flight 182 of January 22, 1986"

The points for my presentation at the Inquiry shall be:
1. The Canadian Aviation Safety Board conclusion of 1986 was correct and the Indian finding was wrong.
2. The verdict in the Canadian trial of the two accused as not guilty was correct. The criminal justice system did not fail the families or all Canadians. There were no bombs, no bombers, no conspiracies, no crimes, no criminals, no guilt.
3. Based upon the benefit of 20 years of hindsight and several similar early model Boeing 747 accidents and in particular United Airlines Flight 811, the actual probable cause of Air India Flight 182 is the shorted wiring/ruptured open forward cargo door/explosive decompression/inflight breakup explanation.
4. A request by the Commission to the Transportation Safety Board (Air) for an updated version of the Aviation Occurrence Report for Air India Flight 182 would be prudent and wise. The older report is now over twenty years old. Safety related explanations are constantly being updated after new accidents. There have subsequently been several similar early model Boeing 747s that have suffered a fatal inflight explosive decompression in the forward cargo compartment after a sudden loud sound on the cockpit voice recorder followed by an abrupt

power cut to the flight recorders.

In summary:
I apply for standing in the Inquiry as a person with an ascertainable interest and perspective. I have demonstrated with this letter a review of the Commission's mandates, a close observation of its premises, the detection of a serious error of fact, a suggested correction, provided confirming documentation quotes, and referenced supporting documents. I will do the same in principle at the Inquiry for the wiring/cargo door explanation.

From the Commission Opening Statement of Commissioner John Major: "We can, however, attempt to understand how this happened and to recommend safeguards and systemic changes to prevent future threats to our national security and intrusions into the lives of so many innocent people."

Yes, sir, we certainly can, and must, attempt to understand how this {Air India Flight 182} happened, recommend safeguards and changes to prevent future threats and intrusions. Please assign me as a person with standing the opportunity to explain how.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
barry@ntsb.org
http://www.montereypeninsulaairport.com

Attached below:
Relevant excerpts from the Commission's website,
Relevant excerpts from Canadian and Indian AAR for Air India Flight 182.

OPENING STATEMENT
June 21, 2006

In announcing the launch of this Inquiry, the Prime Minister, the Right Honourable Stephen Harper, stated that a public inquiry is the only route left to obtaining answers to how the tragedy of June 23, 1985 occurred when Air India Flight 182 exploded over the Atlantic Ocean. The aircraft was flying at an altitude of 31,000 feet (9500 m) just south of Ireland, when all 329 on board were killed. Eighty-two of those victims were children and 280 were Canadian citizens.

Yet, it was not until the following January that the Canadian Aviation Safety Board concluded that the destruction of this aircraft was caused by a bomb.

STANDING

10. A person may be granted full or partial standing as a party by the Commissioner if the Commissioner is satisfied that the person is directly and substantially affected by the mandate of the Inquiry or portions thereof.

12. Any person wishing to be granted standing must apply by way of a motion in writing supported by affidavit on or before July 7, 2006, or at the discretion of the Commissioner at any other date, which must include the following information:

1. name, address, telephone and fax numbers, and e-mail addresses of the person;
2. whether the person seeks standing as a party or as an intervenor for all or a portion of the mandate of the Inquiry;
3. the areas and issues where the person is directly and substantially affected or where the person has a clearly ascertainable interest or perspective which would enhance the work of the Commissioner and the reasons in support thereof;

13. Applicants for standing will be permitted to make oral submissions not exceeding 15 minutes at a public standing hearing in Ottawa, on July 18-20, 2006 at the Bytown Pavilion, Victoria Hall, 111 Sussex Drive, Ottawa, Ontario, or at the discretion of the Commissioner at any other date.

14. The Commissioner will determine any special conditions under which a person may participate and those parts of the Inquiry in which a person granted standing may

B. DEFINITIONS

2. In the Rules, unless otherwise provided, the following words mean:
10. Person: an individual, group, government or agency or other entity.

EVIDENCE

26. The Commissioner may receive any evidence or information which he considers to be helpful in fulfilling his mandate whether or not such evidence or information would be admissible in court.

* . Testimony in Stage 2 of the Inquiry
1. Preparation of Documentary Evidence

30. As soon as possible after being granted standing, parties and intervenors shall provide to the Commission all documents having any bearing on the subject matter of the Inquiry.

Commission of Inquiry into the Investigation of the
Bombing of Air India Flight 182
P.O. Box 1298, Station B
Ottawa, Ontario K1P 5R3
CANADA

Telephone: (613) 992-1834
Fax: (613) 995-3506

TERMS OF REFERENCE

the Commissioner to conduct the Inquiry as he considers appropriate with respect to accepting as conclusive or giving weight to the findings of other examinations of the circumstances surrounding the bombing of Air India Flight 182, including

the report of the Honourable Mr. Justice B.N. Kirpal of the High Court of Delhi of February 26, 1986,

the Aviation Occurrence Report of the Canadian Aviation Safety Board into the crash involving Air India Flight 182 of January 22, 1986,

that the Commissioner be authorized to grant to any other person who satisfies him that he or she has a substantial and direct interest in the subject-matter of the Inquiry an opportunity for appropriate participation in the Inquiry;

To conclude only that the criminal justice system has to date failed the families of Air India victims falls short of the problem. It failed all Canadians. The system failed all Canadians.

It is not possible to undo what happened in 1985. We can, however, attempt to understand how this happened and to recommend safeguards and systemic changes to prevent future threats to our national security and intrusions into the lives of so many innocent people.

AAR for Air India Flight 182 excerpts:

"4.0 CONCLUSIONS
The Canadian Aviation Safety Board respectfully submits as follows:
4.1 Cause-Related Findings
1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
2. The forward and aft cargo compartments ruptured before water impact.
3. The section aft of the wings of the aircraft separated from the forward portion before water impact.
4. There is no evidence to indicate that structural failure of the aircraft was the lead event in this occurrence.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the

evidence does not support any other conclusion."

Kirpal Report:
ANALYSIS AND CONCLUSIONS
4.1 From the evidence which is available what has now to be determined is as to what caused the accident.
4.5 It is evident that an event had occurred at 31,000 feet which had brought down 'Kanishka'. What could have possibly happened to it? The aircraft was apparently incapacitated and this was due either to it having been hit from outside; or due to some structural failure; or due to the detonation of an explosive device within the aircraft.
4.9 Thus we are left with only two of the possibilities viz., structural failure or accident having been caused due to a bomb having been placed inside the aircraft.
4.10 After going through the entire record we find that there is circumstantial as well as direct evidence which directly points to the cause of the accident as being that of an explosion of a bomb in the forward cargo hold of the aircraft. At the same time there is complete lack of evidence to indicate that there was any structural failure.
http://www.majorcomm.ca/en/index.asp

On May 1, 2006, an Order in Council was issued defining the terms of reference for the Commission of Inquiry into the Investigation of the Bombing of Air India Flight 182. The Honourable John C. Major, Q.C., was appointed Commissioner under Part 1 of the Inquiries Act.

The Inquiry will be conducted in two stages. During the first stage, the Commissioner will hear voluntary testimony from the families of the victims. Stage two will deal with matters set out in clause (b) of the Order in Council. For the Order in Council text, please visit the Terms of Reference.

Sheila-Marie Cook is the Executive Director and Commission Secretary. Mark J. Freiman is the Commission's Lead Counsel. Michel Dorval is the Commission's Co-Counsel.

RULES OF PROCEDURE AND PRACTICE

A. THE INQUIRY

1. This Inquiry shall be conducted in accordance with the Inquiries Act and the Terms of Order in Council P.C. 2006-293 and without restricting the generality of the foregoing will, when appropriate, follow the following guidelines.

The Commission proceedings will start with the voluntary testimony of the victims of the bombing of Air India Flight 182 ("Stage 1"). The balance of the Inquiry ("Stage 2") will inquire in phases into the matters set out in clauses (b)(i)-(vii) of the Terms of Reference of the Commission, PC 2006-293.

B. DEFINITIONS

2. In the Rules, unless otherwise provided, the following words mean:

1. Commission: the Commission of Inquiry into the Investigation of the Bombing of Air India Flight 182, established by Order in Council, PC 2006-293;

2. Commissioner: The Honourable John C. Major, Q.C., appointed by Order in Council, PC 2006-293;

3. Commission Counsel: Counsel appointed by the Commissioner to aid and assist the Commissioner in the Inquiry. Commission Counsel shall have standing throughout the Inquiry;

4. Commission Offices: the offices of the Commission are located at 222 Queen Street, Ottawa, Ontario, K1P 5V9;

5. Documents: records made or stored in physical or electronic form and include written, electronic, audiotape, videotape, digital reproductions, photography, maps, graphs, microfiche or any other data and information recorded or shared by means of any device;

6. Family: relatives of the victims of the Bombing of Air India Flight 182 or others to the discretion of the Commissioner;

7. Inquiry: the Commission;

8. Intervenor: a person granted status as an intervenor by the Commissioner;

9. Party: a person granted full or partial standing as a party by the Commissioner;

10. Person: an individual, group, government or agency or other entity.

C. GENERAL

3. The Commissioner may amend these Rules or dispense with compliance with them as he deems necessary to ensure that the Inquiry is thorough, fair and timely.

4. All parties, intervenors, witnesses and their counsel shall be deemed to undertake to adhere to the Rules, and may raise any issue of non-compliance with the Commissioner.

5. The Commissioner shall deal with a breach of these Rules as he sees fit including, but not restricted to, revoking the standing of a party, and imposing restrictions on the further participation in or attendance at (including exclusion from) the hearings by any party, intervenor, counsel, individual, or member of the media.

6. Subject to the Inquiries Act, the conduct of and the procedure to be followed on the Inquiry is under the control and discretion of the Commissioner.

7. Hearings will be convened in Ottawa unless otherwise directed in the discretion of the Commissioner

8. Insofar as he needs to hear evidence, the Commissioner is committed to a process of public hearings to the greatest extent possible. However, the Terms of Reference direct the Commissioner to take all steps necessary to prevent disclosure of information that, if it were disclosed to the public could, in the opinion of the Commissioner, be injurious to international relations, national defence or national security. The procedure which will govern hearings where such issues may arise is addressed in the section on "National Security Confidentiality".

9. Applications may also be made to proceed in camera for reasons of personal confidentiality, referred to as "Personal Confidentiality" in these Rules. Such applications should be made in writing at the earliest possible opportunity.

D. STANDING

10. A person may be granted full or partial standing as a party by the Commissioner if the Commissioner is satisfied that the person is directly and substantially affected by the mandate of the Inquiry or portions thereof.

11. A person may be granted standing as an intervenor by the Commissioner if the Commissioner is satisfied that the person represents clearly ascertainable interests and perspectives essential to the Commissioner's mandate, which the Commissioner considers ought to be separately represented before the Inquiry, in which event the intervenor may participate in a manner to be determined by the Commissioner.

12. Any person wishing to be granted standing must apply by way of a motion in writing supported by affidavit on or before July 7, 2006, or at the discretion of the Commissioner at any other date, which must include the following information:

1. name, address, telephone and fax numbers, and e-mail addresses of the person;

2. whether the person seeks standing as a party or as an intervenor for all or a portion of the mandate of the Inquiry;

3. the areas and issues where the person is directly and substantially affected or where the person has a clearly ascertainable interest or perspective which would enhance the work of the Commissioner and the reasons in support

thereof;

4. the names of the lawyers, if any representing the person, together with the lawyer's address, telephone number, e-mail address and fax number.

13. Applicants for standing will be permitted to make oral submissions not exceeding 15 minutes at a public standing hearing in Ottawa, on July 18-20, 2006 at the Bytown Pavilion, Victoria Hall, 111 Sussex Drive, Ottawa, Ontario, or at the discretion of the Commissioner at any other date.

14. The Commissioner will determine any special conditions under which a person may participate and those parts of the Inquiry in which a person granted standing may participate.

15. From time to time, the Commissioner may, in his discretion, at any time grant to or rescind standing from a person, or modify the status or conditions of the standing of a person.

16. The Commissioner will determine on what terms and in which parts of the Inquiry a party or intervenor may participate, and the nature and extent of such participation.

17. The Commissioner may direct that a number of applications share in a single grant of standing.

18. Counsel representing witnesses called to testify before the Commission may participate during the hearing of such evidence as provided in these Rules.

E. FUNDING

19. For the purposes of the Inquiry, parties who would not otherwise be able to participate may seek funding by way of a motion in writing, with supporting affidavit(s), to be

filed with the Commission on or before August 16, 2006, or at the discretion of the Commissioner at any other date. Funding will be recommended at the Commissioner's discretion in accordance with paragraph (h) of the Terms of Reference. There will be no oral hearing with respect to funding.

20. Where the Commissioner's funding recommendation is accepted, funding shall be in accordance with approved Treasury Board guidelines respecting rates of remuneration and reimbursement and the assessment of accounts.

F. RIGHT TO COUNSEL

21. Witnesses have the right to consult counsel at their own expense unless funding for said costs is ordered by the Commissioner as provided in these Rules. Anyone interviewed by or on behalf of Commission Counsel is entitled to have one personal counsel present for the interview to represent his or her interests.

G. HEARING AND DECORUM

22. In so far as it needs to consider evidence under the Inquiry, the Commission is committed to a process of public hearings.

23. However, applications may be made by a party asking that the Commissioner issue an order that any portion of the proceedings be in camera, or issue an order prohibiting the disclosure, publication or communication of any testimony, document, personal information or evidence. Such applications shall be made in writing, supported by affidavit(s), at the earliest opportunity. The evidence and submissions on such applications may be presented in private or in public, or a combination of both, at the discretion of the Commissioner, according to these Rules, which are applicable to in camera matters with appropriate

modifications.

24. The Commissioner may, at his discretion, issue an order that any portion of the proceedings be in camera, or issue an order prohibiting the disclosure, publication or communication of any testimony, document, personal information or evidence.

25. The Commission will set the dates, hours and places of its hearings. Unless otherwise directed by the Commissioner in his discretion, hearings will start at 9:30 a.m. and end at 4:30p.m., from Monday to Friday, inclusive, and will take place in Ottawa at the Bytown Pavilion, Victoria Hall, 111 Sussex Drive, Ottawa, Ontario or at such other place as the Commissioner determines.

H. EVIDENCE

26. The Commissioner may receive any evidence or information which he considers to be helpful in fulfilling his mandate whether or not such evidence or information would be admissible in court.

27. The Commissioner, in his discretion, may accept as conclusive or give such weight as he deems appropriate to the findings of the examinations of the circumstances surrounding the bombing of Air India Flight 182 set out in paragraph (a) of the Commission's Terms of Reference, Order in Council, PC 2006-293.

* 1. Commencement of the Inquiry (Stage 1)

28. Family of the victims of the bombing of Air India Flight 182 who participate in Stage 1 of the Inquiry will not be required to give their testimony upon oath or upon affirmation and shall not be subject to cross-examination.

29. The Commissioner, in his discretion, may make such

further Rules as he deems appropriate with respect to the conduct of Stage 1 of the Inquiry. The Rules with respect to evidence in the balance of the Inquiry (Stage 2) will not apply to Stage 1, unless specifically so ordered by the Commissioner.

* 2. Testimony in Stage 2 of the Inquiry
    1. Preparation of Documentary Evidence

30. As soon as possible after being granted standing, parties and intervenors shall provide to the Commission all documents having any bearing on the subject matter of the Inquiry.

31. Where a party objects to the production of any document on the grounds of privilege, the document shall be produced in its original unedited form to Commission Counsel who will review and determine the validity of the privilege claim. The party, intervenor and/or counsel may be present during the review process. In the event the party or intervenor claiming privilege disagrees with Commission Counsel's determination, the Commissioner, on application, may either inspect the impugned document(s) and make a ruling, or may direct the issue to be resolved by the Federal Court.

