MASA Planet

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Safety First!

Safety by the Numbers

MASA statistics help show the way

Ted Cochran
NAR 69921

"What are the chances that this rocket will fly well?" "How often do motors CATO?" "What are the odds that the rocket will prang into the prep area?" If answers to questions such as these were known, or could be estimated with more precision, we could develop a better set of safety practices that reflect experience, allowing us to address potential hazards without causing unnecessary expense or inconvenience. If the answers are guessed at, hazards may go undetected and opportunities for prevention may be missed.

So, what is the true incidence of failures? I took advantage of MASA RSOs' laborious recording of flight outcomes over the past seven years to determine the incidence of a variety of failures as a function of the size (total installed impulse at launch) of the rocket and its complexity in order to support future safety studies and risk modeling efforts.

Of 6169 total flights by MASA that I assessed, 518, or 8%, were of complex rockets (more than one motor in a staged and/or clustered configuration). The distribution of these flights by installed impulse is presented in Figure 1 below. This distribution compares well with data from other clubs.

Failure rates, continued on page 2

Also in This Issue

Contest Flying

MASA Has Best Ever NARAM

Top Ten finish for section; Four Firsts and a Fourth for MASA competitors

Ted Cochran, Seth Cochran, Mike Erpelding, Alan Estenson, Ellison Lenz, Stuart Lenz, Glen Overby, and Glen Scherer, Jr.

MASA's largest contingent to ever compete at a NARAM traveled to Cincinnati, OH during the first week of August, and it was well worth the trip! MASA contestants took four First Place trophies and one Fourth Place trophy, sending the Section to a ninth place finish for the meet, thus breaking the top ten for the first time.

The meet was held at VOA Park, an abandoned antenna farm originally used for Voice of America broadcasts and now largely an overgrown field, liberally sprinkled with concrete antenna footings, briar patches, trees, and cattail marshes. Civilization was not far away however, as a nearby Target shopping center came into play as a recovery hazard during several of the events early in the week.

Team Challenger made 13 contest flights, and took first place with a perfect score in set duration. The Cochrans flew 21 contest flights. Seth continued a proud MASA tradition by using a Stomp Rocket to take first place in Spot Landing; he also won A-BG with a Slingwing. Those flights were good enough for fifth place in B-Division. Ted's flights all finished in the middle of the pack except for fifth in spot landing (also with a Stomp Rocket) and fourth in plastic model conversion. Ted also won the R&D competition and finished fifth overall. Alan Estenson flew two qualified A cluster altitude flights; the top altitude was 189m (14th place). His B Super-Roc flights were dq'ed.

NARAM-47, continued on page 4

Failure rates, continued from page 1

The overall rate of failure for MASA rockets was 8.5% (523 failures in 6169 launch attempts). For simple, one motor rockets, the rate was 7.7%, and for clustered and/or staged rockets, the rate was 17.4%.

This failure data, categorized by impulse, is presented in Figure 2. The data are presented as the rate of failure for all rockets of the same complexity in the same impulse class. For example, there were 107 C-impulse complex rocket flights flown since 1998, and 22 of them (21%) suffered failures. The failure rate is reliably higher for complex rockets than for simple rockets across the board.

Almost 1 in 5 complex rockets fail

How consistent are these failure rates? How confident can we be in these numbers? Could we expect MASA to have the same failure rates this year as it has in the past? Since the incidences are low, it is challenging to determine the level of consistency for these data, and the data is also subject to longer-term trends in the types of rockets flown, the impact of the introduction of new motors, and the like. However, to the extent that data for the past eight years is similarly affected, we can determine the level of confidence in the MASA data by calculating a standard error-based confidence interval for the failure rate data. In order to do this, we need to limit our analysis to years and impulse categories for which there are sufficient numbers of flights. This limits us to only the simple rockets, and only the A through G flights. These data are presented in Figure 3 at right.

These data indicate that MASA failure rates are relatively consistent: The highest values of the confidence intervals are all less than twice the mean failure rate, usually much less. And, our confidence in the overall failure rate of 7.7 % for simple rockets is excellent: The standard error of this estimate is less than one percent.

