Space troubles

With the successful launch of PSLV C1 India has come a long way from just producing 'Sea Loving Vehicles' (SLVs).

■ G.P. Vinayababu

Space Research is an essential requirement for any developing country. India's more than humble beginning and tremendous progress later on has elevated its position as one of the leaders in space research today, on par with the developed countries.

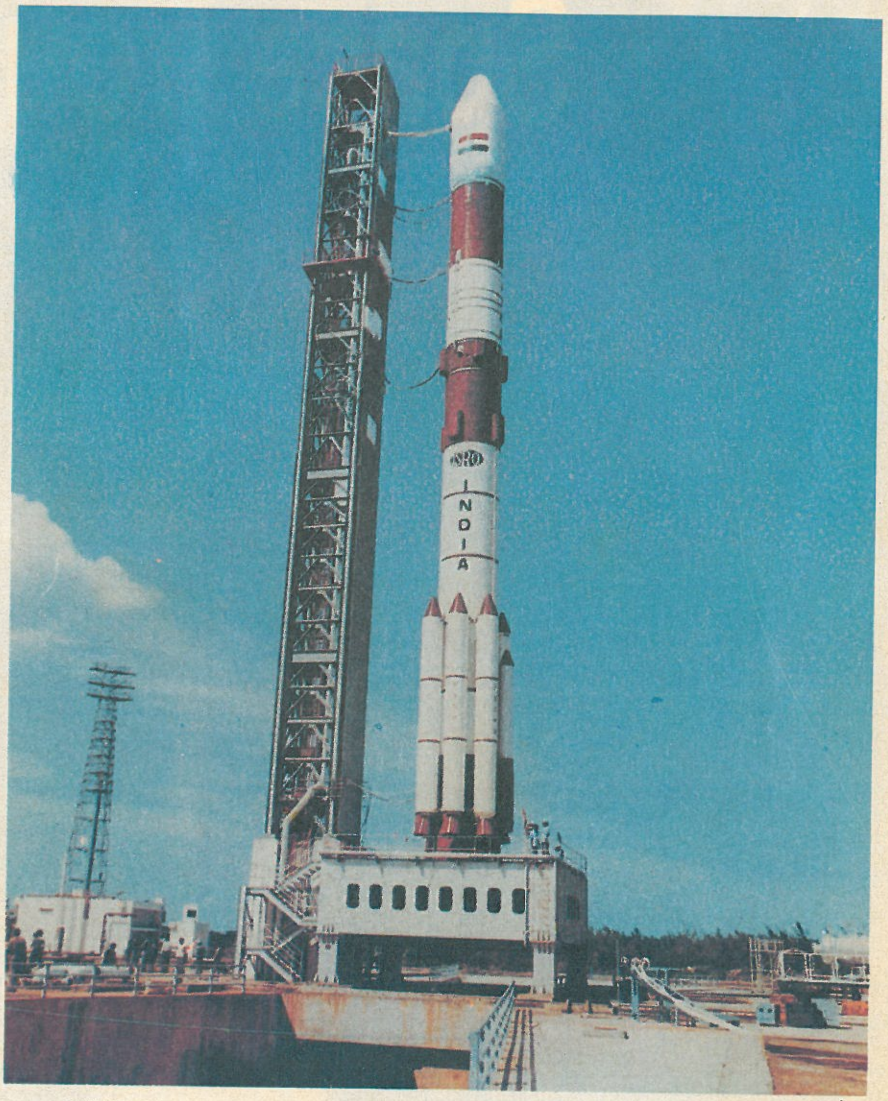
In spite of its position as a superior space power, India's ability to launch satellites into space is still suspect. Added to that, the much publicised INSAT series satellites built with huge expenditure haven't performed to the expected levels. The recent failure of INSAT-2D due to power problems has severely affected India's credibility as a satellite builder.

While Indian space scientists can take solace in blaming the minor power problems for the failure and not the technical aspects, the fact remains that the Indian communication satellites are not making commercial sense.