32. Upon the request of Commission Counsel, parties and intervenors shall provide originals of relevant documents.

33. Documents received from a party, intervenor, or any other organization or individual, shall be treated as confidential by the Commission unless and until they are made part of the public record or the Commissioner otherwise declares. This does not preclude Commission Counsel from producing a document to a proposed witness prior to the witness giving his or her testimony, as part of

the investigation being conducted, all subject to National Security Confidentiality.

2. Witness Interviews

34. Commission Counsel may interview people who have information or documents which have any bearing upon the subject matter of the Inquiry. People who are interviewed are entitled, but not required, to have a legal counsel present at their expense unless otherwise ordered by the Commissioner, as provided in these Rules.

35. If Commission Counsel determines that a person will be called as a witness following an interview, Commission Counsel will prepare a statement of the witness' anticipated evidence. Commission Counsel will provide a copy of the statement of anticipated evidence to the witness for review before the witness testifies before the Commission. Where a statement of anticipated evidence is released to persons with party status prior to the testimony of a witness, the statement will be deemed confidential and unless otherwise ordered by the Commissioner shall be not be disclosed to third parties until after the completion of the testimony of the witness in question.

3. Witnesses

36. All government entities, agencies and officials and all witnesses shall co-operate fully with the Commission and shall make available all documents and witnesses relevant to the mandate of the Commission.

37. Witnesses who testify will give their evidence at a hearing under oath or upon affirmation unless otherwise ordered by the Commissioner in his discretion.

38. Commission Counsel may issue and serve a subpoena or summons upon each witness before he or she testifies.

Witnesses may be called more than once.

39. Witnesses who are not represented by counsel for parties are entitled to have their own counsel present while they testify, subject to National Security Confidentiality. Counsel for a witness will have standing only for the purpose of that witness' testimony to make any objections thought appropriate and for other purposes as directed by the Commissioner in his discretion.

40. Parties and intervenors are encouraged to advise Commission Counsel of the names, addresses and telephone numbers of all witnesses they wish to have called and, if possible, to provide summaries of the information the witnesses may have.

41. If the proceedings are televised, applications may be made for an order that the evidence of a witness not be televised or broadcast.

4. Commission Dossier

42. At the commencement of any phase of Stage 2 of the Inquiry, Commission Counsel may present to the Commissioner a statement of evidence, facts or conclusions together with the sources or basis for the evidence, facts or conclusions that Commission Counsel proposes that the Commissioner adopt for purposes of the Commission's findings or conclusions with respect to that phase of Stage 2 (a "Commission Dossier").

43. Commission Counsel may call witnesses or experts to support or supplement the Commission Dossier.

44. A person who has been granted party status with respect to a phase of Stage 2 with respect to which Commission Counsel has presented a Commission Dossier may cross-examine witnesses called with respect to the Dossier. A person granted status as a party or as an

intervenor may propose witnesses to be called with respect to the Dossier. Where Commission Counsel declines to call a witness proposed by a person with party or intervenor status, that person may follow the procedure as set out in Rule 49.

5. Oral Examination

45. In the ordinary course Commission Counsel will call and question witnesses who testify at the Inquiry. Counsel for a party may apply to the Commissioner to lead a particular witnesses' evidence in chief. If counsel is granted the right to do so, examination shall be confined to the normal rules governing the examination of one's own witness in court proceedings, unless otherwise directed by the Commissioner.

46. Commission Counsel have a discretion to refuse to call or present evidence.

47. The order of examination in the ordinary course will be as follows:

1. Commission Counsel will lead the evidence from the witnesses. Except as otherwise directed by the Commissioner, Commission Counsel is entitled to ask both leading and non-leading questions;

2. parties will then have an opportunity to cross-examine the witness to the extent of their interest. The order of cross-examination will be determined by the parties and, if they are unable to reach agreement, by the Commissioner;

3. after cross-examinations, counsel for a witness may then examine the witness. Except as otherwise directed by the Commissioner, counsel for the witness is entitled to ask both leading and none-leading questions;

4. Commission Counsel shall have the right to re-

examine last.

48. After a witness has been sworn, affirmed, or otherwise qualified at the commencement of giving evidence, no counsel other than Commission Counsel may speak to such witness about the evidence that he or she has given until the evidence of such witness is complete except with the permission of the Commissioner. Commission Counsel may not speak to any witness about his or her evidence while the witness is being cross-examined by other counsel.

49. When Commission Counsel indicate that they have called the witnesses whom they intend to call in relation to a particular issue, a party may then apply to the Commissioner for leave to call a witness whom the party believes has the evidence relevant to that issue. If the Commissioner is satisfied that the evidence of the witness is needed, Commission Counsel shall call the witness, subject to Rule 47.

6. Use of Documents at Hearings

50. In advance of a witness' testimony, Commission Counsel will endeavour to provide to parties and intervenors with an interest in the subject matter of the proposed evidence, a statement of that witness' anticipated evidence and associated documents, subject to the Rules regarding National Security Confidentiality, and subject to receipt of an undertaking that all such documents or information will be used solely for the purpose of the Inquiry. In addition, the Commissioner may require that documents provided, and all copies made, be returned to the Commission if not tendered in evidence. Counsel are entitled to provide such documents or information to their respective clients only on terms consistent with the undertakings given, and upon the clients entering into written undertakings to the same effect. These undertakings will be of no force regarding any document or information once it has become an exhibit. The

Commissioner may, upon application, release any party or intervenor in whole or in part from the provisions of the undertaking in respect of any particular document or other information.

51. Parties shall provide Commission counsel with any documents that they intend to file as exhibits or otherwise refer to during the hearings at the earliest opportunity, and in any event shall provide such documents to Commission counsel no later than two business days before the document will be referred to or filed.

52. Before using a document for purposes of cross-examination, counsel shall provide a copy to the witness and to all parties having an interest in the subject matter of the proposed evidence not later than two business days prior to the commencement of that witness' testimony.

7. National Security Confidentiality

53. As contemplated by paragraph (m) of the Terms of Reference, Order in Council, P.C. 2006-293, the Attorney General of Canada may apply from time to time to have certain evidence heard in camera to prevent public disclosure of information on grounds of National Security Confidentiality. The Commissioner will conduct proceedings to determine the disposition of such applications in accordance with paragraph (m) (i-v) of the Terms of Reference subject to such additional procedures consistent with the Terms of Reference as the Commissioner may at his discretion direct.

8. Personal Confidentiality

54. Upon application, the Commissioner may make an order for a grant of "Personal Confidentiality", aimed at protecting the identity of any person. For the purposes of the Inquiry, Personal Confidentiality shall include the right of any person to have his or her identity disclosed only by way of non-identifying initials, and, if the Commissioner so

rules, the right to testify before the Commission in camera, together with any other privacy measures which the Commissioner grants.

55. Upon application, the Commissioner may make an order to conduct hearings in camera when he is of the opinion that intimate financial, personal or other matters are of such a nature, having regard to the circumstances, that the desirability of avoiding disclosure outweighs the desirability of adhering to the general principle that the hearings should be open to the public.

56. A person who is granted Personal Confidentiality will not be identified in the public records and transcripts of the hearing except by non-identifying initials, and the public transcripts may be redacted to exclude any identifying details. Any reports of the Commission referring to a person who has been granted Personal Confidentiality will use non-identifying initials only, and may exclude reference to identifying details.

57. Media reports relating to a person granted Personal Confidentiality shall avoid references that might reveal the identity of the person. No photographic or other reproduction of a person granted confidentiality shall be made either during the person's testimony or upon his or her entering and leaving the site of the Inquiry.

58. Any witness who is granted Personal Confidentiality may either swear an oath or affirm to tell the truth using the non-identifying initials given for the purpose of the witness's testimony.

59. Any party, intervenor or witness may apply to the Commissioner to have intimate financial or personal information which is not relevant to the subject matter of the Inquiry redacted from documents proposed to be introduced into evidence.

60. All media representatives shall be deemed to undertake to adhere to the Rules respecting Personal Confidentiality. A breach of these Rules by a media representative shall be dealt with by the Commissioner as he sees fit.

9. Access to Evidence

61. All evidence shall be categorized and marked P for public sittings and C for sittings in camera

62. Copies of the P transcript of evidence will be made available on the Inquiry's website. One copy of the P transcript and the P exhibits of the public hearings will be made available for public review at the Commission offices.

63. Only those persons authorized by the Commission, in writing, shall have access to C transcripts and exhibits.

I. CONSULTATION PAPERS, POLICY FORUMS, PUBLIC CONSULTATIONS

64. The Commissioner, in his discretion, may authorize the commissioning of Consultation Papers, and/or the convening of Expert Policy Forums or Public Consultations for use in the preparation of Commission Dossiers.

65. The Commissioner, in his discretion, may receive evidence at any stage of Phase 2 of public hearings from one or more panels of expert witnesses. The Commissioner may modify the Rules for cross-examination of witnesses as he deems appropriate, so as to allow persons with standing in relation to the relevant phase of Stage 2 to participate appropriately in relation to the evidence of the panel in question.

66. Persons with an interest in any phase of Stage 2 may, prior to the commencement of that phase, may make a

submission in writing about any matter relevant to that phase, including specific proposals for the recommendations to be made by the Commissioner with respect to that phase.

67. The Commissioner may convene public and private consultations to hear submissions with respect to any matter raised in any phase of Stage 2 of the Inquiry. The participants in such consultations may include any persons whom the Commissioner concludes will contribute to the process.

J. MEDIA COVERAGE

68. The Commission may authorize the tape recording and live broadcasting of the public hearings by a designated media representative who will provide such recording and live feed to all other media pursuant to a pooling agreement. If the media cannot agree on a pooling agreement, they may apply to the Commissioner for a decision.

69. Representatives of the media who have signed the pooling agreement have the same rights in connection with the utilization of the tape recording and live broadcasting feed of the public hearings as the designated media representative.

70. The designated media representative authorized to tape record and broadcast the public hearings shall provide a copy of such recording to the Commission's Registrar, not later than three days after the recorded hearing.

71. Cameras and microphones will be located at pre-determined places in the hearing rooms. Only fixed cameras and the lighting system in the hearing room will be allowed.

72. No media scrums, interviews, or reporting will be allowed in the hearing rooms or within a prescribed distance from the hearing room entrances.

73. Media representatives will have to abide by the Commission's directives.

74. Whenever the Commission decides pursuant to Rules 8, 9, 53, 54 and 55 to proceed in camera, or issue a publication, disclosure or communication ban, the designated media representative must, to the satisfaction of the Commission, take all necessary measures to ensure that all tape recording or sound recording machines have been turned off.

75. No other forms or means of recording, re-broadcasting or photographing beyond those permitted by these Rules will be allowed in the hearing rooms.

76. Notwithstanding Rule 75, the Commission may allow, at his discretion at times and under conditions set by him, one photographer to take pictures in the hearing room with the understanding that he make available his negatives to representatives of the media pursuant to a pooling agreement of the kind described in Rule 68 above.

Last Modified: 21/06/2006

Opening Statement (open to the public)

June 21, 2006

Deadline: Written Applications for Standing
July 7

Public Hearings: Standing
July 18 – 20

Deadline: Written Applications for Funding
August 16

Public Hearings
September 25 – October 13
October 23 – November 10
November 20 – December 1
January 8 – January 26, 2007
February 5 – February 23
March 5 – March 23
April 2 – April 20

Closing Statements
May 2007

Report
September 2007

Public Hearings
Victoria Hall, Bytown Pavilion
111 Sussex Drive
Ottawa, Ontario
CANADA

Her Excellency the Governor General in Council, on the recommendation of the Prime Minister, hereby directs that a Commission do issue under Part I of the Inquiries Act and under the Great Seal of Canada appointing the Honourable John C. Major, Q.C., as Commissioner to conduct an inquiry into the investigation of the bombing of Air India Flight 182 (the "Inquiry"), which Commission shall direct

1. the Commissioner to conduct the Inquiry as he considers appropriate with respect to accepting as conclusive or giving weight to the findings of other examinations of the circumstances surrounding the bombing of Air India Flight 182, including

    1. the report of the Honourable Bob Rae entitled Lessons to Be Learned of November 23, 2005,

    2. proceedings before the superior courts of British Columbia,

    3. the 1991–1992 Security Intelligence Review Committee review of Canadian Security Intelligence Service activities in regard to the destruction of Air India Flight 182,

    4. the report of the Honourable Mr. Justice B.N. Kirpal of the High Court of Delhi of February 26, 1986,

    5. the Aviation Occurrence Report of the Canadian Aviation Safety Board into the crash involving Air India Flight 182 of January 22, 1986,

    6. the 1985 report of Blair Seaborn entitled Security Arrangements Affecting Airports and Airlines in Canada, and

    7. the reports prepared by the Independent Advisory Panel assigned by the Minister of Transport to review the provisions of the Canadian Air Transport Security Authority Act, the operations of the Canadian Air Transport Security Authority and other matters relating to aviation security;

2. the Commissioner to conduct the Inquiry specifically for the purpose of making findings and recommendations

with respect to the following, namely,

1. if there were deficiencies in the assessment by Canadian government officials of the potential threat posed by Sikh terrorism before or after 1985, or in their response to that threat, whether any changes in practice or legislation are required to prevent the recurrence of similar deficiencies in the assessment of terrorist threats in the future,

2. if there were problems in the effective cooperation between government departments and agencies, including the Canadian Security Intelligence Service and the Royal Canadian Mounted Police, in the investigation of the bombing of Air India Flight 182, either before or after June 23, 1985, whether any changes in practice or legislation are required to prevent the recurrence of similar problems of cooperation in the investigation of terrorism offences in the future,

3. the manner in which the Canadian government should address the challenge, as revealed by the investigation and prosecutions in the Air India matter, of establishing a reliable and workable relationship between security intelligence and evidence that can be used in a criminal trial,

4. whether Canada's existing legal framework provides adequate constraints on terrorist financing in, from or through Canada, including constraints on the use or misuse of funds from charitable organizations,

5. whether existing practices or legislation provide adequate protection for witnesses against intimidation in the course of the investigation or prosecution of terrorism cases,

6. whether the unique challenges presented by the

prosecution of terrorism cases, as revealed by the prosecutions in the Air India matter, are adequately addressed by existing practices or legislation and, if not, the changes in practice or legislation that are required to address these challenges, including whether there is merit in having terrorism cases heard by a panel of three judges, and

7. whether further changes in practice or legislation are required to address the specific aviation security breaches associated with the Air India Flight 182 bombing, particularly those relating to the screening of passengers and their baggage;

3. the Commissioner to conduct the Inquiry under the name of the Commission of Inquiry into the Investigation of the Bombing of Air India Flight 182;

4. that the Commissioner be authorized to adopt any procedures and methods that he may consider expedient for the proper conduct of the Inquiry, and to sit at any times and in any places in or outside Canada that he may decide;

5. that the Commissioner be authorized to conduct consultations in relation to the Inquiry as he sees fit;

6. that the Commissioner be authorized to grant to the families of the victims of the Air India Flight 182 bombing an opportunity for appropriate participation in the Inquiry;

7. that the Commissioner be authorized to recommend to the Clerk of the Privy Council that funding be provided, in accordance with approved guidelines respecting rates of remuneration and reimbursement and the assessment of accounts, to ensure the appropriate participation of the families of the victims of the Air India Flight 182 bombing;

8. that the Commissioner be authorized to grant to any other person who satisfies him that he or she has a substantial and direct interest in the subject-matter of the Inquiry an opportunity for appropriate participation in the Inquiry;

9. that the Commissioner be authorized to recommend to the Clerk of the Privy Council that funding be provided, in accordance with approved guidelines respecting rates of remuneration and reimbursement and the assessment of accounts, to ensure the appropriate participation of any party granted standing under paragraph (h), to the extent of the party's interest, where in the Commissioner's view the party would not otherwise be able to participate in the Inquiry;

10. that the Commissioner be authorized to rent any space and facilities that may be required for the purposes of the Inquiry, in accordance with Treasury Board policies;

11. the Commissioner to use the automated litigation support program specified by the Attorney General of Canada and to rely, to the greatest extent possible, on documents that have been previously identified for use in Canadian criminal proceedings arising from the bombing of Air India Flight 182, and to consult with records management officials within the Privy Council Office on the use of standards and systems that are specifically designed for the purpose of managing records;