Figure 4 on Page 5 presents data for MASA on the types of failures for simple and complex rockets. A key finding is that complex rockets have a 10% chance of a lawn dart (52 of 518 flights met this sad end) compared to only 1.2% of simple rockets (70 events in 5651 flights). Inspection of the logs leads to

Failure rates, continued on page 5

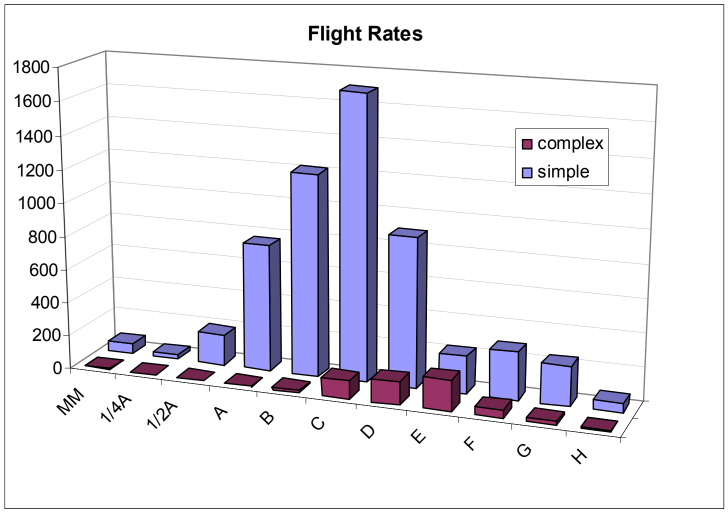


Figure 1. Flight rates by impulse and rocket type.

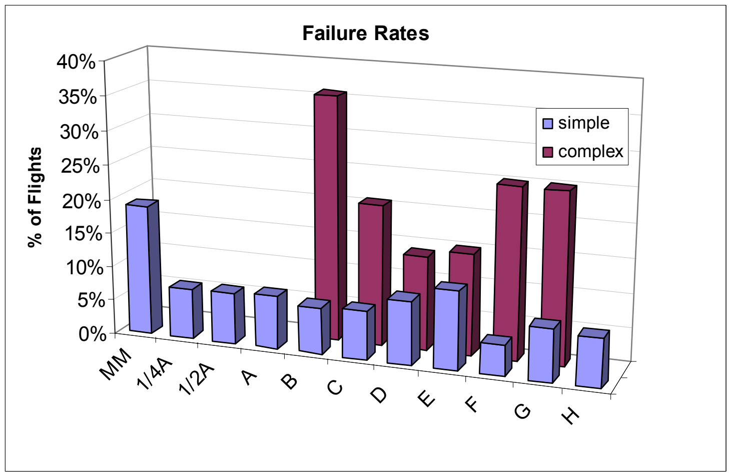


Figure 2. Failure rates by impulse and rocket type.

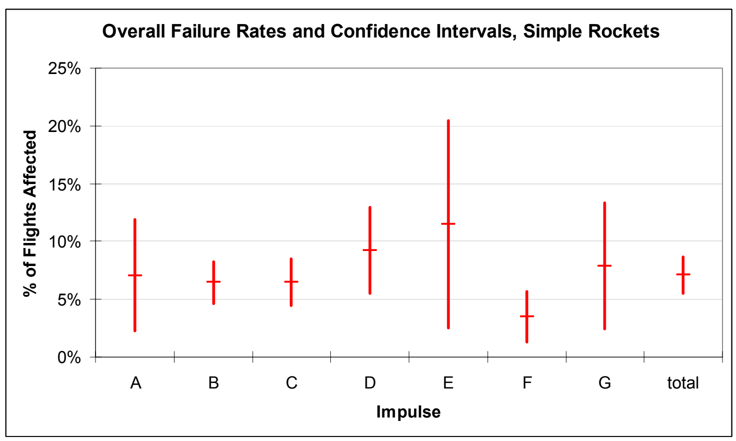


Figure 3. Generalizability of failure rates.