But one needs to understand that even the global leaders like the US aren't spared of such problems. There have been two American satellite failures in the last two months and as many as 11 satellites stopped functioning last year, some of them in their very first year of operation. Many of the ambitious satellite projects of other developed countries including Japan have simply conked off due to non-compliance with the desired performance.

The whole problem lies in the highly sophisticated field that space technology is. Years of hard work and research are put to test in a matter of few minutes. There is practically no margin for error at all.

There are two important aspects in space technology research. One, the building of satellites and two the development of rockets or launch vehicles to put these satellites into orbit.



PSLV C1 carrying IRS 1D, ready for the launch on Sept. 29, 1997

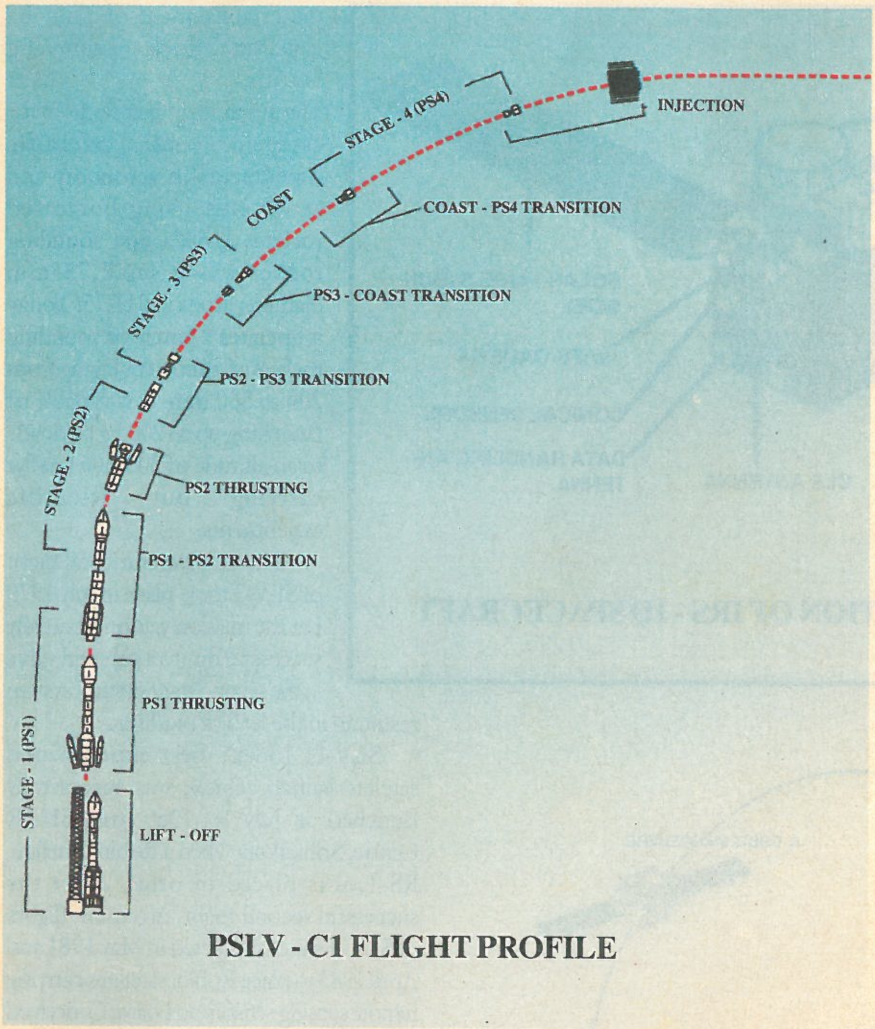
Perfect launch pad

Sriharikota island, located at 13 degree N latitude, is the launch site for ISRO rockets to take advantage of the earth's rotation and other advantages. The range is the world's second best site for launching geosynchronous satellites such as INSAT; the best being Kourou in South America which is at a latitude of 5 degree N.

The satellite can be basically of two types, remote sensing satellites and communication satellites. Remote sensing satellites are those which observe the earth from a fixed point in a geostationary orbit providing valuable inputs in the form of photographs about the physical information on a specified area of the earth's atmosphere, land and oceans. The recently launched IRS-1D (Indian Remote Sensing Satellite) is a remote sensing satellite. On the other hand, communication satellites offer sophisticated communication facilities including facilities for TV broadcast, telecommunication and global communication networks. The INSAT series of satellites are communication satellites.