12. that the Commissioner be authorized to engage the services of any experts and other persons referred to in section 11 of the Inquiries Act, at rates of remuneration and reimbursement approved by the Treasury Board;

13. the Commissioner, in conducting the Inquiry, to take all steps necessary to prevent disclosure of information which, if it were disclosed, could, in the opinion of the

Commissioner, be injurious to international relations, national defence or national security and to conduct the proceedings in accordance with the following procedures, namely,

1. on the request of the Attorney General of Canada, the Commissioner shall receive information in camera and in the absence of any party and their counsel if, in the opinion of the Commissioner, the disclosure of that information could be injurious to international relations, national defence or national security,

2. the Commissioner may release a part or a summary of the information received in camera, if, in the opinion of the Commissioner, its disclosure would not be injurious to international relations, national defence or national security, and shall provide the Attorney General of Canada with an opportunity to make submissions regarding international relations, national defence or national security prior to any release of a part or a summary of information received in camera,

3. if the Commissioner concludes that, contrary to the submissions of the Attorney General of Canada referred to in subparagraph (ii), disclosure of a part or a summary of information received in camera would not be injurious to international relations, national defence or national security, he shall so notify the Attorney General of Canada, which notice shall constitute notice under section 38.01 of the Canada Evidence Act,

4. the Commissioner shall provide the Attorney General of Canada with an opportunity to make submissions regarding international relations, national defence or national security with respect to any reports that are intended for release to the public prior to submitting such reports to the Governor in Council, and

5. if the Commissioner concludes that, contrary to the

submissions of the Attorney General of Canada referred to in subparagraph (iv), disclosure of information contained in reports intended for release to the public would not be injurious to international relations, national defence or national security, he shall so notify the Attorney General of Canada, which notice shall constitute notice under section 38.01 of the Canada Evidence Act;

14. that nothing in that Commission shall be construed as limiting the application of the provisions of the Canada Evidence Act;

15. the Commissioner to follow established security procedures, including the requirements of the Government Security Policy, with respect to persons engaged pursuant to section 11 of the Inquiries Act and the handling of information at all stages of the Inquiry;

16. the Commissioner to perform his duties without expressing any conclusion or recommendation regarding the civil or criminal liability of any person or organization;

17. the Commissioner to perform his duties in such a way as to ensure that the conduct of the Inquiry does not jeopardize any ongoing criminal investigation or criminal proceeding;

18. the Commissioner to file the papers and records of the Inquiry with the Clerk of the Privy Council as soon as reasonably possible after the conclusion of the Inquiry;

19. the Commissioner to submit a report or reports, simultaneously in both official languages, to the Governor in Council; and

20. the Commissioner to ensure that members of the public can, simultaneously in both official languages, communicate with, and obtain services from it, including

transcripts of proceedings if made available to the public.

From: John Barry Smith <barry@johnbarrysmith.com>
Date: September 5, 2009 11:46:50 PM PDT
To: Ian Donaldson@barry@johnbarrysmith.com
Subject: **Air India Flight 182**

Ian Donaldson, QC
Vancouver County
Donaldson Jett⁄
490 - 1090 Homer Street
Vancouver, BC V6B 2W9
604 682 5232 phone
604 681 1331 fax

Dear Mr. Donaldson Wednesday, August 23, 2006

Attached are submissions 4 through 12 which were sent to, received, and acknowledged by the Commission of Inquiry. I've also sent all 12 submissions to RCMP, Attorney General, Transport Canada and Transportation Safety Board. Do you think the Prime Minister would be overkill?

I see the hearing to set a trial date for Mr. Reyat was delayed from 2 August to early September. Why?

From your silence I have to guess you are not going with the 'no bomb, no bombers, no conspiracies, no perjury' defense but probably the 'well, I forgot, that's my story and I'm sticking to it' defense.

It seems funny to me to have to defend someone from a conspiracy charge in which the client was involved with two men who were found not guilty of conspiracy.

Anyway, I'm trying to see your point of view.

1. Requesting bomb report on the Narita event from Japanese authorities is too much trouble, takes too long, and probably written in Japanese anyway
2. Requesting a Canadian aviation safety board that investigates airplane crashes and who has never given its opinion would be a waste of time as they are very busy and understaffed and the report would be too technical to understand anyway.
3. Using the 'no bomb, no conspiracy' defense would undermine efforts of your colleague/friend Dave Crossin since Ole Dave never argued or disputed:
  a. that since all the Vancouver baggage was loaded into the aft cargo compartment

of Air India Flight 182 and the explosion occurred in the forward compartment, the Vancouver guys were innocent.
b. the cause was a bomb since the CASB did not conclude it was a bomb, only an explosion for which there are many causes.
c. the switch from forward compartment explosion which was believed for fifteen years and then suddenly switched to aft cargo compartment when all the evidence in the CASB and Kirpal reports specifically ruled out an explosion of any cause back there.

With a defense counsel like that, who agrees with the Crown it was a bomb and let's just explode it anywhere, who needs prosecutors?

But, he did earn his money, he got verdicts of not guilty and that's what counts in the end as far as the defense for two men goes. Maybe you were involved with the decision not to dispute the bombing conclusion made by the police and ignore the opinions of the people who actually investigate aircraft crashes.

In effect, those decisions have made it much harder to defend Mr. Reyat....who unbeknownst to him, the bomb making materials were used to ....bring down the World Trade Center...

Sheer cunning genius by some Crown prosecutor to have a suspect sign a document saying that unbeknownst to him, something bad happened and he was involved, knowing the media and public would take that as a confession.

However, unbeknownst to Mr. Reyat the
items that he acquired were used by another person or persons to help
make an explosive device that, on or about Jun. 23, 1985, destroyed Air
India Flight 182, killing all 329 people on board."

By STAFF
The Toronto Star, Feb. 11, 2003

"Text of the agreed statement of facts submitted in B.C. Supreme Court
when Inderjit Singh Reyat pleaded guilty Feb. 10 to 329 counts of
manslaughter in the 1985 bombing of Air India Flight 182:"

"In May and Jun. 1985, in the province of British Columbia, Mr. Reyat
acquired various materials for the purpose of aiding others in the
making of the explosive devices. Mr. Reyat was told and believed that
the explosive devices would be transported to India in order to blow up
property such as a car, a bridge or something 'heavy.' Although Mr.
Reyat acquired materials for this purpose, he did not make or arm an
explosive device, nor did he place an explosive device on an airplane,

nor does he know who did or did not do so. At no time did Mr. Reyat intend by his actions to cause death to any person or believe that such consequences were likely to occur. However, unbeknownst to Mr. Reyat the items that he acquired were used by another person or persons to help make an explosive device that, on or about Jun. 23, 1985, destroyed Air India Flight 182, killing all 329 people on board."

Well, my advice still stands:
a. Go with science, not emotion, to explain an airplane crash.
b. Seek information such as Japanese report on the Narita event and the TSB Air opinion on Air India Flight 182 to get expert opinion you respect other than news reports.
c. Appear before the Commission of Inquiry to present your contributions to the cheating done by the Crown in the prosecutions of Malik and Bagri.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
1 831 241 0631 Cell
barry@johnbarrysmith.com
safety@ntsb.org

From: John Barry Smith <barry@johnbarrysmith.com>
Date: September 5, 2009 11:46:50 PM PDT
To: bolthuis@arvayfinlay.com, tony@taylorkelly.co.uk, Robert.Black@ed.ac.uk, jeffreytcampbell@home.com, rjohnston@sccrc.org.uk, mtansey@majorcomm.ca
Subject: **The best defense is a strong offense.**

Air India Flight 182 past and present attorneys
Messrs. Murray L. Smith and Brent B. Olthuis
Smith Barristers,
Suite 1300 -
355 Burrard Street,
Vancouver, BC, V6C 2G8
V6C 2G8

Tel: 604-689-4438
Fax: 604-689-4451
bolthuis@arvayfinlay.com

Ian Donaldson, QC
Vancouver County
Donaldson Jett⁄
490 - 1090 Homer Street
Vancouver, BC V6B 2W9
604 682 5232 phone
604 681 1331 fax
David Crossin

Pan Am Flight 103 past, present, and associated attorneys

Eddie MacKechnie
MacKechnie and Associates
27a Park Circus
Glasgow G3 6AP

Tony Kelly
Mssrs Taylor & Kelly,
3 Main Street, Coatbridge
ML5 3AJ
tony@taylorkelly.co.uk
01236 710999 phone
01236 429080 fax

Professor Robert Black QC FRSE FFCS
The Edinburgh Law School
+44 (0)131 650 2021
+44 (0)131 650 6317 (School fax)
+44 (0)871 247 2026 (Personal e-fax)
+44 (0)7740 541495 (Mobile)

Robert.Black@ed.ac.uk

Kamal Maghur,
Mr. Alistair Duff,
Mr. Stephen Mitchell,
Mr. Richard Keen,
Murdo Macleod,
McGrigor, Donald,
Alex Prentice,
William Taylor,
John Beckett
Jeffrey Campbell jeffreytcampbell@home.com

Judicial official for Pan Am Flight 103
Robin Johnston
Solicitor
Senior Legal Officer
Scottish Criminal Cases Review Commission
Glasgow
rjohnston@sccrc.org.uk

Judicial official for Air India Flight 182
Commission of Inquiry into the Bombing of Air India Flight 182
Commissioner John Major
P.O. Box 1298, Station B
Ottawa, Ontario K1P 5R3
Canada
Telephone:(613) 992-1834
Fax:(613) 995-3506
Spokesperson:
Michael Tansey
Telephone:
(613) 949-8477

(613) 851-4587 (cell)
Email:mtansey@majorcomm.ca, michael@tancom.ca

Air India Flight 182 accused
Inderjit Singh Reyat upcoming perjury trial, convicted, and plea bargained, now in prison.
Ripudaman Singh Malik acquitted but trying to restore his reputation.
Ajaib Singh Bagri acquitted,

Pan Am Flight 103 accused
Abdelbaset Ali Mohmed al-Megrahi convicted, now in prison, appealing
Al-Amin Khalifa Fhimah, acquitted.

Dear Gentlemen Representatives of the Law, the Accused, the Bewildered and the Downhearted, Tuesday, October 10, 2006

The legal controversies continue:

Air India Flight 182
Commission of Inquiry into the Bombing of Air India Flight 182 Started September 2006 through September 2007 Mr. Malik has intervenor status.
Reyat Perjury Trial May 2007
Reyat Parole Hearing Unknown date

Pan Am Flight 103
SCCRC appeal Abdelbaset Ali Mohmed al-Megrahi Awaiting ruling.
Crown appeal for longer sentence for Abdelbaset Ali Mohmed al-Megrahi. Status unknown

Discussion:

Early model Boeing 747s are machines. We say they die when they crash but they were never really alive, now were they? We anthropomorphize. Let me continue with the analogy.

Four early model Boeing 747s were assumed to have been murdered with the killers caught and tried. Some went free and some went to jail. I am here to say to you that there was no murder, no crime, no killers and innocent men are in prison for a crime that was nonexistent but that a machine failed because of a mechanical part, wiring. That safety hazard persists.

It's as if a person falls down dead. The police, the media, the man's family, the courts, the prosecution, and the defence all agree, yes, it was a shot to the head that killed him but we'll argue about who and where and when he was shot. Several men are arrested, and at the trial the defence states that yes, the victim was shot in the head but their clients did not do it. All the while some physicians who examined the dead person are saying, no, it was not a gunshot to the head but a heart attack, while other physicians say we don't know how he died but we may find out later.

And then another man fall down dead at same spot and it's the brother of the previous dead man. Same thing happens, most non physicians say gunshot to head but the autopsy cause of death determined by government physicians claim natural causes. Several more men are accused and tried. The defence agreed with the prosecution as to cause of death as gunshot but their clients did not pull the trigger.

And then another brother falls down dead under similar circumstances...first guesses were gunshot to head but later proven wrong.

And then another brother falls down dead under similar circumstances...first guesses were gunshot to head but later proven wrong.

All four brothers share the same exact DNA and the evidence discovered at their deaths is generally the same. Two brothers are conclusively proven to have died of heart attacks and the deaths of the other two remain controversial.

And all the while, the people who know why people fall down dead are saying, not a gunshot to the head but heart attack, probably caused by poor diet.

Too bizarre an analogy? No. It's happening in your lives and has happened for years.

Gentlemen, do you have time to examine a reasonable alternative explanation for the aircraft crashes for which your clients are accused of being involved in? I would think your clients have time as they have the rest of their lives to think about it, live with it, and integrate the accusations into their lives inside or outside of prison.

How does a four time serial killer called faulty wiring get away with it?

1. The deaths happen over a period of years, 1985 through 1996. Memories are short. Personnel change. Documents are thrown away, misplaced, or lost. Witnesses forget.
2. The deaths happen many thousands of miles apart from each

other, such as Ireland, New York, Lockerbie, and Hawaii.
3. The deaths involve many agencies; RCMP, Scotland Yard, FBI, CIA, CSIS, TSB, NTSB, CASB, AAIB, Indian Civil Aviation Agency, and all the way to the top political leaders. The agencies do not cooperate or communicate fully, they defend their area of investigation, they are secretive, and they have many administrative senior officials directing them. Each agency looks closely at its lone tree/brother/aircraft in the forest/family of four while ignoring the other three.
4 The deaths involve objects that look different at first glance such as different colors in their livery, different names in their titles, and different nicknames.
5. The deaths involve victims who are not wealthy, important, connected to authority, or famous.
6. The deaths involve different complex legal jurisdictions in faraway places such as India, Canada, UK, and USA.
7. The deaths involve billions of dollars which means people get funny when they get around money.

A. The killer is well loved, well connected, wealthy, powerful, and not a suspect and anybody raising suspicion is scorned.
B. The killer has killed before but is still above suspicion having said to have reformed.
C. The killer's freedom is necessary for the financial well being of thousands of workers.

1. The accused are relatively poor, different color skin and language than the accusers, and have in the past expressed violent thoughts.
2. The accused reinforce the prejudices of the accusers.
3. The accused get the suspicion off the real killer.

There are no conspiracies among the agencies, courts, media, or public to hide or protect the real killer or to convict the innocent. All involved really believe the real killer is not guilty and the accused are guilty based upon the public's own self interest. The well meaning accusers all believe in a vast international conspiracy by the accused to commit mass murder and like all zealots, refuse to consider down to earth explanations for such mass grief causing events. The hysteria feeds on itself with the stories gaining myth status with constant repeating, embellishment and modifications.

The real killer is faulty wiring, a small failure which brings down huge machines, early model Boeing 747s, by exploiting the design flaws of non plug cargo doors and no locking sectors on the midspan latches. The dead brothers/machines are Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and TWA Flight 800.

Details:

The innocent accused are:

Air India Flight 182
Inderjit Singh Reyat now in prison.
Ripudaman Singh Malik acquitted but trying to clear his reputation.
Ajaib Singh Bagri acquitted,

Pan Am Flight 103 accused
Abdelbaset Ali Mohmed al-Megrahi now in prison
Al-Amin Khalifa Fhimah, acquitted.

United Airlines Flight 811
A ground crewman accused of killing nine passengers by

negligence in improper latching of the forward cargo door before takeoff. He was proven innocent years later when the cargo door was found to be properly latched but the inadvertent opening was caused by an electrical problem in the wiring or switch.

TWA Flight 800
US Navy by firing a missile which blew up the aircraft.
Disproved by lack of evidence after two years.
Unknown terrorists who placed bomb in aircraft. Disproved after seventeen months of attempts to confirm by FBI.

The deaths are respectively 329, 270, 9, and 230 for a total of eight hundred thirty eight fatalities. That's a mass killing in four events over eleven years and thousands of miles apart involving the governments of four countries. (And it can happen again and it may have with China Airlines Flight 611 in 2003 but more evidence is needed to rule out or rule in so that early model Boeing 747 inflight breakup is not considered in this report.)