Meeting Schedule

Thursday, September 1
Location: Science Museum of Minnesota
Time: 7 PM to 9 PM
Topic: NARAM Highlights (NARAM attendees)

Thursday, October 6
Location: Science Museum of Minnesota
Time: 7 PM to 9 PM
Topic: Kit Bash! (Glen Overby)

Thursday, November 3
Location: Science Museum of Minnesota
Time: 7 PM to 9 PM
Topic: Finishing Rockets (David Whitaker)

Launch Schedule

Note: Times and locations subject to change!
Check the web site for updates

Saturday, September 24
Location: Nowthen (Waiver to 5500 ft. MSL)
Time: 9 AM to 4 PM
Theme: Clusters!
Fun Event: Deuces Wild drag race!

Saturday, October 22
Location: (TBD)
Time: 9 AM to 2 PM
Theme:

Saturday, November 19 (ONE WEEK EARLY!)
Location: TBD
Time: 9 AM to 1 PM
Theme:

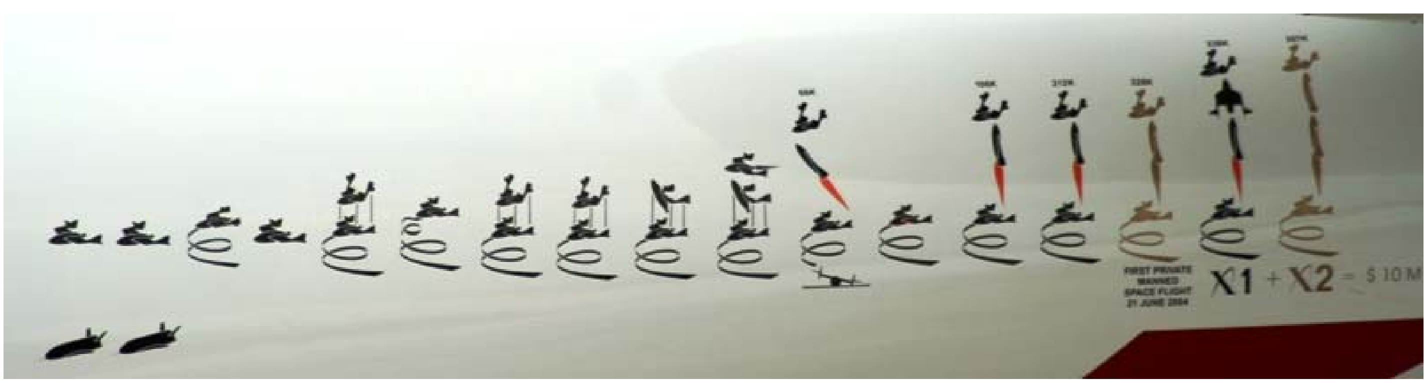
President's Corner

Alan Estenson

[Everyone gets to congratulate Mike Erpelding on his successful Level 2 certification flight at NARAM! --Ed.]

Chris Taylor

Rocketry in far away places



Alan Estenson

Fuselage art on White Knight shows a record of accomplishment. Not bad, for the private sector!

NARAM 47, continued from page 1

Alan Estenson put up 27 sport flights, including his original Der Big Red Max that flew for the first time in over 20 years. He also flew his "Tube-Ces Wild" (Deuce with tube fins--Jim Flis liked it), and his autographed MASA Patriot for the first time. His only casualty was his flying pyramid, Khufu's Revenge: The F21 ejection charge was too much for it...

Ted launched 11 sport flights, including his RingHawk (the Tim Bush design), Tethys (I285 Redline: Wheee!), and Silver Comet (Flight 56). The Lenz family was on the sport range, launching Micro Classics and a variety of other interesting rockets. Glen Overby managed to tree a two-stage rocket, which shall henceforth be called the Pole Recovery Challenger--it landed in a huge tree, and Glen had to use all three of the available extendable poles to retrieve it.

The highlight of MASA's sport range flights were undoubtedly Mike's Level 2 certification flights. The first attempt suffered an unexplainable CATO near burnout: The casing was destroyed and the rocket sustained a nasty zipper. Undeterred, Mike procured a new casing and a new reload, and patched up his rocket with duct tape and epoxy. The second certification attempt was successful, although Mike's rocket did manage to land (softly) on some cars behind vendors' row.