The launch vehicles are as important as the satellites itself. Only a few countries in the world have the requisite technology and expertise to put satellites into proper orbit. In fact, the building of launch vehicles is a more critical activity than the satellites.

To perfect the technology of rocket building, several test flights need to be made under different load conditions. But whatever the experience during experimental launches, the actual launch of a satellite is always crucial. This is exactly the reason why launch facilities are



PSLV - C1 FLIGHT PROFILE

sometimes costlier than the building of the satellites itself. Even as India was building satellites for its own requirements, it was doing extensive research and testing on indigenous launch vehicles. Several launches with SLV-3 (200 kg with payload satellites), ASLV (113 kg with satellites) and PSLV D2 (804 kg IRS-P2) and PSLV D3 (922 kg IRS-P3) brought ISRO to a stage where it was able to launch an operational satellite into space. IRS-1D was a 1,200 kg payload remote sensing satellite. The successful launch of this satellite, with its own set of glitches however, has made India a commercial player in the space market. With a better management and quality consciousness India can offer launch vehicles to other countries, to launch 1,200 kg class satellites in future. And the development of GSLV (Geostationary Satellite Launch Vehicles) which can put 2,500 kg communication satellites into space orbits would be a major achievement for Indian space scientists.

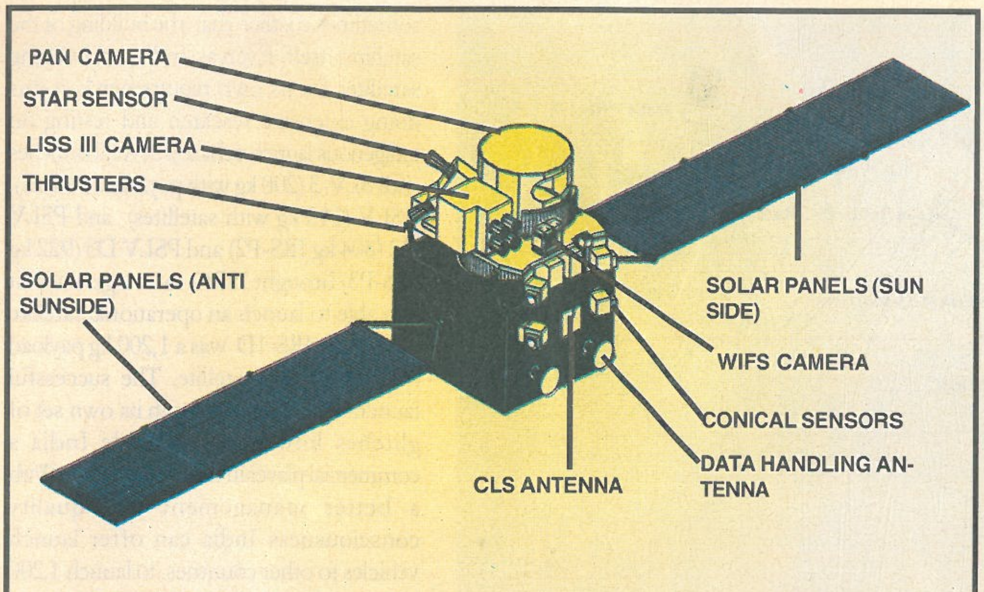
Keeping the real problem of satellite and launch failure aside, we shall concentrate on technology aspects of Launch Vehicles, Indian Remote Sensing Satellites and the history of Indian space research here.