And the four victims are virtually identical. They are early model Boeing 747s. There are tens of thousand of airliners out there in hundreds of model and submodels but there are currently about five hundred Boeing 747-100 and 747-200 aircraft still in service of which only four have the below similar evidence after inflight breakups.

The similarities in the circumstances and of the wreckage of those events are many: larger version at http://www.montereypeninsulaairport.com/

How can it be that the court systems of two countries had partial failure and partial success in determining who did what?

That's where you gentlemen come in. You are the defence. You are the professionals who represent the mature society's belief that it could make mistakes and therefore offers an opportunity to present alternative explanations and alternative culprits.

That opportunity has not been realized in the past. For the record: In the several trials in two countries against several men accused of being involved in the killing of 838 men women and children, the defence has never said, "It was not gunshots that killed the four brothers". The defence never claimed it was a heart attack, just that their clients never pulled the trigger of the guns.

Enough of the analogy already...

Defence Strategy:

The defence for Inderjit Singh Reyat, Ripudaman Singh Malik, Ajaib Singh Bagri, Abdelbaset Ali Mohmed al-Megrahi, Al-Amin Khalifa Fhimah, never once said that Air India Flight 182 or Pan Am Flight 103 was not brought down by bombs but by something else. The defence essentially stipulated to the cause of the crashes as bombs and quibbled over a few feet of where it was in the aircraft and challenged the Crown to prove who planted the bombs.

And the defence followed that strategy all the while knowing (assuming they did their homework) that the actual government experts in aviation crash investigations were saying they did not know the cause, or the cause was an explosive decompression and that one UK crash expert even refuted the bomb cause. The defence knew that similar type aircraft had similar type fatal accidents in 1989 and 1996 and the cause was electrical, not a bomb explosion. The defence uncritically believed the police story and that of the Crown prosecutors, the media, the public, and the anguished victim's families, while ignoring the one group who knew what they were talking about, the Canadian Aviation Safety Board investigators, the UK Air Accidents Investigation Board investigators, the National Transportation Safety Board investigators, and the Indian accident investigators.

The defence was caught up in the hateful revenge seeking hysteria of the moment which was kept hot by those that wanted to believe it for their own self interest motives. Everybody loves the bomb explanation except for a few and we know who they are, they are the clients you represent or have represented. The accused probably believe the crashes were caused by bomb explosion but they know and I know they had nothing to do with those tragic events.

For Air India Flight 182 the location of the explosion was in the forward cargo compartment for fifteen years. That conclusion is amply supported by hard wreckage evidence and yet on the day of the trial the location switched to the aft bulk cargo compartment, a location conclusively ruled out by earlier investigators. The defence never disputed the move of the explosion from forward to aft compartments.

For Pan Am Flight 103 the AAIB investigator of the wreckage observed that the cause of the soot in the container alleged to have held a powerful, spherical and loud bomb was actually: "Where these panels formed the boundary of the shatter zone, the metal in the immediate locality was ragged, heavily distorted, and the inner surfaces were pitted and sooted - rather as if a very large shotgun had been fired at the inner surface of the fuselage at close range." The defence never objected to the premise of a bomb explosion which was shown by evidence to be mild, directed, and silent, three physical impossibilities for a bomb but natural for a 'very large shotgun' in the luggage which was safe unless a huge explosive decompression were to occur nearby were a cargo door to rupture open inflight.

Emotion trumped science. Wishful thinking ruled the day. Pleasant explanations based on grief salving emotions were believed while unpleasant explanations supported by hard evidence that could be touched, seen, and listened to was rejected without consideration.

Esteemed attorneys, barristers, solicitors, members of the bar, I'm sure you have heard of the saying, "The best defense is a strong offense." Well, now is the time to go on the offense, become offensive, risk scorn, accept ridicule, take charge and present to the world at large and the courts in specific the reality scientific explanation for those airplane crashes to counter the conspiracy nonsense with its Mr. Xs and bombs flying around the world in multiple aircraft sometimes detonating and sometimes not.

I'm asking that you consider the hard evidence that supports the science explanation for the aircraft crashes your clients are accused of being involved in. They are innocent, they did not do it because nobody did it. It was a mechanical problem, a problem which still exists which involves my interest in aviation safety. I wish to have the hazards of faulty wiring and non plug cargo doors removed and repaired.

More Discussion and Quotes:

Speaking legally as an amateur, I understand there are several types of evidence possible; circumstantial, indirect, hearsay, and direct. All can be very persuasive. The best evidence is direct evidence. For Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and TWA Flight 800 there is only once source of direct evidence and much of circumstantial such as altitude and time of day and indirect such as wreckage debris pattern and twisted metal. Hearsay is for the conspiracy guys.

The one source for the best evidence which is direct and irrefutable is the cockpit voice recorder and the flight data recorder. They were there. Those recorders were put there to do precisely what they did, record for later evaluation events which took place in the cockpit and in the aircraft at large. They tell us directly what went on in the final minutes.

And what does the best and indisputable direct evidence show as to what the cause of Air India Flight 182 and Pan Am Flight 103 and two others?

Chart 12 above from NTSB public docket for TWA Flight 800 showing the sudden loud sound from the CVRs in graphical format. Air India is Air India Flight 182, PanAm is Pan Am Flight 103, and United is United Airlines Flight 811. (Philippine Air was a Boeing 737 that had a fuel tank explode on the ground and not a Boeing 747 exploding in the air as the others.)

The graph shows a sudden loud sound followed by an abrupt power cut to the flight data recorders, a rare event separately, and extremely rare to have both together.

The sudden loud sound was analyzed very carefully by the government analysts for frequency, duration, limiting, and rise and fall time.

The conclusion reached by all the analysts in the UK, USA, Canada and India is that the sudden loud sound is not a bomb explosion sound, nor a missile exploding sound, but that of an explosive decompression sound. The bomb sound was ruled out because necessary low frequencies were not present and the rise time was too slow. There was no bomb sound in the cockpit at the initial event time for Air India Flight 182, Pan Am Flight 103, United Airlines Flight 811, and TWA Flight 800.

If not a bomb sound, then what was the cause of the sudden loud sound?

Air India Flight 182
"Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K. 3.4.6.16 In conclusion, Mr. Davis reported as follows :- "It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182. There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified. It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

2.10.2 Analysis by Accidents Investigation Branch (AIB), United Kingdom
The AIB analysis was restricted to the CVR and the Shannon ATC tape. An analysis of the CVR audio found no significant very low frequency content which would be expected from the

sound created by the detonation of a high explosive device. A comparison with CVRs recording an explosive decompression* on a DC-10, a bomb in the cargo hold of a B737, and a gun shot on the flight deck of a B737 was made. Considering the different acoustic characteristics between a DC-10 and a B747, the AIB analysis indicates that there were distinct similarities between the sound of the explosive decompression on the DC-10 and the sound recorded on the AI 182 CVR. *Explosive decompression is an aviation term used to mean a sudden and rapid loss of cabin pressurization.

(Gentlemen, note the DC-10 explosive decompression above referenced in the Air India Flight 182 CVR analysis was probably the Turkish Airlines DC-10 fatal event when the aft cargo door blew open causing an explosive decompression which destroyed the flight controls leading to the crash.)

Pan Am Flight 103
"It is not clear if the sound at the end of the recording is the result of the explosion or is from the break-up of the aircraft structure. The short period between the beginning of the event and the loss of electrical power suggests that the latter is more likely to be the case."

United Airlines Flight 811
"The Safety Board believes that the approximate 1.5 to 2.0 seconds between the first sound (a thump) and the second very loud noise recorded on the CVR at the time of the door separation was probably the time difference between the initial failure of the latches at the bottom of the door, and the subsequent separation of the door, explosive decompression, and destruction of the cabin floor and fuselage structure. The door did not fail and separate instantaneously; rather, it first opened at the

bottom and then flew open violently. As the door separated, it tore away the hinge and surrounding structure as the pressure in the cabin forced the floor beams downward in the area of the door to equalize with the loss of pressure in the cargo compartment."

TWA Flight 800
"The TWA flight 800 CVR recorded noise characteristics that were most similar to those recorded by the CVRs on board the United flight 811 and Philippine Airlines airplanes."

Summary:

The Pan Am Flight 103 sudden loud sound is 'more likely' to be the case for the break-up of the aircraft structure, not a bomb sound.

The United Airlines Flight 811 sudden loud sound is indisputably and irrefutably the explosive decompression sound when the forward cargo door burst open because that aircraft barely landed at Honolulu.

The TWA Flight 800 sudden loud sound is most similar to United Airlines Flight 811 as that both were early model Boeing 747s.

United Airlines Flight 811 is the model that fits the other three, it is the victim of the killer wiring that was able to make it back to Honolulu to point to the culprit, the electrical system of wiring or a switch. Just as it was only after United Airlines Flight 811 that the cause of the sound on Air India Flight 182 was identified, it was only after TWA Flight 800 that the true extent of the pervasive and dangerous Poly X wiring in all early model Boeing 747s was made known. To put it another way: If United Airlines Flight 811 had been caused by a bomb explosion, all causes would be bombs, if United Airlines Flight 811 were a missile attack, all four events would be missile attacks, but the cause was electrical thus all were electrical.

(United Airlines Flight 811 is the case law analogy; it was a similar case that was tried and proven beyond doubt to be a certain cause and that cause may be applied to other similar cases.)

The best evidence for these similar events in similar aircraft is the direct evidence which is the cockpit voice recorder which recorded the sudden loud sound which when analyzed indicated an explosive decompression from a ruptured open forward cargo door and not a bomb explosion sound. That's science, that's real, that's confirmable, and it's corroborated by government sound analysts.

Human Nature Conjecture:

Why has the shorted wiring/unlatch motor on/ruptured open forward cargo door/explosive decompression/inflight breakup explanation for Air India Flight 182, Pan Am Flight 103, and TWA Flight 800 not been advanced before in the public's mind?

I would hope I would not but I might very well have reacted as others have if my job, my reputation, my income, and my freedom depended upon the bomb explosion explanation being the accepted one and the wiring/cargo door explanation rejected. There is no conspiracy, just people acting in their own perceived best interests. What are they?

1. The manufacturer wants the blame for the loss of the aircraft and life to be placed upon factors out its control and not on its design errors of non plug cargo doors and absent locking sectors in the midspan latches. The manufacturer does not want to have to spend millions to correct the manufacturing faults in the wiring nor modify the cargo doors.
2. The airline wants the blame placed on others such as airport screening personnel and not on itself for not finding the frayed wires to the cargo door unlatch motor. The aircrews want to believe the event was a rare occurrence and do not want to believe that every minute they fly in early model Boeing 747s the aircraft can come apart in flight in seconds when the cargo door blows open as it did in United Airlines Flight 811.
3. The police, the RCMP, the FBI, Scotland Yard and prosecutors all welcome the inclusion of the high profile catastrophes into their jurisdiction so they can solve the crime and increase their budgets and staff to counter the threats. They would reject the mechanical cause as their general involvement would end.
4. The court system welcomes the chance to establish justice by punishing the criminals asserted by the law enforcement agencies. Vast amounts of bailiffs, new court facilities, numerous attorneys, and much tax money goes into trials while a mechanical cause is relegated to settlement meetings between insurance attorneys.
5. The victims' families have turned their grief to anger to hate and want someone to vent their emotion of revenge against. They would prefer to believe their loved ones died in some vast international conspiracy which is part of a worldwide larger force instead of a trivial event such as bare wire shorting to metal and turning on a motor which is supposed to remain off while in flight.
6. The media such as TV, radio, and newspapers much prefer an

emotional human tragedy interesting story to tell rather than a scientific story which requires education into basic laws of nature such as gravity, lift, thrust, drag, and pressure differential. Emotional stories require feelings which everyone has while science stories require education which is absent in many viewers, listeners, and readers. The media tells people what they want to hear and that is exciting, illogical, conspiracy stories, not boring mechanical proofs.

7. The government oversight agencies want to shift the blame of the crashes to foreign terrorists slipping through lax airport security and not their own failures as regulators and monitors of safety issues. The wiring/cargo door explanation reveals their failure to order the airlines and manufacturer to fix the documented problem of faulty wiring causing cargo doors to open in early model Boeing 747s such as Pan Am Flight 125 in 1987, United airlines preflight in 1991, and United Airlines Flight 811 in 1989.

8. The public demands revenge for a great loss of human life which was preventable. Dying in a bombed airplane crash offends two basic instincts of all humans at birth, a startle reflex shown by arms stretched wide and the falling reflex shown by grasping hands. The public pays money to hear what it wants and rejects that which is unpleasant. The bombing explanation reinforces their prejudices of xenophobia and racism; it implies the event was a one off affair and not likely to reappear if only security were tighter. The bombing story gives an opportunity for revenge; it gives an exciting tale of intrigue, spying, shootouts, and chase scenes. The wiring/cargo door explanation is dry, has lots of charts and statistics, and implies the faulty wiring and dangerous non plug cargo doors are industry wide, not fixed, and the problems could reappear the next time they fly as a passenger.

I say again, there are no conspiracies among the principals, only people acting in their own perceived best interests which is essentially, "It's not my fault, nor my company's fault, nor my government's, nor the police, nor the airline, nor the media, nor the courts' fault; it's the fault of those revenge seeking turbaned terrorists over there."

And to support that blame shifting exculpatory bomb explosion explanation, vast illogical and science defying fantasies had to be devised and repeated until the myth of the Lockerbie bombing and the bombing of Air India Flight 182 was implanted into the public psyche. Debunking will be very difficult as myths are generated and believed by a people needing them.

However......zealots defeat their cause eventually. Conspiracy guys are zealots. The continued controversies with Air India Flight 182 and Pan Am Flight 103 are evidence that something is not right and thus the trials, the appeals, the inquiries continue.

Summing Up:

This is your opportunity, gentlemen of the law and the defence. You have been given the power to present the other side of the criminal prosecutions. You have authority to request certain documents and interview certain people. You have the responsibility to prevent innocent men from being punished unfairly.

You can:
1. Request all reports on the Narita explosion from RCMP and the Japanese police.
2. Request all reports on the staged Boeing 747 bomb explosion at Bruntingthorpe from Scotland Yard and AAIB.

3. Request all copies of the film and photographs of the wreckage of Air India Flight 182 and Pan Am Flight 103 now held by law enforcement and withheld from the public.
4. Request updated supplements from TSB and AAIB to the CASB AOR for Air India Flight 182 and the AAIB AAR for Pan Am Flight 103 based upon the twenty and sixteen year age of those reports and the subsequent similar accidents of United Airlines Flight 811 and TWA Flight 800 after which much was learned why early model Boeing 747s come apart in the air. The new findings for those similar events were not bomb explosions but electrical switch or faulty Poly X wiring.
5. Conduct interviews with previous AAIB and CASB officials to have them explain why they believe Air India Flight 182 and Pan Am Flight 103 were not bomb explosions but mechanical problems, as they have officially claimed in their reports.
6. Present the wiring/cargo door explanation to the aviation media in TV, newsletters, and magazines for their evaluations for credibility or rejection by their experienced and skeptical staff.
7. Seek expert outside opinion as to the actual causes of the aircraft crashes. There are many independent aviation accident investigators, such as myself, available for counsel.
8. Review my extensive websites at http://www.montereypeninsulaairport.com and http://www.ntsb.org. I suggest you download my many pdf files to include my three aircraft accident reports for Air India Flight 182, Pan Am Flight 103, and United Airlines Flight 811 which give details and supporting documents for the wiring/cargo door explanation.

The current emphasis is on the human victims and those accused of the deaths. The actual victims are the aircraft. If a dog drowns and the fleas it carries drown also, it can be said the fleas are victims although they were just along for the ride. So it is with the passengers. If the plane had not crashed, they would not be victims. Air India Flight 182 and Pan Am Flight 103 were airplane crashes first and always; they were the anthropomorphized victims. The emphasis needs to be why the airplanes crashed first and that was not done at any of the trials nor in the media. The assumption was the cause was a bomb explosion and that assumption is wrong as proven by evidence, not emotion.