MASA Results at NARAM-47

C Streamer Duration Multiround

Div	Place	Contestant	Flt 1	Flt 2	Flt 3	Total	Pts
B	6	Cochran, Seth	32	53	SEP	85	66
C	19	Cochran, Ted	99	55		154	66
T	14	CHALLENGER	62	58	50	170	66

Set Duration

Div	Place	Contestant	Flt 1	Flt 2	Flt 3	Total	Pts
C	7	Cochran, Ted	36.9			369	38
T	1	CHALLENGER	0			0	378

1/2A Boost Glider Duration

Div	Place	Contestant	Flt 1	Flt 2	Flt 3	Total	Pts
B	1	Cochran, Seth	31	59		90	804
C	24	Cochran, Ted	EJ	25		25	80
T	7	CHALLENGER	17	93		110	80

A Cluster Altitude

Div	Place	Contestant	Flt 1	Flt 2	Flt 3	Total	Pts
C	11	Cochran, Ted	203	TL		203	76
C	14	Estenson, Alan	189	171		189	76
T	10	CHALLENGER	181	TL		181	76

1/4A Helicopter Duration

Div	Place	Contestant	Flt 1	Flt 2	Flt 3	Total	Pts
C	10	Cochran, Ted	6	6		12	95
T	14	CHALLENGER	3			3	95

B Super-Roc Altitude

Div	Place	Contestant	Flt 1	Flt 2	Flt 3	Total	Pts
C	23	Cochran, Ted	84 m	TL		16800	71
C	--	Estenson, Alan	EJ	UNS		0	0
T	15	CHALLENGER	110 m	83 m		16600	71

D Dual Egg Lofting Duration

Div	Place	Contestant	Flt 1	Flt 2	Flt 3	Total	Pts
T	--	CHALLENGER	NDP			0	0

Open Spot Landing

Div	Place	Contestant	Flt 1	Flt 2	Flt 3	Total	Pts
B	1	Cochran, Seth	6.47			647	189
C	5	Cochran, Ted	12.3			1230	19
T	10	CHALLENGER	36.14			3614	19

Plastic Model Conversion

Div	Place	Contestant	Model	Static	Flt	Total	Pts
C	4	Cochran, Ted	TF-104G	510	60	570	246

Research and Development

Div	Place	Contestant	Topic	NAR Pts
C	1	Cochran, Ted	Failure Rates...	1703

NARAM 47 Meet Champions

DIv	Place	Contestant	NAR Points
B	5	Cochran, Seth	1059
C	5	Cochran, Ted	2394
C	39	Estenson, Alan	76
T	13	CHALLENGER	785
S	9	MASA	4314

Photos by Alan Estenson

More NARAM sport flights: Glen's two stage Pole Recovery Challenger *(AKA 'Ain't no oak tree high enough'), Alan's* Razzle Dazzle, *Alan's* MASA Patriot *(about to make its first flight), and Stuart's* MicroVega *at ignition.*

Failure rates, continued from page 2

the conclusion that black powder rockets that fail to stage account for most of this difference, and incomplete cluster ignitions account for most of the rest.

When the data is analyzed as a function of motor class, it becomes apparent that the motors that are the most often flown by MASA also tend to be the ones with the lowest failure rates. There is also an obvious spike in lawn darts by E-impulse rockets, which appears to be due to a combination of factors, including inappropriate use of Estes E motors as heavy lifters and the use of composite E motors on fairly heavy models. This spike was especially apparent in MASA's early years, and has been eliminated since.

The NAR safety committee is going to use this data to develop more sound approaches to risk modeling. Consider the following example of the benefit that good failure data could have. Table 1 below depicts a highly simplified relative risk chart that is primarily based on deliverable event energy. The idea is to assign a weight to each combination of impulse and failure mode that approximates the potential risk of that event. Thus, risks double for each impulse class, and lawn darts are, because of the higher velocities involved, roughly twice as bad as core samples within a class.