Launch vehicle development in India

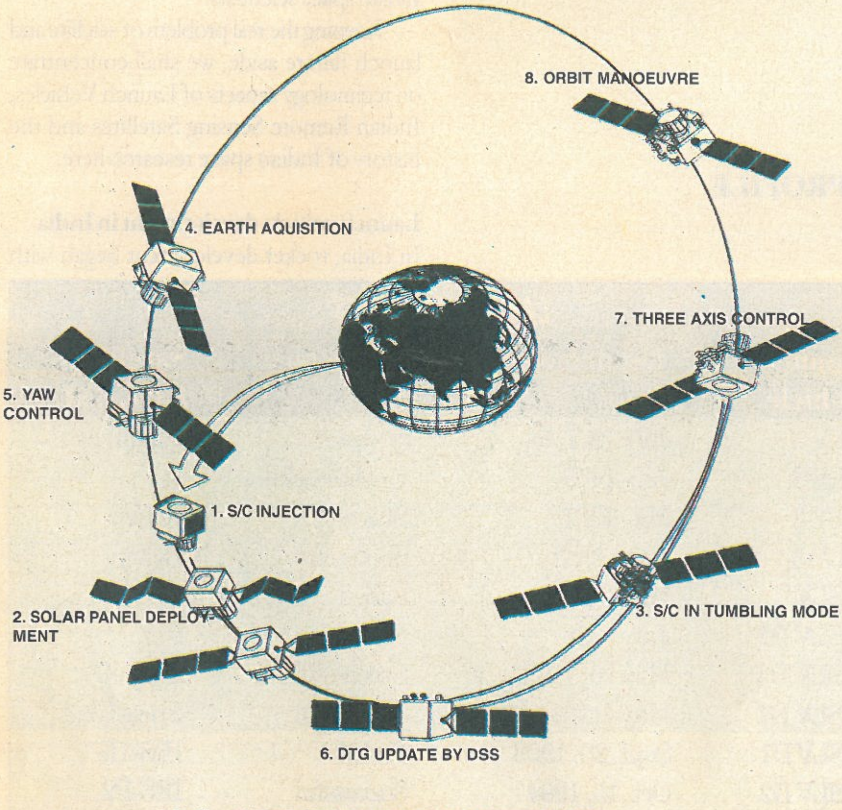
In India, rocket development began with

LAUNCH VEHICLES

Launch vehicle	Launch date	Mission	Satellite launched
SLV-3	July 18, 1980	Successful	Rohini RS-1
SLV-3	July 1979	Unsuccessful	-
SLV-3	May 1981	Successful	Rohini
SLV-3	April 1983	Successful	Rohini
ASLV	March 1987	Failed	-
ASLV D2	July 1988	Failed	-
ASLV D3	May 20, 1992	Successful	Sross-C
ASLV D4	May 4, 1994	Successful	Sross C2
PSLV D1	Sept. 20, 1993	Failed	IRS-1E
PSLV D2	Oct. 15, 1994	Successful	IRS-P2
PSLV D3	March 21, 1996	Successful	IRS-P3
PSLV C1	Sept. 29, 1997	Successful	IRS-1D
GSLV	1998-99		



DEPLOYED CONFIGURATION OF IRS - 1D SPACECRAFT



IRS - 1D MISSION SEQUENCE

the establishment of Thumba Equatorial Rocket Launching Station near Thiruvananthapuram in 1963 for carrying out scientific experiments in aeronomy and astronomy using borrowed rockets. India's first sounding rocket was a small 75 mm diameter Rohini, RH-75. Today it operates a family of sounding rockets of diameter ranging from 200 to 560 mm. It is capable of launching up to 200 kg payloads to an altitude of 300-400 km for carrying out scientific experiments.

The first experimental flight of SLV-3 took place in July 1979 but the mission was only partially successful due to a jammed valve in the second stage control system resulting in the leak of oxidiser.

SLV-3, India's first experimental satellite launch vehicle, was successfully launched on July 18, 1980 from SHAR Centre, Sriharikota when a Rohini Satellite, RS-1, was placed in orbit. After the successful second flight, two more flights of SLV-3 were conducted in May 1981 and April 1983 to place Rohini satellites carrying remote sensing sensors on board. Conceived in 1969, SLV-3 was a 22 metre long, four stage vehicle weighing 17 tonne. All stages used solid propellant. SLV-3 employed open loop guidance with stored pitch programme to steer the vehicle along a pre determined trajectory.

ASLV

SLV-3's success pushed Indian space research to new heights.