Conclusion:

There were no bombs on Air India Flight 182 nor on Pan Am Flight 103. There were no crimes and no criminals and no conspiracies. There was and is a mechanical problem which exists to this day, aging and failing Poly X wiring which exploits design errors of non plug cargo doors and omitted midspan locking sectors allowing an explosive decompression when the forward cargo door ruptures open in flight.

To know the cause of Air India Flight 182 and Pan Am Flight 103, you must know the details of United Airlines Flight 811, the model and irrefutably explained event. All of those official AARs are available at http://ntsb.org.

I appeal to you all to consider my suggested actions to confirm or rule out the wiring/cargo door mechanical explanation for the aircraft crash you are involved in. Please present my arguments to your clients for their consideration. They can be proven innocent which is a lot better than not guilty. Please communicate with each other although in different jurisdictions and time zones. Please realize you are similar in language and culture and you represent clients who are different from that culture, you are similar in being involved with similar type accident scenes with similar type vehicles under similar circumstances; you are similar in being part of a similar type British based justice system with its adversary relationships and discovery and disclosure rules for evidence. I implore you to reject conspiracy nonsense and consider a down to earth explanation with precedent.

My interest is aviation safety for millions first and justice for a few second. I believe your interests are reversed as it should be. Let us work together to accomplish both our goals.

I am available for consultations to clarify or further explain my mechanical premises for the crashes. Call, write, or email anytime.

Sometimes it's good to ask questions for which you do not already know the answers.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
1 831 241 0631 Cell
barry@johnbarrysmith.com
montereypeninsulaairport.com
safety@ntsb.org

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On May 1, 2006, an Order in Council was issued defining the terms of reference for the Commission of Inquiry into the

Investigation of the Bombing of Air India Flight 182. The Honourable John C. Major, Q.C., was appointed Commissioner under Part 1 of the Inquiries Act.

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Air India bomb maker's perjury trial set for May
Canadian Press
VANCOUVER Ñ Convicted Air India bomb-maker Inderjit Singh Reyat will go to trial next May on perjury charges.
Lawyers appeared in B.C. Supreme Court to set the date although they will return next month to confirm it before Associate Chief Justice Patrick Dohm.
Mr. Reyat was charged with perjury after his testimony in the trial of two men co-accused in the Air India case.
Ripudaman Singh Malik and Ajaib Singh Bagri were acquitted in March 2005 of murder and conspiracy charges in the 1985 bombing of Air India Flight 182 that killed 329 people.
The indictment filed against Mr. Reyat in B.C. Supreme Court lists 27 times where he allegedly misled the court during his testimony in September 2003.
Mr. Reyat is currently serving a five-year sentence for manslaughter as part of a plea agreement for the deaths of those killed after the bomb exploded aboard the plane on June 23, 1985.
He could spend a maximum of 14 years in prison if convicted of perjury.
Before that, Mr. Reyat served 10 years for a blast at Tokyo's Narita airport the same day as Flight 182.

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By STAFF

The Toronto Star, Feb. 11, 2003

"Text of the agreed statement of facts submitted in B.C. Supreme Court
when Inderjit Singh Reyat pleaded guilty Feb. 10 to 329 counts of
manslaughter in the 1985 bombing of Air India Flight 182:"

"In May and Jun. 1985, in the province of British Columbia, Mr. Reyat
acquired various materials for the purpose of aiding others in the
making of the explosive devices. Mr. Reyat was told and believed that
the explosive devices would be transported to India in order to blow up
property such as a car, a bridge or something 'heavy.' Although Mr.
Reyat acquired materials for this purpose, he did not make or arm an
explosive device, nor did he place an explosive device on an airplane,
nor does he know who did or did not do so. At no time did Mr. Reyat
intend by his actions to cause death to any person or believe that such
consequences were likely to occur. However, unbeknownst to Mr. Reyat the
items that he acquired were used by another person or persons to help
make an explosive device that, on or about Jun. 23, 1985, destroyed Air
India Flight 182, killing all 329 people on board."

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Acquitted Air India suspect wins role in public inquiry

Ripudaman Singh Malik leaves B.C. Supreme Court in Vancouver with supporters after he was found not guilty on March 16, 2005 in the bombing of Air India flight 182 in 1985.

By Jim Brown, Canadian Press
Published: Tuesday, July 25, 2006
OTTAWA - A man once a prime suspect in the Air India bombing has won the right to limited participation in a public inquiry into the tragedy.
Ripudaman Singh Malik was granted intervenor status Tuesday by former Supreme Court judge John Major, the head of the inquiry.
In a brief written ruling, Major cautioned that Malik's interventions will be limited to challenging "any evidence that directly and adversely affects his reputation."
Any submissions by Malik or his lawyers will have to be made in writing, at least to start. They will have to apply for leave if they want to go further and participate in oral statements and examination of witnesses.
Malik and Ajaib Singh Bagri were acquitted last year -- after an18-month trial -- of criminal charges stemming from the downing of Air India Flight 182 by a terrorist bomb off the coast of Ireland in 1985.
The bombing, believed to be work of Sikh extremists campaigning for a separate homeland in northern India, took the lives of 329 passengers, most of them Canadian citizens of Indian origin or descent.
It was the worst terrorist attack ever mounted from Canadian

soil, and the worst involving civil aviation anywhere in the world until the 9-11 attacks in the United States in 2001.
Malik's lawyers had argued, in a written brief last week, that their client needed legal standing at the inquiry to protect his reputation and respond to any evidence that 'may impugn his character."
They also warned that Malik may want to ask for some evidence to be heard behind closed doors "where he anticipates prejudice to his reputation or other intimate matters."
Major is required, under the inquiry's terms of reference, to hear some evidence in private if it endangers national security as defined by the federal government.
He can consider other requests to hold closed hearings, but commission counsel Mark Freiman has noted it would be unusual to do so.
Major has granted full standing at the inquiry to seven organizations and individuals, including the federal government, Air India and a number of family members who lost loved ones in the bombing.
Another nine groups and individuals, including Malik, will be permitted to play more limited roles.
Among them are a number of organizations with no direct link to the Air India tragedy, but that want to have a say on more general questions of anti-terrorist policy.
They include the Canadian Jewish Congress, B'nai Brith, the Canadian Council on American Islamic Relations and the Canadian Muslim Civil Liberties Association.
Major will examine a range of issues, including investigative turf wars between the RCMP and CSIS, airline security, better protection of witnesses in terrorist cases, and the possibility of holding high-profile trials before a three-judge panel rather than a single jurist.
Testimony is to begin in September and run through next April. A

report is due in September 2007.

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Lockerbie bomber appeal dates set
Abdelbaset Ali Mohmed al-Megrahi
Megrahi was convicted of the Lockerbie bombing in 2001
The appeal launched by Lockerbie bomber Abdelbaset Ali Mohmed al-Megrahi over his 27-year minimum prison sentence is to be heard in July, it has emerged.

An appeal by the Crown Office arguing for a longer sentence for the Libyan will also be heard at the same time.

The Crown will claim the minimum period Megrahi must serve is too lenient.

A panel of five judges will hear the case on 11 and 12 July, although it has not yet been decided whether it will take place in Edinburgh or Glasgow.

The High Court in Glasgow is closer to Greenock Prison, where Megrahi is currently being held, if he wants to be present is likely to be used for security reasons.

The Libyan was found guilty in 2001 of killing 270 people in the 1988 bombing of PanAm flight 103.

He has claimed the 27-year minimum sentence is too long, having been told at his original trial that he should serve at least 20 years.

However, the Crown will argue that the maximum punishment period that courts can impose in murder cases should be raised and with it the length of time Megrahi should remain in prison before he can apply for release on parole.

The appeals will not affect the work of the Scottish Criminal Cases Review Commission which has been studying the case for almost two years to see if there was a miscarriage of justice.
It said it would announce its decision in the summer.
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Lockerbie bomb appeal lined up for summer
JOHN ROBERTSON LAW CORRESPONDENT

THE appeal launched by the Lockerbie bomber against the length of his sentence is due to be heard this summer, it emerged yesterday.
Abdelbaset Ali Mohmed al-Megrahi's legal bid against his 27-year minimum prison sentence will be considered by a panel of five judges on 11 and 12 July, the Scottish Executive said.

At the same time, a counter-appeal by the Crown Office arguing that the sentence was unduly lenient will also be heard.

Tony Kelly, Megrahi's solicitor, questioned the fixing of the hearing. "I find it illogical, when we are still waiting to hear whether there is to be an appeal against conviction," he said.

Megrahi has had an application before the Scottish Criminal Cases Review Commission since September 2003. It investigates possible miscarriages of justice and has the power to refer a case to the Court of Criminal Appeal, even if an appeal has previously been heard and refused, as happened to Megrahi.

Mr Kelly did not know when the commission might decide on a referral, but said the process must be in its closing stages. A successful appeal against conviction would make an appeal against sentence unnecessary.

"So what is the point in holding this hearing at this stage?" asked Mr Kelly.

A court spokesman said that as an appeal against sentence had been lodged and was outstanding, it was right to press on with it. He added: "There might be a referral from the commission, but there might not be."

Megrahi was convicted in 2001 of bombing Pan Am flight 103 and killing 270 people.
A fellow Libyan, Al-Amin Khalifa Fhimah, was acquitted.

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EXECUTIVE SUMMARY

On February 24, 1989, United Airlines flight 811, a Boeing 747-122, experienced an explosive decompression as it was climbing between 22,000 and 23,000 feet after taking off from Honolulu, Hawaii, en route to Sydney, Australia with 3 flightcrew, 15 flight attendants, and 337 passengers aboard.
The airplane made a successful emergency landing at Honolulu and the occupants evacuated the airplane. Examination of the airplane revealed that the forward lower lobe cargo door had separated in flight and had caused extensive damage to the fuselage and cabin structure adjacent to the door. Nine of the passengers had been ejected from the airplane and lost at sea.
A year after the accident, the Safety Board was uncertain that the

cargo door would be located and recovered from the Pacific Ocean. The Safety Board decided to proceed with a final report based on the available evidence without the benefit of an actual examination of the door mechanism. The original report was adopted by the Safety Board on April 16, 1990, as NTSB/AAR-90/01.

Subsequently, on July 22, 1990, a search and recovery operation was begun by the U.S. Navy with the cost shared by the Safety Board, the Federal Aviation Administration, Boeing Aircraft Company, and United Airlines. The search and recovery effort was supported by Navy radar data on the separated cargo door, underwater sonar equipment, and a manned submersible vehicle. The effort was successful, and the cargo door was recovered in two pieces from the ocean floor at a depth of 14,200 feet on September 26 and October 1, 1990.

Before the recovery of the cargo door, the Safety Board believed that the door locking mechanisms had sustained damage in service prior to the accident flight to the extent that the door could have been closed and appeared to have been locked, when in fact the door was not fully latched. This belief was expressed in the report and was supported by the evidence available at the time. However, upon examination of the door, the damage to the locking mechanism did not support this hypothesis. Rather, the evidence indicated that the latch cams had been backdriven from the closed position into a nearly open position after the door had been closed and locked. The latch cams had been driven into the lock sectors that deformed so that they failed to prevent the back-driving.

Thus, as a result of the recovery and examination of the cargo door, the Safety Board's original analysis and probable cause have been modified. This report incorporates these changes and supersedes NTSB/AAR-90/01.

The issues in this investigation centered around the design and

certification of the B-747 cargo doors, the operation and maintenance to assure the continuing airworthiness of the doors, cabin safety, and emergency response.
The National Transportation Safety Board determines that the probable cause of this accident was the sudden opening of the forward lower lobe cargo door in flight and the subsequent explosive decompression. The door opening was attributed to a faulty switch or wiring in the door control system which permitted electrical actuation of the door latches toward the unlatched position after initial door closure and before takeoff. Contributing to the cause of the accident was a deficiency in the design of the cargo door locking mechanisms, which made them susceptible to deformation, allowing the door to become unlatched after being properly latched and locked. Also contributing to the accident was a lack of timely corrective actions by Boeing and the FAA following a 1987 cargo door opening incident on a Pan Am B-747.
As a result of this investigation, the Safety Board issued safety recommendations concerning cargo doors and other nonplug doors on pressurized transport category airplanes, cabin safety, and emergency response.

From: John Barry Smith <barry@johnbarrysmith.com>
Date: September 5, 2009 11:46:50 PM PDT
To: Brent Olthuis <bolthuis@arvayfinlay.com>
Cc: "Murray L. Smith" <msmith@smithbarristers.com>
Subject: **RE: Air India Flight 182 mechanical probable cause.**

Messrs. Murray L. Smith and Brent B. Olthuis
Smith Barristers,
Suite 1300 - 355 Burrard Street,
Vancouver, BC, V6C 2G8

Dear Mr. Olthuis and Mr. Smith, Thursday, October 5, 2006

Thank you Mr. Olthuis for your prompt and polite reply to my email regarding the shorted wiring/unlatch motor on/ruptured open forward cargo door/explosive decompression/inflight breakup explanation for Air India Flight 182.

I would have hoped I would have become inured to polite brushoffs after having received so many over the years by the conspiracy believing good folk out there, but no, it still rankles somewhat. But...a polite brushoff is better than no brushoff.

If I had emailed you stating the cause of Air India Flight 182 was a midair with a Pluto flying saucer by revenge seeking Plutonians mad because we demoted their planet I think your response would have been the same; to paraphrase:

"Here, Mr. Malik, look at this email, this is good for a chuckle, and Mr. Smith, there is nothing we can do at this stage as judges and newspapers said it was a bomb, and our client can't do much talking anyway, and your flying saucer story does not help our client so we can't use it. But..thanks anyway for a juicy story, it could be true!"

The only difference between my science based wiring cargo door email and the nonsense crazy conspiracy story is you would have asked questions about the flying saucer such as, what color was it, how fast was it going, and was there a money trail between the Iranians and the Plutonians?

The science explanation with supporting documentation gets nary a query.

Surprise me please by saying you read the pdf file I sent about my submissions to the Commission of Inquiry into the Bombing of Air India Flight 182. Perused it? Scanned? Glanced. http://www.ntsb.org and http://wwwmontereypeninsulaairport.com are two good websites with pictures, text, and diagrams to assist the visitor.

Surprise me please by saying you sent that pdf file to Mr. Malik. Sikhs revere writing and respect the thoughts when well written. The Sikh holy temples do not house bones, teeth, or weapons but books. My SmithAAR for Air India Flight 182 is thicker than most books and better documented. I have attached to this email my Smith AAR182. It's full of technical stuff since, after all, Air India Flight 182 was an airplane crash, first and always. Mr. Malik will understand both documents I'm sure.

I wrote to Mr. Malik while he was in prison awaiting trial. I met Mrs. Malik, a lovely lady. We chatted for an hour in the Malik's office in Vancouver. I met their sons, we went to a Vancouver hockey game, I had dinner at their house and met their families. There are only two people on the planet that know for certain that Mr. Malik had nothing to do with Air India Flight 182, me and him. Mr. Malik believe it was a bomb but he knows he did not plant it. I know he did not plant anything because nobody did. It was a mechanical problem, and has happened since with United Airlines Flight 811. Associating with suspected airplane terrorists was a little scary for me but it had to be done for the sake of aviation safety and justice.

Let Mr. Malik read my submissions to the Commission he has applied to appear before and then either have him suggest you followup on the mechanical explanation with me or let him direct you to tell me he is not interested.

My key point of persuasion is that saying at the hearing he is a good family man and a judge said he is not guilty will not restore his reputation nor that of his religion. The only way he can do that is to either show up with two confessed non-Sikh terrorists with videotape of them making the bombs and putting them in the planes or to be proven innocent which is a lot different than not guilty. He can be proven innocent and thus exonerated by the wiring/cargo explanation because it clears everybody, nobody did it. Mr. Malik and the Sikhs would be vindicated by exoneration through science not convicted by myth.

Mr. Olthuis, let me go over your reply for specifics:

At 8:47 AM -0700 10/5/06, Brent Olthuis wrote:
Mr. Smith:

Thank you for your correspondence, which we have brought to the attention of our client.