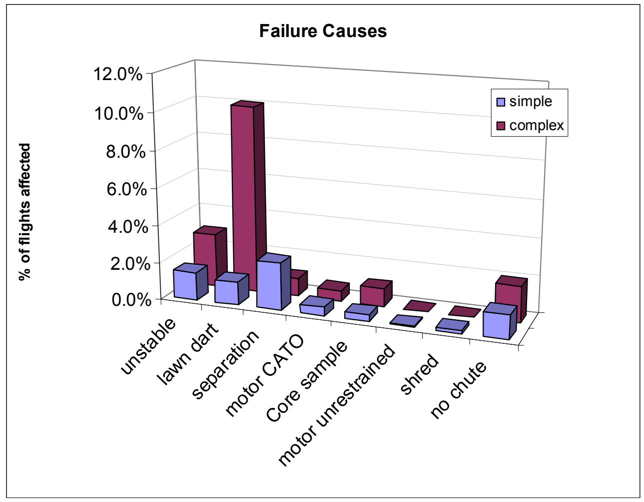


Figure 4. Failure rates by cause.

For purposes of this discussion, I have applied colors to the table to categorize the relative risk: The risk of serious injury increases as one moves across the chart from the bottom left to the top right. Table 1 thus attempts to characterize the risk of a bad outcome, should a specific failure occur in a specific size of rocket.

But what is the likelihood that the event will actually occur on any given flight? Our best estimate, as of now, is derived from the present study: The flight failure rates that were developed, that are listed in Table 2 below and Table 3 on page 8.

Relative Risk	MM	1/4A	1/2A	A	B	C	D	E	F	G	H
Lawn Dart	2	5	10	20	40	80	160	320	640	1280	2560
Core Sample	1	2	5	10	20	40	80	160	320	640	1280
Separation	0	1	2	5	10	20	40	80	160	320	640
No Chute	0	0	1	2	5	10	20	40	80	160	320
Shred	0	0	0	1	2	5	10	20	40	80	160
Unstable	0	0	0	0	1	2	5	10	20	40	80
CATO	0	0	0	0	0	1	2	5	10	20	40

Table 1. A candidate relative risk chart.

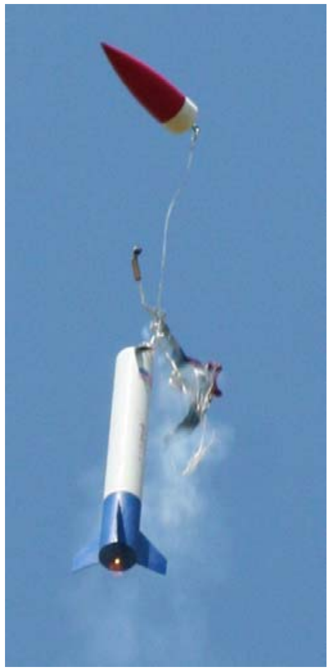
Failure Rate--simple	MM	1/4A	1/2A	A	B	C	D	E	F	G	H
lawn dart	3.2%	3.7%	2.1%	0.4%	0.3%	1.2%	2.0%	4.8%	0.7%	1.7%	0.0%
Core sample	0.0%	0.0%	0.0%	0.3%	0.2%	0.2%	0.7%	1.3%	0.4%	0.0%	3.5%
separation	0.0%	3.7%	2.7%	2.6%	3.6%	2.5%	2.6%	1.3%	1.1%	1.7%	0.0%
no chute	3.2%	0.0%	0.5%	1.7%	1.1%	1.1%	1.9%	0.9%	0.7%	1.7%	1.8%
shred	0.0%	0.0%	1.1%	0.3%	0.1%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%
unstable	13%	0.0%	0.5%	1.8%	1.5%	1.5%	1.1%	2.6%	0.7%	0.0%	0.0%
motor CATO	0.0%	0.0%	0.0%	0.7%	0.0%	0.4%	0.8%	0.4%	0.7%	2.1%	1.8%

Table 2. Incidence statistics for simple rockets.

Failure rates, continued on page 8

Sport Flying at NARAM

Ted's Tethys*, on an I285 Redline.*



Mike's Level II rocket CATOs...