The next step in India's quest to build indigenous rockets was the development of Augmented Satellite Launch Vehicles (ASLV). It was undertaken to act as a low cost intermediate launch vehicle for demonstrating critical technologies. ASLV was configured as a five stage solid propellant vehicle, weighing about 40 tonne and having a length of about 32.8 m. The total flight time of the mission was about 500 seconds. The strap-on-stage consisted of two

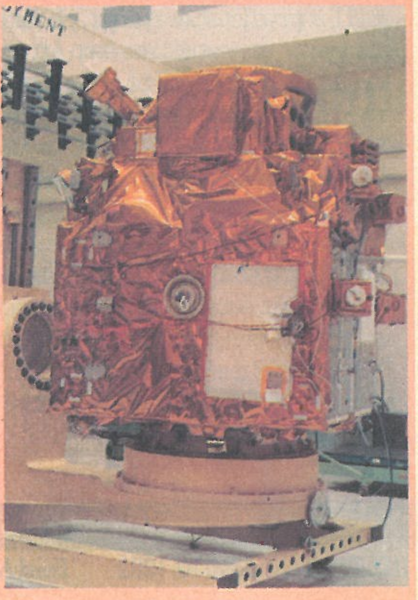
Indian remote sensing satellites

Earth observation satellites provide a vantage point and coverage necessary to look at our planet as an integrated, interactive physical and biological system. Over the past decade, India has been increasingly using remote sensing satellites to gather data about the earth's atmosphere, land and oceans.

IRS-1D will continue and further enhance the data services to users. The satellite is injected at 27 degree South (latitude) and 75 deg East (longitude) by PSLV-C1 into a polar sun-synchronous orbit of 817 km with the local time of equator crossing 1030 Hrs (descending node). After injection of the satellite into orbit, the

INDIAN REMOTE SENSING SATELLITES

Satellite	Launched on	Mission life	Mission
IRS-1A	March 1988	3 years/8years	To gather
IRS-1B	August 1991	Still in service	data about
IRS-1C	December 1995	Still in service	the earth's
IRS-1D	September 1997	Still in service	atmosphere,
IRS-P2	October 1994	Complementing data	land and
IRS-P3	March 1996	from other satellites	oceans
IRS-P4	In the		Physical & biological parameter of oceans
IRS-P5	near		Cartographic applns
IRS-P6	future		Agricultural resources survey



IRS-1D

solar panel development, sun acquisition, earth acquisition and 3-axis stabilisation tasks are carried out. A series of in-plane and out-of-plane manoeuvers are then carried out to place the satellite in the designated orbit. The payloads are switched on in the subsequent days. The initial phase operations are expected to be completed in about 30 days. IRS-1D satellite operates in a circular, sun-synchronous, near polar orbit of 817 km with an inclination of 98.69 deg in the descending node. The satellite takes 101.35 minutes to complete one revolution around the earth and thus completes about 14 orbits a day. The entire earth is covered in 341 orbits during a 24 day cycle. IRS-1C and IRS-1D will be positioned in such a way that the combined repetitivity is 12 days.

IRS-1D payloads

IRS-1D satellite carries three Imaging Sensors as follows:

Panchromatic (PAN) Camera with spatial resolution of 5.8 metre, has offnadir viewing capability to provide stereo imaging. It provides a total coverage of 70 km on ground.

Linear imaging self-scanner (LISS-III), is a multispectral camera operating in visible and near-IR spectral bands with spatial resolution of 23.5 metre and a Short Wave IR (SWIR) band with a resolution of around 70.5 metre.

Wide Field Sensor (WiFS), operating in visible and near-IR region, has a spatial resolution of 188.3 metre and a wide swath of 810 kms.

identical 1m diameter solid propellant motors similar to SLV-3 first stage, other stages being the same as in SLV-3.