Thank you, I'm sure he will be interested, especially in the fourteen submissions in the pdf file which lay out the wiring/cargo door case for Air India Flight 182 and debunk the bomb explanation.

We write to let you know that we are unable to do anything at this stage with the information you provide.

Ah. A scientific explanation with documentation that vindicates your client, fulfills your goal of restoring his reputation and ....nothing can be done? Not even a question or two? The good thing about science is that premises and allegations can be substantiated or refuted, unlike crazy conspiracy nonsense that relies on emotional conversations from years ago. Everything I say about Air India Flight 182 can be corroborated.

Let me help you go through the mental reactions to the no bomb explanation for Air India Flight 182 after twenty one years of hearing about the bomb explanation week after week:

No Bomb!

1. No.
2. You are wrong.
3. You are crazy.
4. Go away.
5. I'm ignoring you.
6. Attack.
7. Ask a real question to check it out.
8. Take action on new knowledge acquired.

You implied number one, were polite and did not state numbers two and three, hoping for number four with your email, and considering number five after reading this email which may provoke number six. I invite number seven. Number eight stands not within the prospect of belief.

First, the mandate of the Commission in our opinion does not extend into a questioning of the prevailing theory that a bomb brought down the plane.

Not true. Well, in your opinion it is true. In my opinion the mandate does extend. Shall we duel with mandates and quotes? In my submissions I refute Commissioner Major's premise that a Commission of Inquiry about a plane crash can not inquire about that plane crash.

Let me quote Prime Minister Harper and Commissioner Major:

Speech excerpts - Prime Minister Harper announces inquiry into Air India bombing:
"A full public inquiry is required. This inquiry will be launched immediately and led by an outstanding Canadian, retired Supreme Court Justice John Major. He has agreed to serve as Commissioner for this inquiry and I have every confidence that he will conduct a thorough and compassionate investigation into the events surrounding this tragedy. This inquiry is about analyzing the evidence that has come to light since 1985 and applying it to the world we live in today."
The Prime Minister desires a full, thorough, and compassionate public inquiry into the events surrounding Air India Flight 182 by analyzing the evidence that has come to light since 1985.
Commissioner Major, from transcript of 18 July 2006, Hearing on Standing: The Commissioner: "Yes. Well, I will confirm that. The nature of this Commission was to be very broad in the evidence that it heard, in order to put to rest the various theories, rumours and neglect that have occurred since the explosion in 1985."

For the record: There has never been any official refutation of the bomb explanation in any of the trials of those accused of participating in it. The bomb explanation has been stipulated by the defence. The Crown has never had to defend the allegation that it was not a bomb, just where it was and who put it there.

To review:
1. The CASB was correct, there was an explosion and they did not yet understand the cause because the answer only became apparent four years later with United Airlines Flight 811.

2. Justice Josephson was correct, the two accused did not put a bomb on board, nobody did.
3. There were no lapses in security that led to Air India Flight 182's bombing that need to be rectified because there was no bombing.
4. The Mounties did not get their man because there were no men to get.
5. There will be closure for the families when they can clearly understand through science what happened and why.
6. A divisive issue of anger, hate, and revenge will be removed from the Canadian psyche.
7. This Commission of Inquiry can examine and put to rest the various theories, rumours and neglect that have occurred since the explosion in 1985 if it is very broad in the evidence it hears.

Indeed, this is probably the reason that your standing application turned out as it did.

Hmmmm....I was denied standing and yet B'nai Brith, Canada Canadian Civil Liberties Association (CCLA), Canadian Coalition Against Terror (C-CAT), Canadian Council on American Islamic Relations, Canadian Muslim Civil Liberties Association (CMCLA), Canadian Coalition for Democracies, and the Canadian Jewish Congress were granted standing, where is the logic in that?

In addition I was personally involved in a strict reading of the mandate in the Term of Reference:

I was personally investigated by the RCMP Air India Task Force during their investigation of the bombing of Air India Flight 182. I was personally questioned by the TSB about the events surrounding the bombing of Air India Flight 182. I received erroneous information from Securitas of the TSB. The two agencies did not cooperate based upon the information I gave them. Details in Smith Submission 8: Specific Term of Reference: Non Cooperation.

To sum up regarding the term of reference of non cooperation that I am personally involved in which justifies my request for grant of standing: There was noncooperation between TSB Air and the RCMP AITF regarding relevant and important visual evidence in the form of videotapes and 35 MM color film of the wreckage of Air India Flight 182. The Canadian air accident investigating board was denied visual evidence of an airplane crash by the police authorities who claimed an exemption to law to justify the denial.

Further, as you may be aware, Commissioner Major gave our client only a limited standing before the Commission: Mr. Malik has the status of an intervener, and even then has only the ability to respond (in writing) to evidence that directly and adversely affects his reputation.

Jackpot! Every time there is a reference to a 'bombing', which is every fifteen minutes, the reputation of Mr. Malik is impugned because the belief in Canada is strong that he was the bomber and the only reason he is free is because of bungling by the RCMP and CSIS, so much so that a special Commission of Inquiry was created to explain the bungling that let two callous mad killers go free. Every time some witness mentions 'bomb', object and ask how does he know it was a bomb? Is he an expert in aircraft accident investigations such as the Canadian Aviation Safety Board investigators who did not conclude it was a bomb?

Aviation Occurrence Report of the Canadian Aviation Safety Board for Air India Flight 182 of January 22, 1986
"4.0 CONCLUSIONS
The Canadian Aviation Safety Board respectfully submits as follows:
4.1 Cause-Related Findings
1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion."

The witnesses may refer to the 'explosion' in Air India Flight 182 that brought the aircraft down, that is correct. To give the cause of the explosion as a bomb is unsubstantiated by the witness and the Crown experts. The bomb explanation is even refuted by hard evidence of the cockpit voice recorder, the only direct evidence available:

"Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K. 3.4.6.16 In conclusion, Mr. Davis reported as follows :- "It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182. There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified. It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

Any witness who claims a bombing of Air India Flight 182 is presuming to know more than the Crown and UK experts in aircraft accidents. Any judge, police, or attorney who says it was a bomb incorrectly presumes that also.

As your information does not directly touch on Mr. MalikÕs reputation and does not do so adversely,

What does that mean? My information does directly touch on Mr. Malik's reputation, it proves his innocence, it exonerates him, it vindicates him, it restores him and his religion to its former stature.

What does "...does not do so adversely,..." mean? My information does not adversely affect Mr. Malik's reputation? Well, I should say so, we agree.

we are not in a position to use or refer to it.

Ah, the polite stage four, go away.

That said, we thank you again for your assistance.

What assistance?

Here's the thing, Mr. Olthuis, until you can show me you understand the basic foundations of the wiring/cargo door explanation by asking a few questions, I will assume your mind is closed and holds tight the bombing explanation. That's not proper for an attorney at the start of a year long case. I have shown you by a few quotes that the bombing explanation and your excluding mandate of the Commission are disputed or in error. That is proper for this independent aviation accident investigator.

I will let Mr. Malik decide whether my logic and reasoning make sense. He pays the piper (you, not me); he gets to call the tune. Please show him this email, my SmithAAR182.pdf, and my Smithsubmission1-14 to the Commission of Inquiry.

If he tells me to go away, I will. If he indicates he would like to pursue the wiring/cargo door explanation, then we will. The telling clue to his direction will be if he starts to ask questions.

Thanks again, really, for your prompt and polite reply; I've tried to respond to it with a little humor, some history, a few facts, and lots of disguised pleading.

(Might you or Mr. Smith be pilots? Would I actually be talking with someone who knows why airplanes fly and why they don't? How sweet that would be. If you don't know why airplanes crash I can show you. I've been in one that did and lived to tell about it.)

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
1 831 241 0631 Cell
barry@johnbarrysmith.com
safety@ntsb.org

From: John Barry Smith [mailto:barry@johnbarrysmith.com]
Sent: 4-Oct-06 2:39 PM
To: Murray L. Smith; bolthuis@smithbarristers.com.
Subject: Air India Flight 182 mechanical probable cause.

Messrs. Murray L. Smith and Brent B. Olthuis
Smith Barristers,
Suite 1300 - 355 Burrard Street,
Vancouver, BC, V6C 2G8

Dear Mr. Smith and Mr. Olthuis, Wednesday, October 4, 2006

My name is John Barry Smith and I have evidence which will completely exonerate your client from suspicion and restore his reputation as well as that of his religion.

There was no bomb on Air India Flight 182, and therefore no bombers, no conspiracy, no crime, and no criminals. The cause was a mechanical systems failure, faulty wiring shorted on the forward cargo door unlatch motor which caused an explosive decompression leading to the inflight breakup.

Further details to substantiate the wiring/cargo door explanation are at http://www.ntsb.org and http://www.montereypeninsulaairport.com. The SmithAAR for Air India Flight 182 is available for download also which gives exhaustive details.

Mr. Malik previously was interested in the mechanical explanation in the early part of 2001 and I traveled to Vancouver to speak to his attorneys, Mr. Crossin and Mr. Donaldson, at Mr. Malik's request. I failed to impress. Let's hope I do better this time.

I recently went to Ottawa to try to achieve standing in front of the Commissioner of the Commission of Inquiry into the Bombing of Air India Flight 182. I was promised fifteen minutes of oral submission but was cut off after four. It appears I again failed to impress.

Well, never give up, especially since the evidence in the form of cockpit voice recorders, flight data recorders, twisted metal, and damaged engines supports a mechanical explanation over the conspiracy nonsense so emotionally tinged that up is down and inside out. In aviation matters I always defer to reality.

For the record: The only official Canadian aircraft accident investigator's opinion about the probable cause of Air India Flight 182 did not conclude it was a bomb, only an explosion. There are many potential causes for an explosion in the pressurized hull of an early model Boeing 747, the rarest of which is a bomb.

Aviation Occurrence Report of the Canadian Aviation Safety Board for Air India Flight 182 of January 22, 1986 "4.0 CONCLUSIONS The Canadian Aviation Safety Board respectfully submits as follows: 4.1 Cause-Related Findings 5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment."

The TSB (Air) has never given an official opinion.

In fact, the UK AAIB investigator ruled out a bomb in the original report: "Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K. 3.4.6.16 In conclusion, Mr. Davis reported as follows :- "It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182. There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified. It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

The cause Mr. Davis alluded to only became apparent four years later with United Airlines Flight 811, the model for the inflight breakups for early model Boeing 747s.

I have asked TSB and the Commissioner to request TSB (Air) to provide an updated supplement to the twenty year old Aviation Occurrence Report to the Commission for their consideration. That reasonable request would certainly be within your rights to ask for.

The Commissioner granted me leave to provide material to the Commission and I have done so. A pdf file of my fourteen additional submissions is attached to this email. Those submissions lay out the framework that debunks the bomb theory and substantiates the mechanical explanation.

There is an error of fact on the Commission Website which harms your client. It is the highly prejudicial error that states the CASB concluded it was a bomb; they did not. ("Yet, it was not until the following January that the Canadian Aviation Safety

Board concluded that the destruction of this aircraft was caused by a bomb.") I have repeatedly asked the Commissioner to correct the error but he has not.

In the past few months of dealing with the Canadian government about Air India Flight 182 I realize what you are up against. You have Crown prosecutors who cheat, a Commissioner who lies, a police force who is confused and creative with facts, a media who loves intrigue and danger, and family members and a public lusting for revenge. Into that stew of emotion all I ask is that you check out a lead that is down to earth, offers confirmable evidence, follows rigid rules of logic, and offers reasonable explanations for tragic events.

You might tell Mr. Malik I followed his trial and offer him congratulations on his release. I have known he was innocent since he was arrested years ago. As was Mr. Bagri.

I've also been in written communication with Mr. Donaldson but may have offended him with my unkind comments about Mr. Crossin.

Regardless, if Mr. Malik wants his reputation restored, he will have to do better than a not guilty verdict by the honest Justice Josephson. The way to do that is to resort to science, not myth.

The shorted wiring/unlatch motor on/ruptured open forward cargo door/explosive decompression/inflight breakup explanation is science.

I am available for follow up questions or to clarify aspects of the explanation.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
1 831 241 0631 Cell
barry@johnbarrysmith.com
safety@ntsb.org
Commercial pilot, instrument rated, former FAA Part 135 certificate holder.
US Navy reconnaissance navigator, RA-5C 650 hours.
US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5

From: John Barry Smith <barry@johnbarrysmith.com>
Date: September 5, 2009 11:46:50 PM PDT
To: msmith@smithbarristers.com, bolthuis@smithbarristers.com.
Subject: **Air India Flight 182 mechanical probable cause.**

Messrs. Murray L. Smith and Brent B. Olthuis
Smith Barristers,
Suite 1300 - 355 Burrard Street,

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US Navy patrol crewman, P2V-5FS 2000 hours.
Air Intelligence Officer, US Navy
Retired US Army Major MSC
Owner Mooney M-20C, 1000 hours.
Survivor of sudden night fiery fatal jet plane crash in RA-5

From: John Barry Smith <barry@johnbarrysmith.com>
Date: September 5, 2009 11:46:50 PM PDT
To: barry@johnbarrysmith.com

Unterman, David H., Barrister & Solicitor,
South Fraser Law
200 - 6330 Fraser Street
Vancouver BC V5W 3A4   Telephone: 604.321.3232

Dear Mr. Unterman, Thursday, March 22, 2007

My name is John Barry Smith. Mr. Malik is aware of my explanation for Air India Flight 182 which absolves him and his religion of any responsibility. ItÕs called the shorted wiring/unlatch motor on/ruptured open forward cargo door/explosive decompression/inflight breakup explanation. ItÕs mechanical with precedent and relies on science for confirmation. It is not a conspiracy story with a secret Mr. X and wild shootouts.
The phrase, Òmalicious prosecutionÓ was the exact phrase I used in speaking personally with Mr. Dave Crossin and Ian Donaldson in late 2001 at the request of Mr. Malik, who paid my

expenses to Vancouver from Carmel Valley. I met his family and friends. I knew then and know now Mr. Malik is innocent because nobody put a bomb on Air India Flight 182, there was no bomb, no crime, no criminals. The cause is mechanical and has happened since with United Airlines Flight 811 in 1989.

If you want to talk about why airplanes such as a Boeing 747 crash I can explain it to you. If you want to talk about conspiracies of Sikhs or Mounties or the press to injure your client, then, well, read the newspapers. If you respect science and reason, contact me. If you like exciting stories with intrigue, revenge, and betrayal, well, keep on assuming what the RCMP and prosecutors want you to assume, bomb!

Sgt Bart Blachford of RCMP Air India Task Force and Mr. Bill Tucker (now retired) of TSB (Air) have visited me in my home to discuss the wiring/cargo door explanation. The authorities have known for years that Malik and Bagri could not have placed a bomb in Air India Flight 182 because all the bags loaded in Vancouver went into the aft cargo compartment and the explosion occurred in the forward cargo compartment.

In addition, there has never been an official Crown aviation investigation conclusion of a bomb at all. The press and the current Commission of Inquiry into the Bombing of Air India Flight 182 incorrectly state the CASB concluded it was a bomb. The Canadian Aviation Safety Board made no such bombing conclusion.

Aviation Occurrence Report of the Canadian Aviation Safety Board for Air India Flight 182 of January 22, 1986
"4.0 CONCLUSIONS
The Canadian Aviation Safety Board respectfully submits as

follows:
4.1 Cause-Related Findings
1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion."

Mr. Unterman, there was an explosion in the forward cargo compartment, a powerful explosive decompression, just like what happened four years later with a similar sudden loud sound on the CVR:
United Airlines Flight 811:

"The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.
NTSB Accident Report 92-02 Page 25
Air India Flight 182:
"From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued

for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder."
Canadian Aviation Safety Board Air India 23 June 1985, page 21

Please relay my congratulations to Mr. Malik, he got lucky and ran into a competent judge, Justice Josephson. I respect his decision for redress of grievance. I have known he was innocent since he was arrested many years ago.