...but he succeeds later on.

Ellison's nondairy creaminator

Stuart flies a MicroClassic

Alan's Super Duper V2

Alan's Khufu's Revenge.

The MicroClassic booth

Jay Apt waves goodbye

Photos by Seth Cochran (top left), Ted Cochran (bottom right) and Alan Estenson (all the rest)

Contest Flying at NARAM

Mike hooks up his 4A cluster

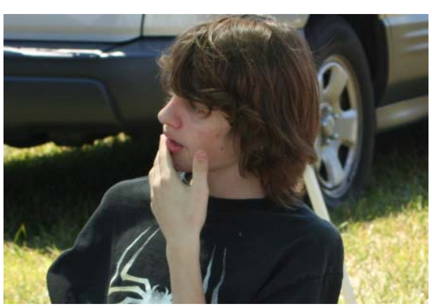
Ted hooks up his *4A cluster.*

Ted's PMC: 1/144 scale TF-104G

Mike's B Super-Roc in the tower.

Ted had one, too.

Waiting for a nice thermal to come along.



Seth ponders motor selection.

Hooking up the F104.

Posing with the loot.

Photos by Alan Estenson.

Failure rates, continued from page 5

Failure Rate--complex	MM	1/4A	1/2A	A	B	C	D	E	F	G	H
lawn dart	0.0%		0.0%	0.0%	14.3%	14.0%	8.7%	9.3%	12.5%	0.0%	0.0%
Core sample	0.0%		0.0%	0.0%	0.0%	1.9%	0.7%	0.0%	0.0%	10.0%	0.0%
separation	0.0%		0.0%	0.0%	7.1%	0.9%	0.0%	0.5%	4.2%	0.0%	0.0%
no chute	0.0%		0.0%	0.0%	0.0%	0.9%	2.2%	1.6%	2.1%	10.0%	0.0%
shred	0.0%		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
unstable	0%		0.0%	0.0%	7.1%	1.9%	2.2%	2.7%	6.3%	5.0%	0.0%
motor CATO	0.0%		0.0%	0.0%	7.1%	0.9%	0.0%	0.5%	0.0%	0.0%	0.0%

Table 3. Incidence statistics for complex rockets.

In general, it does not matter how likely a failure is if the risk represented by that failure is minimal. A separation in a 1/4A rocket--even if it happens every time--does not deserve the same respect that even a rare separation in an H-powered rocket deserves.

One way to estimate the actual risk of a rocket launch is to simply multiply the relative risk matrix in Table 1 by the appropriate failure rate table to get a measure of combined risk. This is depicted below, in Table 4 for simple rockets, and Table 5 for complex rockets.

Combined risk	MM	1/4A	1/2A	A	B	C	D	E	F	G	H
lawn dart	0	0	0	0	0	1	3	16	4	22	-
Core sample	-	-	-	0	0	0	1	2	1	-	45
separation	-	0	0	0	0	0	1	1	2	5	-
no chute	-	-	0	0	0	0	0	0	1	3	6
shred	-	-	-	0	0	0	0	-	-	-	-
unstable	-	-	-	-	0	0	0	0	0	-	-
motor CATO	-	-	-	-	-	0	0	0	0	0	1
Total Risk	0	0	0	0	1	2	5	19	8	30	51

Table 4. Combined risk for simple rockets (values in Table 2 multiplied by values in Table 3).

Combined risk	MM	1/4A	1/2A	A	B	C	D	E	F	G	H
lawn dart	-	-	-	-	6	11	14	30	80	-	-
Core sample	-	-	-	-	-	1	1	-	-	64	-
separation	-	-	-	-	1	0	-	0	7	-	-
no chute	-	-	-	-	-	0	0	1	2	16	-
shred	-	-	-	-	-	-	-	-	-	-	-
unstable	-	-	-	-	0	0	0	0	1	2	-
motor CATO	-	-	-	-	-	0	-	0	-	-	-
Total Risk	-	-	-	-	7	12	15	31	90	82	-

Table 5. Combined risk for complex rockets (values in Table 2 multiplied by values in Table 4).