The first developmental flight test of ASLV took place in March 1987 but the mission did not succeed due to non-ignition of the first stage motor after the strap-on stage burn out. And when ASLV-D2 fell into the Arabian Sea, it brought the infamous nomenclative of 'Sea Loving Vehicles' to the SLV series. After a detailed failure analysis and incorporation of all the above modifications, the third development flight, ASLV-D3, was successfully conducted on May 20, 1992 when SROSS-C satellite, carrying a Gamma-ray burst detector and an aeronomy payload was placed in the intended orbit. Another launch of ASLV (ASLV-D4) was conducted on May 4, 1994 when a 113 kg SROSS-C2 satellite was put into a low earth orbit.

PSLV Developmental flight

The first developmental launch of PSLV (PSLV-D1) on September 20, 1993 did not fulfil the mission of injecting the IRS-1E satellite into orbit. The failure of this flight

INSAT Series

Ariane Vol 97 - INSAT 2D & INMARSAT 3F4-3 June 1997

Intelsat, one of the major players in the Asian satellite market developed a total of 5 communication satellites for a requirement of just 4, obviously foreseeing a failure of at least one of its satellites. Motorola which plans to have constellation of 77 satellites in space has already launched 22 satellites, of which 3 are already lost. Telestar of Canada simply stopped functioning recently midway through its mission life.

Satellite launch and subsequent effective functioning of the satellites are still unpredictable things. No satellite developer can confidently claim the success of any satellite even after its successful launch simply because, once launched the control of the satellite is highly difficult. There is no way a satellite can be repaired in the sun synchronous orbit.

"Even INSAT 1A and INSAT 1C developed and deployed by Ford Aerospace, US failed in their mission. So, satellite failures are not uncommon and it is not India alone which is suffering such failures", says Mr. S. Krishnamurthy, Director, Public Relations Unit, ISRO.

Considering the unpredictable ways of satellites, all satellite manufacturers insure their satellites against failures. So, satellite failure does not mean a financial loss for the manufacturer as he recovers them through insurance.

ISRO is now keen on launching the next communication satellite INSAT 2E despite the failure of INSAT 2D and has plans for the launch of 5 INSAT 3 series satellite in the next 5-6 years, keen to set its record straight in satellite technology.

Satellite	Launch date	Developed by	Launch vehicle	Mission life	Reasons for failure
INSAT 1A	April 10, 1982	Ford Aerospace, USA	Delta vehicle	7-9 years	Deactivated in Sep 1982 due to propellant depletion
INSAT 1B	Aug 30, 1983	Ford Aerospace, USA	US space shuttle	7-9 years	Served for 8 years
INSAT 1 C	July 22, 1988	Ford Aerospace, USA	Ariane	7-9 years	Power anamoly- abandoned
INSAT 1D	June 1990	Ford Aerospace, USA	US Delta	7-9 years	Still in service
INSAT 2A (demo sat.)	July 1992	ISRO	Ariane	7-9 years	Still in service
INSAT 2B (demo sat.)	July 1993	ISRO	Ariane	7-9 years	Still in service
INSAT 2C	Dec. 1995	ISRO	Ariane	7-9 years	Still in service
INSAT 2D	June 4, 1997	ISRO	Ariane	7-9 years	Deactivated due to power short circuit in Oct. 1997
INSAT 2E	June-July 1998	ISRO	Ariane	7-9 years	To be launched

was primarily due to a software system error in the pitch control loop of the on-board guidance and control processor.

The second developmental flight, PSLV-D2, on October 15, 1994, was a complete success when the vehicle injected the 804 kg remote sensing satellite, IRS-P2, into the desired orbits. During the third developmental test flight, on March 21, 1996, PSLV could place a 922 kg IRS-P3 satellite, in the intended 817 km polar orbit. With these two consecutive successes, PSLV became an operational vehicle.