More details at:
http://www.montereypeninsulaairport.com
http://www.ntsb.org

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
1 831 241 0631 Cell
barry@johnbarrysmith.com
http://www.montereypeninsulaairport.com
http://www.ntsb.org

David Unterman is a contributor to the Continuing Legal Education Society of BC professional development in family law courses for lawyers.

Recent CLE work includes:

* Advanced Family Law Issues

- Course Presenter November 13, 2003
* Family Law Advanced Issues
  - Course Materials Author
* Mastering Family Chambers for Lawyers
  - Course Presenter, May 18, 2001
* Family Law Issues
  - 2000 - Course Materials Author,
* Issues in Family Law
  - Course Presenter,

Malik says he lost reputation, savings

VANCOUVER -- He was once a wealthy and well-respected British
Columbia businessman, but after he was charged in relation to the
murder of 329 people in the bombing of Air-India Flight 182,
Ripudaman Singh Malik lost his reputation and his savings.

Now, seven years after he was charged along with Ajaib Singh Bagri,
of Kamloops, and two years after both men were acquitted on all
counts, Mr. Malik has filed a writ against the Attorneys-General of
B.C. and Canada.

In a filing in the Supreme Court of British Columbia, Mr. Malik
claims unspecified damages "for malicious prosecution, wrongful
imprisonment, breach of the Plantiff's Charter rights, Conspiracy to
Injure, negligent performance of duty and damage to the Plantiff's

reputation in connection with the Plaintiff's wrongful
prosecution."

David Unterman, Mr. Malik's lawyer and a member of the South Fraser Law Group, declined to comment yesterday.

The Globe and Mail

B.C. Attorney-General Wally Oppal, who is away from work to undergo surgery, was not available for comment, but a government spokesman said the writ would have to be studied before any response could be made.

Mr. Malik and Mr. Bagri were both arrested in October, 2000, some 15 years after the RCMP began investigating the bomb blast that downed Air-India Flight 182 off the coast of Ireland on June 23, 1985, killing all aboard.

The prosecution contended the bomb was contained in baggage that was loaded aboard the flight in Vancouver and that Mr. Malik and Mr. Bagri were key players in Canada's worst act of terrorism.

The two men were jointly charged with first-degree murder, of conspiring to commit murder and of conspiring to cause bombs to be placed onboard aircraft. They were also jointly charged with a second

count of first-degree murder in relation to the explosion of
another
bomb, in the luggage terminal at Narita airport in Japan.

Mr. Malik and Mr. Bagri were denied bail and remained in jail
until
March, 2005, when Mr. Justice Ian Bruce Josephson acquitted
them both.

"Justice is not achieved . . . if persons are convicted on anything
less than the requisite standard of proof beyond a reasonable
doubt,"
he stated.

During the lengthy trial Mr. Malik said that his savings, of
several
millions, had been exhausted and he obtained about $6-million in
funding from the Crown. The government has been trying to
recover
those funds, but Mr. Malik has pleaded poverty.
http://www.theglobeandmail.com/servlet/story/LAC.
20070321.BCAIRINDIA21/TPStory/?query=Malik

From: John Barry Smith <barry@johnbarrysmith.com>
Date: September 5, 2009 11:46:50 PM PDT
To: barry@johnbarrysmith.com
Subject: **Unterman 2**

Unterman, David H., Barrister & Solicitor,
South Fraser Law
200 - 6330 Fraser Street
Vancouver BC V5W 3A4   Telephone: 604.321.3232
Dear Mr. Unterman, Thursday, March 22, 2007

Well, as usual, after writing my previous letter I realize what I should have said...so here goes...

"Malicious" is a funny word; it's so subjective.

"Malicious from legal Encyclopedia.

Involving malice; characterized by wicked or mischievous motives or intentions.

An act done maliciously is one that is wrongful and performed willfully or intentionally, and without legal justification."

It seems to me that every acquitted person would file a malicious prosecution lawsuit if it were easy to show maliciousness.

I can show you that the prosecution of Mr. Malik was done willfully and intentionally and without legal justification. Any prosecution of anyone would have been malicious since no one brought Air India Flight 182 down and the evidence from Canadian and UK aircraft investigators supports my assertion.

The Canadian Aviation Safety Board respectfully submits as follows:
Ò4.1 Cause-Related Findings
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment.Ó
That finding from CASB is absolutely correct. It also does not conclude the destruction of the aircraft was caused by a bomb. It is specific on the location. There are several alternative explanations for that confirmed explosion, from fire in the cargo

hold or hull rupture at a door, or bomb in baggage go boom. I agree there was an explosion in the forward cargo compartment, all the experts agreed on that point in 1986 for solid reasons.

The Canadian and United Kingdom government experts in aircraft accident investigation for Air India Flight 182 did not state the cause was a bomb and in fact, the UK expert stated in 1986 it was not a bomb and gave strong evidence for his conclusion.

Mr. R.A. Davis, Head, Flight Recorder Section, Accidents Investigation Branch, Farnborough, U.K. 3.4.6.16 In conclusion, Mr. Davis reported as follows :- "It is considered that from the CVR and ATC recordings supplied for analysis, there is no evidence of a high explosive device having detonated on AI 182. There is strong evidence to suggest that a sudden explosive decompression occurred but the cause has not been identified. It must be concluded that without positive evidence of an explosive device from either the wreckage or pathological examinations, some other cause has to be established for the accident".

That 'other cause' was established by me in 1996 based on an event in 1989, UAL 811, plus other accidents. (And there is good reason why it is called an ÔexplosiveÕ decompression. It is an explosion that mimics a bomb.)
The Canadian crash experts (CASB) called Air India Flight 182 a 'crash'. It was. The word ÔbombÕ was never used in relation with Air India Flight 182 in their entire CASB report. ÒBombÓ was used only once in reference to a different aircraft and event for comparison purposes. There was no match.

Mr. Unterman, are you perchance a pilot? Might you understand why airplanes fly and why they don't? Would you understand terms such as lift, drag, thrust, PSI, TAS?

The RCMP and CSIS were chasing ghosts, that's why they could not get a conviction, not sloppy administrative work and non cooperation between agencies.

If you are going to turn over stones not yet turned over, why not turn over one that absolutely clears your client of any wrongdoing, which takes him from 'not guilty' to 'innocent', one that restores his religion to the stature it deserves and removes a blot of evil which will last centuries if not corrected?

The shorted wiring/unlatch motor on/ruptured open forward cargo door/explosive decompression/inflight breakup explanation does all that.

Mr. Malik has been given standing before the Commission of Inquiry into the Bombing of Air India Flight 182. What a great opportunity to clear his name. If you want a specific lie that the Crown has used to prejudice the case against Mr. Malik I can refer you the the Commission website in which they state a terribly biased 'fact' which is incorrect. I pointed the error out to Commissioner Major personally at the hearing in July in Ottawa, I have written to the Commission often, but they will not correct the error of fact which has persisted for eight months. That is malicious.

From Commission website: Background

'In announcing the launch of this Inquiry, the Prime Minister, the Right Honourable Stephen Harper, stated that a public inquiry is the only route left to obtaining answers to how the tragedy of June 23, 1985 occurred when Air India Flight 182 exploded over the Atlantic Ocean. The aircraft was flying at an altitude of 31,000 feet (9500 m) just south of Ireland, when all 329 on board were killed. Eighty-two of those victims were children and 280 were Canadian citizens.

Many issues remain unresolved relating back to that 1985 terrorist attack on Air India flight 182 that began in Canada but never reached its destination. In the middle of the night, more than 300 Canadians, some of Indian ancestry, lost their lives in a senseless act of unprecedented violence over the skies of Ireland. Yet, it was not until the following January that the Canadian Aviation Safety Board concluded that the destruction of this aircraft was caused by a bomb. This massive murder was the most insidious episode of cowardice and inhumanity in our history at the time, and its death toll has been surpassed only by the September 11, 2001 attacks on the World Trade Centre in New York. The Air India destruction remains among the worst aviation disasters in Canadian and world history.'

Below is excerpt in my letter to the Commission August 1, 2006 regarding a statement on the Commission website http://www.majorcomm.ca/en/index.asp:

"My first point is to repeat my observation made to the Commission in
writing and in person several weeks ago that a grievous error of fact
persists every day in the Commission's Opening Statement on the official website: June 21, 2006, Background:

"Yet, it was not until the following January that the Canadian Aviation Safety Board concluded that the destruction of this aircraft
was caused by a bomb."

Not so. Absolutely incorrect. Terribly misleading. That error leads
to a hysterical rant such as the next statement by the Commission:
"This massive murder was the most insidious episode of cowardice and
inhumanity in our history at the time,..."

The Canadian Aviation Safety Board made no such bombing conclusion.

Aviation Occurrence Report of the Canadian Aviation Safety Board for
Air India Flight 182 of January 22, 1986
"4.0 CONCLUSIONS
The Canadian Aviation Safety Board respectfully submits as follows:
4.1 Cause-Related Findings
1. At 0714 GMT, 23 June 1985, and without warning, Air India
Flight 182 was subjected to a sudden event at an altitude of 31,000
feet resulting in its crash into the sea and the death of all on board.
5. There is considerable circumstantial and other evidence to
indicate that the initial event was an explosion occurring in the
forward cargo compartment. This evidence is not conclusive. However,
the evidence does not support any other conclusion."

When an error as serious as the false statement about the Canadian
accident experts calling the explosion a bomb is allowed to

persist,
the erroneous deductions are compounded over time. The Prime Minister
even repeated the error to Parliament. There are several reasons with
precedent for an explosion in the forward cargo compartment of a
Boeing 747 with a bomb being a very unlikely cause and a mechanically
caused explosive decompression very likely. To continue to misquote
the Canadian Safety Board and call their conclusion a bombing is bewilderingly deceptive."

Mr. Unterman, on my website at www.ntsb.org is a link to a pdf file of my many submissions to the Commission of Inquiry. They will give you a overview of the entire wiring/cargo door explanation for Air India Flight 182. I would mail it but the pdf file is over a hundred pages and you have not made your email address public. In this day and age I find this mailing and stamping things quaint.

I'm hoping you do not assume something that all other criminal attorneys have assumed: Evil exists in human hearts and a tragedy such as Air India Flight 182 could only be caused by criminals...which require their services.

I would hope you are not emotional when it comes to reality but fact based. I'm hoping you respect science and not myth for truth. I know what happened to Air India Flight 182 and I can explain it to you. It's mechanical, the hazard of faulty wiring still exists in over five hundred early model Boeing 747s still in service today. My motive is aviation safety and there is danger out there still.

Below is United Airlines Flight 811. The same thing happened years earlier to Air India Flight 182. The evidence matches.

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
1 831 241 0631 Cell
barry@johnbarrysmith.com
http://www.montereypeninsulaairport.com
http://www.ntsb.org

Unterman, David H., Barrister & Solicitor,
South Fraser Law
200 - 6330 Fraser Street
Vancouver BC V5W 3A4   Telephone: 604.321.3232
Dear Mr. Unterman, Thursday, March 22, 2007

My name is John Barry Smith. Mr. Malik is aware of my explanation for Air India Flight 182 which absolves him and his religion of any responsibility. ItÕs called the shorted wiring/unlatch motor on/ruptured open forward cargo door/explosive decompression/inflight breakup explanation. ItÕs mechanical with precedent and relies on science for confirmation. It is not a conspiracy story with a secret Mr. X and wild shootouts.
The phrase, Òmalicious prosecutionÓ was the exact phrase I used in speaking personally with Mr. Dave Crossin and Ian Donaldson in late 2001 at the request of Mr. Malik, who paid my expenses to Vancouver from Carmel Valley. I met his family and friends. I knew then and know now Mr. Malik is innocent because nobody put a bomb on Air India Flight 182, there was no bomb, no crime, no criminals. The cause is mechanical and has happened since with United Airlines Flight 811 in 1989.

If you want to talk about why airplanes such as a Boeing 747 crash I can explain it to you. If you want to talk about conspiracies of Sikhs or Mounties or the press to injure your client, then, well, read the newspapers. If you respect science and reason, contact me. If you like exciting stories with intrigue, revenge, and betrayal, well, keep on assuming what the RCMP and prosecutors want you to assume, bomb!

Sgt Bart Blachford of RCMP Air India Task Force and Mr. Bill

Tucker (now retired) of TSB (Air) have visited me in my home to discuss the wiring/cargo door explanation. The authorities have known for years that Malik and Bagri could not have placed a bomb in Air India Flight 182 because all the bags loaded in Vancouver went into the aft cargo compartment and the explosion occurred in the forward cargo compartment.

In addition, there has never been an official Crown aviation investigation conclusion of a bomb at all. The press and the current Commission of Inquiry into the Bombing of Air India Flight 182 incorrectly state the CASB concluded it was a bomb. The Canadian Aviation Safety Board made no such bombing conclusion.

Aviation Occurrence Report of the Canadian Aviation Safety Board for Air India Flight 182 of January 22, 1986
"4.0 CONCLUSIONS
The Canadian Aviation Safety Board respectfully submits as follows:
4.1 Cause-Related Findings
1. At 0714 GMT, 23 June 1985, and without warning, Air India Flight 182 was subjected to a sudden event at an altitude of 31,000 feet resulting in its crash into the sea and the death of all on board.
5. There is considerable circumstantial and other evidence to indicate that the initial event was an explosion occurring in the forward cargo compartment. This evidence is not conclusive. However, the evidence does not support any other conclusion."

Mr. Unterman, there was an explosion in the forward cargo compartment, a powerful explosive decompression, just like what happened four years later with a similar sudden loud sound on the CVR:

United Airlines Flight 811:

"The CVR revealed normal communication before the decompression. At 0209:09:2 HST, a loud bang could be heard on the CVR. The loud bang was about 1.5 seconds after a "thump" was heard on the CVR for which one of the flightcrew made a comment. The electrical power to the CVR was lost for approximately 21.4 seconds following the loud bang. The CVR returned to normal operation at 0209:29 HST, and cockpit conversation continued to be recorded in a normal manner.
NTSB Accident Report 92-02 Page 25
Air India Flight 182:
"From the CVR and DFDR, AI 182 was proceeding normally en route from Montreal to London at an altitude of 31,000 feet and an indicated airspeed of 296 knots when the cockpit area microphone detected a sudden loud sound. The sound continued for about 0.6 seconds, and then almost immediately, the line from the cockpit area microphone to the cockpit voice recorder at the rear of the pressure cabin was most probably broken. This was followed by a loss of electrical power to the recorder."
Canadian Aviation Safety Board Air India 23 June 1985, page 21

Please relay my congratulations to Mr. Malik, he got lucky and ran into a competent judge, Justice Josephson. I respect his decision for redress of grievance. I have known he was innocent since he was arrested many years ago.

More details at:
http://www.montereypeninsulaairport.com
http://www.ntsb.org

Regards,

John Barry Smith
541 Country Club Drive
Carmel Valley, California 93924
1 831 659 3552
1 831 241 0631 Cell
barry@johnbarrysmith.com
http://www.montereypeninsulaairport.com
http://www.ntsb.org

David Unterman is a contributor to the Continuing Legal Education Society of BC professional development in family law courses for lawyers.

Recent CLE work includes:

* Advanced Family Law Issues
  - Course Presenter November 13, 2003
* Family Law Advanced Issues
  - Course Materials Author
* Mastering Family Chambers for Lawyers
  - Course Presenter, May 18, 2001
* Family Law Issues
  - 2000 - Course Materials Author,
* Issues in Family Law
  - Course Presenter,

Malik says he lost reputation, savings

VANCOUVER -- He was once a wealthy and well-respected British

Columbia businessman, but after he was charged in relation to the
murder of 329 people in the bombing of Air-India Flight 182, Ripudaman Singh Malik lost his reputation and his savings.

Now, seven years after he was charged along with Ajaib Singh Bagri,
of Kamloops, and two years after both men were acquitted on all counts, Mr. Malik has filed a writ against the Attorneys-General of
B.C. and Canada.