PSLV-C1

The Polar Satellite Launch Vehicle, PSLV C1, is the first operational launch of India. PSLV completed its development with two successful flights (in October 1994 and March 1996). The vehicle was used, for the first time, to launch an operational Indian remote sensing satellite, IRS-ID, weighing 1,200 kg, into an 817 km polar sun-synchronous orbit. The previous operational satellites of IRS series, IRS-1A, IRS-1B and IRS-1C were launched by the erstwhile USSR/Russian launch vehicles. During its two successful development

Experimental Satellites

Satellite	Launched on	Mission	Rocket
1. Aryabhata	April 19, 1975	Experimental	Intercosmos USSR
2. Bhaskara-I	June 7, 1979	Experimental	Intercosmos USSR
3. Bhaskara-II	Nov. 20, 1981	Experimental	Intercosmos USSR
4. APPLE (Ariane Passenger Payload Experiment)	June 19, 1981	Experimental	ALV (ESA)
5. Rohini-1	Kuly 18, 1980	Measure the	SLV-3
6. Rohini-2	May 1981	performance	SLV-3
7. Rohini-3	April 1983	of SLV-3	SLV-3
8. SROSS-C (Stretched Rohini Satellite Series)	May 20, 1992	- " -	ASLV
9. SROSS-C2	May 4, 1994	- " -	ASLV

flights, PSLV placed remote sensing technology satellites, IRS-P2 and IRS-P3 in the intended polar orbit.

It represents technological self-reliance not only in designing and building state-of-the-art remote sensing satellite but also launching it from within the country, using an Indian-designed and built launch vehicle.

Several improvements were incorporated in the PSLV since its last launch to increase its payload capability to 1,200 kg which is the weight of IRS-1D:
- increasing the solid propellant in the first core stage from 128 tonne to 138 tonne,
- increasing the liquid propellant loading in the second stage from 37.5 tonne to 40.6 tonne by stretching stage tankages,
- replacing the metallic payload adopter by a CFRP adopter and
- effecting weight reduction in the vehicle equipment bay were some of the improvements made.

Development of PSLV has involved path breaking advances in solid motors, liquid propulsion stages, materials and fabrication technology, inertial navigation and guidance systems, SITVC, flex nozzle and gimbal control systems, on-board and ground software, telemetry, aerospace mechanisms, remote vhicle checkout, automatic launch processing systems, ground infrastructure for fabrication and testing, launch complex and tracking network.

The future

Two more PSLV continuation flights have already been planned over the next two years for launching IRS-P4 and IRS-P5 satellites. The launch services from PSLV is also available for placing satellites of other countries either with a fully dedicated vehicle or as piggy-backs along with other satellite missions, depending on the requirements.

On to GSLV

All the major developments and products and facilities established by PSLV will be useful, directly or with modification, to India's next launch vehicle, GSLV. The latter is now under development for placing 2,500 kg INSAT class of satellites in geostationary transfer orbit.

GSLV is a three stage vehicle, the core being the 129 tonne solid booster as in PSLV, the second stage being a liquid propulsion system with a propellant loading of 37.5 tonne as used in the earlier PSLV flights.

The upper stage is a restartable cryogenic engine with a propellant loading of 12 tonne (liquid oxygen and liquid hydrogen).

The higher propulsion efficiency of the cryogenic stage in terms of its specific impulse makes it an ideal choice of the upper stage of GSLV.

Specific impulse achievable with cryo fluids is of the order of 450 sec compared to 300 sec of earth storable and solid fuels, giving significant payload increase. For every one second in the specific impulse, the payload gain is of the order of 10 kg. Therefore the development of a cryogenic stage using liquid oxygen and liquid hydrogen is important for large launch vehicles.

While the initial flights of GSLV will use Russian supplied cryogenic stage, a project has already been initiated to develop the stage indigenously for use in the subsequent flights; a one tonne pressure-fed engine has already been successfully developed and tested. The first developmental test flight of GSLV is expected in 1998.

INSAT-2D was lost within the first 6 months of its operation. The IRS-1D was almost lost on the very first day due to improper injection of satellite into its orbit. Whatever be the justification and insurance returns, the failure of satellites before the completion of their mission life is a big loss to the satellite manufacturers. Is there no way to redeem the satellite back into action? Palapa satellite launched by Indonesia failed just after the launch. But it was restored back into action by an American space shuttle.

Can't the same thing be done with other satellites? Probably not. The Palapa was in the transfer orbit (i.e., within 250 kms from the earth) when it was restored back. But communication satellites are in sun synchronous orbits of 36,000 kms where no space shuttle can reach. The only option for the space scientists is to ensure precision as far as possible for a longer life.