In a filing in the Supreme Court of British Columbia, Mr. Malik claims unspecified damages "for malicious prosecution, wrongful imprisonment, breach of the Plantiff's Charter rights, Conspiracy to
Injure, negligent performance of duty and damage to the Plantiff's
reputation in connection with the Plaintiff's wrongful prosecution."

David Unterman, Mr. Malik's lawyer and a member of the South Fraser
Law Group, declined to comment yesterday.

The Globe and Mail

B.C. Attorney-General Wally Oppal, who is away from work to undergo
surgery, was not available for comment, but a government spokesman
said the writ would have to be studied before any response could be made.

Mr. Malik and Mr. Bagri were both arrested in October, 2000, some 15
years after the RCMP began investigating the bomb blast that downed
Air-India Flight 182 off the coast of Ireland on June 23, 1985, killing all aboard.

The prosecution contended the bomb was contained in baggage that was
loaded aboard the flight in Vancouver and that Mr. Malik and Mr. Bagri were key players in Canada's worst act of terrorism.

The two men were jointly charged with first-degree murder, of conspiring to commit murder and of conspiring to cause bombs to be
placed onboard aircraft. They were also jointly charged with a second
count of first-degree murder in relation to the explosion of another
bomb, in the luggage terminal at Narita airport in Japan.

Mr. Malik and Mr. Bagri were denied bail and remained in jail until
March, 2005, when Mr. Justice Ian Bruce Josephson acquitted them both.

"Justice is not achieved . . . if persons are convicted on anything less than the requisite standard of proof beyond a reasonable doubt,"
he stated.

During the lengthy trial Mr. Malik said that his savings, of

several
millions, had been exhausted and he obtained about $6-million in funding from the Crown. The government has been trying to recover
those funds, but Mr. Malik has pleaded poverty.
http://www.theglobeandmail.com/servlet/story/LAC.20070321.BCAIRINDIA21/TPStory/?query=Malik

OPENING STATEMENT
June 21, 2006

1. INTRODUCTION

Today, we begin the public proceedings of The Commission of Inquiry into the Investigation of the Bombing of Air India Flight 182, which was established by Order in Council P.C. 2006-293, issued on May 1, 2006 pursuant to Part I of the Inquiries Act.

Following the Terms of Reference contained in the Order in Council, this Commission's mandate is to hold hearings, either in public or in camera, anywhere inside or outside Canada in order to provide a report on the following questions:

* The extent to which potential threats posed by Sikh terrorism prior to 1985 have been resolved, and any legislative and procedural changes that are still needed;
* The extent to which any systemic problems in the inter-agency cooperation in the investigation of the bombing of Air India Flight 182 have been resolved and any legislative and procedural changes that are still needed;
* How best to establish a reliable and workable relationship between security intelligence and evidence that can be used in a criminal trial;

* Whether Canada's existing legal framework provides adequate constraints on terrorist financing in, from or through Canada;
* Whether existing practices or legislation provide adequate protection for witnesses against intimidation in the context of terrorism cases;
* The sufficiency of our existing system to meet the unique challenges presented in prosecuting terrorism cases; and any changes that might be required, in particular the merits in having terrorism cases heard by a panel of three judges; and
* The question of whether further changes in practice or legislation are required to address the specific aviation security breaches associated with the Air India Flight 182 bombing, particularly those relating to the screening of passengers and their baggage.

This Inquiry has broad powers of subpoena, but is not a court of law. We cannot find guilt nor make any award. We are authorized to call witnesses from any place to testify before us in order to establish facts that will support conclusions and recommendations as to how the system should have or could have functioned. That will help us determine how we can assure the families who have spent more than twenty years seeking answers that the Canadian system has been or can be fixed.

The Air India tragedy or its like must never be repeated. To ensure that, we have to conduct a thorough investigation of the areas specified by the Terms of Reference established in the Order in Council. Our mandate requires answers to how the criminal investigation process in relation to terrorist activities should be conducted and how evidence is gathered and shared among authorities. It will be necessary to review airport and other transportation security measures adopted subsequent to

June 1985. We must understand how our system can uncover sources and prevent the flow of funds that have been used to finance terrorist activities. Also to be examined is the adequacy of our system to protect witnesses in terrorism cases and the merits of having terrorism cases heard by panels comprised of three judges. Some of these matters may be heard in camera for reasons of national security. I will deal with the details of procedural matters later.

Background

In announcing the launch of this Inquiry, the Prime Minister, the Right Honourable Stephen Harper, stated that a public inquiry is the only route left to obtaining answers to how the tragedy of June 23, 1985 occurred when Air India Flight 182 exploded over the Atlantic Ocean. The aircraft was flying at an altitude of 31,000 feet (9500 m) just south of Ireland, when all 329 on board were killed. Eighty-two of those victims were children and 280 were Canadian citizens.

Many issues remain unresolved relating back to that 1985 terrorist attack on Air India flight 182 that began in Canada but never reached its destination. In the middle of the night, more than 300 Canadians, some of Indian ancestry, lost their lives in a senseless act of unprecedented violence over the skies of Ireland. Yet, it was not until the following January that the Canadian Aviation Safety Board concluded that the destruction of this aircraft was caused by a bomb. This massive murder was the most insidious episode of cowardice and inhumanity in our history at the time, and its death toll has been surpassed only by the September 11, 2001 attacks on the World Trade Centre in New York. The Air India destruction remains among the worst aviation disasters in Canadian and world history.

More than 20 years have passed since this terrible tragedy, and while Canadians have not forgotten what took place, there has been a tendency to see the issues that surround this incident as a problem related to politics in India - as part of the fight for an independent Sikh homeland. This result circumvents the fact that this was and is a Canadian tragedy. Yet, after prolonged criminal investigations and public reviews both here and in other countries, the families of the victims remain in a state of limbo. Their concerns are largely unresolved and it is not yet possible for them to achieve any peace of mind with knowing what happened and why it should not happen again. Many of these citizens have expressed disappointment at the length of time taken and the results to date in the criminal justice system. But our Inquiry is not mandated to comment upon such proceedings. Nor is it appropriate to revisit the past to assess evidence while the courts continue to hear cases on these matters.

This Inquiry will not focus on dissecting the past. It will look to how we can establish parameters for the future - to help shape a system that contains sufficient safeguards to prevent tragedies from occurring. We must collect evidence that provides guidance on systemic changes to prevent terror attacks against Canadians, whether on land or sea, in airspace, or anywhere else.

To conclude only that the criminal justice system has to date failed the families of Air India victims falls short of the problem. It failed all Canadians. The system failed all Canadians. Certainly, the majority of grief and suffering was borne within the families of the victims, but all Canadians suffered a loss in June 1985. The personal losses and unspeakable tragedies are the most immediate and visible aspect of our loss. The systemic weaknesses that have been identified are less visible, but potentially as fatal, as what happened.

This Inquiry will provide recommendations to public policy and procedural questions that can continue to repair the system that allowed such horrific acts to take place. The courts have attempted, and continue to attempt, to address issues relating to criminal justice. It is hoped that this Inquiry can help to achieve justice on a broader scale.

It is not possible to undo what happened in 1985. We can, however, attempt to understand how this happened and to recommend safeguards and systemic changes to prevent future threats to our national security and intrusions into the lives of so many innocent people.

The Inquiry

The Terms of Reference for this Inquiry call for me, as Commissioner, to accept as conclusive or take into account as appropriate the findings of various other investigations into the circumstances surrounding the bombing of Air India Flight 182, including:

The report entitled Lessons to be Learned submitted November 23, 2005 by The Honourable Bob Rae;

Proceedings before the superior courts of British Columbia;

The 1991-1992 Security Intelligence Review Committee review of Canadian Security Intelligence Service activities with respect to Air India Flight 182;

The report of The Honourable Mr. Justice B. N. Kirpal of the High Court of Delhi of February 26, 1986;

The Aviation Occurrence Report of the Canadian Aviation Safety Board into the crash involving Air India Flight 182 of January 22, 1986;

The 1985 report of Blair Seaborn on Security Arrangements Affecting Airports and Airlines in Canada; and

The reports prepared by the Independent Advisory Panel assigned by the Minister of Transport to review the provisions and operation of the Canadian Air Transport Security Authority Act and to review the actions taken since 1985 to address the specific aviation security breaches associated with the Air India flight 182 bombing.

Prior to the formal initiation of this Inquiry, I met with many of those Canadians who lost loved ones in that terrorist act. Their grief, anger and bereavement were palpable. I reported my impressions to the Prime Minister.

To recognize the significance of their losses and the critical importance that this Inquiry has to them, I am pleased that many of them are present today to witness the beginning of this public Inquiry. Although it must be painful for them, I hope that they can take some comfort in the fact that the quest for truth is today renewed.

I should note that the Commission of Inquiry is independent from the Government of Canada. The only obligations upon us are to comply with the Terms of Reference, and to abide by the legal requirement to act fairly. As Commissioner, I will be guided only by the evidence, documentation and representations reviewed by me in the course of this Inquiry.

Organization

I will now tell you a bit about myself and the senior staff who will be working with me in managing the Commission's work.

I am John C. Major, and have recently retired from my position as a Justice of the Supreme Court of Canada, where I served from November 1992 to December 2005. Following my retirement from the Court, I returned to private law practice in Calgary with the firm of Bennett Jones LLP.

The management of the overall operations of this Commission will be the responsibility of Mrs. Sheila-Marie Cook, whom I have appointed to be Executive Director and Commission Secretary. Mrs. Cook has extensive experience with major public inquiries and Royal Commissions. Her reputation gives me confidence that everything will be done in a timely and effective manner to support our hearings and the eventual production of our final report.

The public hearings will be held in Ottawa. The Commission has set up premises at 222 Queen Street, and hearings will take place in the Victoria Hall of the Bytown Pavilion at 111 Sussex Drive where we are launching this Inquiry today.

The Commission's Senior Lead Counsel will be Mr. Mark J. Freiman, who is a partner in the Toronto office of McCarthy Tetrault LLP. He has extensive experience in law and public policy and is a former Deputy Attorney General in the Province of Ontario.

Michel Dorval, a senior partner in the Montreal firm of Waxman, Dorval and Associates will be the Commission's Co-Counsel. He was Crown prosecutor for the Attorney General of Quebec and the Senior Independent Chairperson for the Solicitor General of Canada (Quebec region).

Together, they will have the primary responsibility for preparing the Commission's legal and investigative activities, and will, with the assistance of others, see to the orderly presentation of evidence.

2. RULES OF PROCEDURE AND PRACTICE

The Commission proceedings will start with the voluntary testimony of the victims of the bombing of Air India Flight 182 ("Stage 1"). The balance of the Inquiry ("Stage 2") will inquire in phases into the matters set out in clauses (b)(i)-(vii) of the Terms of Reference of the Commission, PC 2006-293. Appendix II to this statement provides a tentative schedule of the Commission's proceedings.

It is important for all parties to consult and review the full Rules, which are contained in Annex A.

Section B of the Rules provides various definitions about the Commission and its operations. I would like to point out four such definitions today:

Rule B 2(f) defines "Family" as relatives of the victims of the Bombing of Air India Flight 182 or others in the discretion of the Commissioner. Rule B 2(h) defines an intervenor as a person granted status as an intervenor by the Commissioner. Rule B 2(i) defines a party as a person granted full or partial standing as a party by the Commissioner. And Rule B 2(j) defines person as an individual, group, government or agency or other entity.

Under section C of the Rules, I point out C 3, which states that the Commissioner may amend these Rules or dispense with compliance of them as he deems necessary to ensure that the Inquiry is thorough, fair and timely. And Rule C 4 states that all parties, intervenors, witnesses and their counsel shall be deemed to undertake to adhere to the Rules, and may raise any issue of non-compliance with the Commissioner.

Section D of the Rules deals with standing. Rule D 10 states that the Commissioner may grant a person full or partial standing as a party if the Commissioner is satisfied that the person is directly and/or substantially affected by the mandate of the Inquiry or portions thereof. Rule D 11 provides that a person may be granted standing as an intervenor by the Commissioner if the Commissioner is satisfied that the person represents clearly ascertainable interests and perspectives essential to the Commissioner's mandate and which the Commissioner considers to be separately represented before the Inquiry. If granted status, that intervenor may participate in a manner to be determined by the Commissioner.

Any person wishing to be granted standing must apply by a motion in writing supported by an affidavit on or before July 7, 2006, or at the discretion of the Commissioner at any other date, but such motion must include information specified in Rule D 12.

Applicants for standing will be permitted to make oral submissions not exceeding 15 minutes at a public standing hearing in Ottawa, on July 18-20, 2006 in the Bytown Pavilion, where we are meeting today, or at the discretion of the Commissioner at any other place or date.

Section F of the Rules establishes a final date of August 16, 2006 for parties who would not otherwise be able to participate to seek funding by way of a motion in writing, with supporting affidavit (s), to be filed with the Commission. At the discretion of the Commissioner another date may be allowed. Funding will be recommended at the Commissioner's discretion in accordance with paragraph (h) of the Terms of Reference. There will be no oral hearing with respect to funding.

Section H of the Rules deals with evidence brought before the Commission. Of particular importance, upon commencement of the Inquiry (Stage 1), family of the victims of the bombing of Air India Flight 182 who participate in Stage 1 of the Inquiry will not be required to give their testimony upon oath or upon affirmation and shall not be subject to cross-examination. Rule H 29 states that the Commissioner, in his discretion, may make such further Rules as he deems appropriate with respect to the conduct of Stage 1 of the Inquiry. The Rules with respect to evidence in the balance of the Inquiry (Stage 2) will not apply to Stage 1, unless specifically so ordered by the Commissioner.

Rules 30 through 63 provide important criteria for testimony in Stage 2 of the Inquiry. These Rules cover: the preparation of documentary evidence; witness interviews; witnesses; Commission Dossier (which will comprise a statement of evidence, facts or conclusions together with the sources or basis for the evidence, facts or conclusions that Commission Counsel proposes that the Commissioner adopt for purposes of the Commission's findings or conclusions with respect to that phase of Stage 2); oral examination; the use of documents at hearings; in camera proceedings for reasons of national security or personal confidentiality; and access to evidence.

Section I of the Rules deals with the Commissioner's discretion to authorize the commissioning of Consultation Papers, and/or the convening of Expert Policy Forums or Public Consultations for use in the preparation of Commission Dossiers. Section J of the Rules establishes parameters for media coverage throughout the Commission's hearings.

3. FUNDING

The Government has agreed to provide assistance, in the form of contribution payments, to ensure the appropriate participation of Families, Parties and Intervenors in accordance with the following principles and criteria, and subject to the Commissioner's recommendations:

Commission Counsel has the primary responsibility for representing the public interest at the Inquiry, including the responsibility to ensure that all interests that bear on the public interest are brought to the Commissioner's attention.

The aim of the contribution payments is to: provide Families an opportunity for appropriate participation in the Inquiry, and assist the Parties and Intervenors to the extent of their interest where, in the Commissioner's view, they would not otherwise be able to participate in the Inquiry, but is not intended to indemnify all costs.

The Terms and Conditions define "Families" as the Families of the victims of the Air India Flight 182 bombing as determined by the Commissioner. A "Party" is defined as a Recipient with a substantial and direct interest in the subject matter of the factual Inquiry; and an "Intervenor" will be a Recipient with limited participation who would attend the hearings as required for particular aspects of the Inquiry.

4. CONCLUSION

I reiterate my earlier comment that this Inquiry is neither connected to nor involved with ongoing police investigations or court proceedings. Where appropriate, however, we are empowered to seek access to relevant material resulting from such investigations or proceedings if not precluded, by law. Any such actions will be taken in such a way as not to jeopardize any of those proceedings.

I think that some words from Bob Rae's report sum up the raison d'∆tre of this Inquiry and what it must achieve:

"Let it be said clearly: the bombing of the Air India flight was the result of a conspiracy conceived, planned and executed in Canada. Most of its victims were Canadians. This is a Canadian catastrophe, whose dimension and meaning must be understood by all Canadians."

Last Modified: 21/06/2006