These tables describe the rockets that clubs should worry the most about--the ones that fail a lot, are dangerous when they do fail, or (especially) both. The numbers in the chart can even be used as a measure of how much more worry is justified: An RSO could, for example, justifiably spend four times the effort to check a simple E rocket than he/she does for a simple D rocket, based on club experience.

The combined risk charts presented here can be improved further. First, the charts should take the experience base into consideration. For example, the entries for complex H rockets are all based upon just three flights, none of which failed. That's obviously not enough experience to justify giving complex H rockets a free ride. A workable solution to lack of experience is to modify the values in the failure rate table so that failure of the next rocket is *assumed*. If there are 500 flights and only 10 failures for the combination under consideration, this change will have almost no effect.

However, if there are only 3 flights and no failures for the combination under consideration, the estimated failure rate with this change will jump from 0 to 25%.

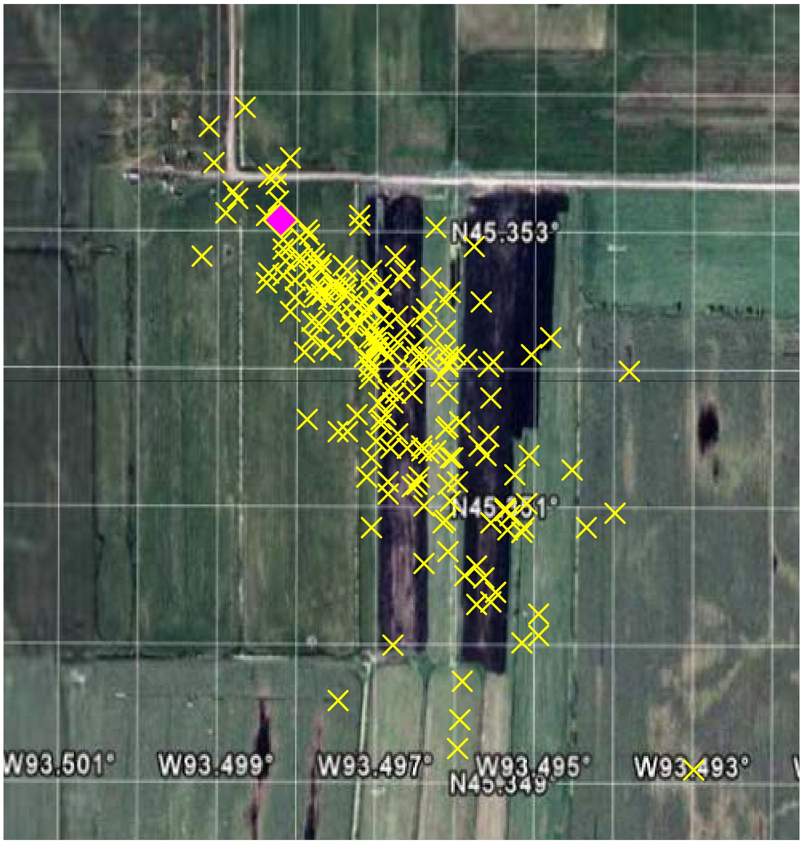


Figure 5 Simulated distribution of the landing points of 200 Alpha flights on C6-7 motors in light no rthwest winds. The launch point is the pink diamond.

Also, the risk consideration should be much more attuned to the launch conditions. Table 1 reflects the

worst case outcome if a failure occurs, but offers no help in predicting whether the failure will occur on a particular flight. Table 2 and Table 3 reflect the chances that a failure will happen based on past experience, but does not take current conditions into consideration.

But the outcomes of launches *can* be statistically modeled, even given uncertainty about initial conditions. Figure 5 shows the output of *Splash,* a program sold by Apogee. *Splash* has plotted 200 impact points for a single rocket given modest variability in a variety of factors such as fin alignment, weight, motor thrust, recovery system failure probability, and launch rod angle--18 variables in all. Splash provides landing coordinates in longitude and latitude; an aerial photograph of MASA's Nowthen launch site has been superimposed for convenience. In the example, wind was set as mostly northwesterly, which accounts for the dispersal of the recovery points downwind.

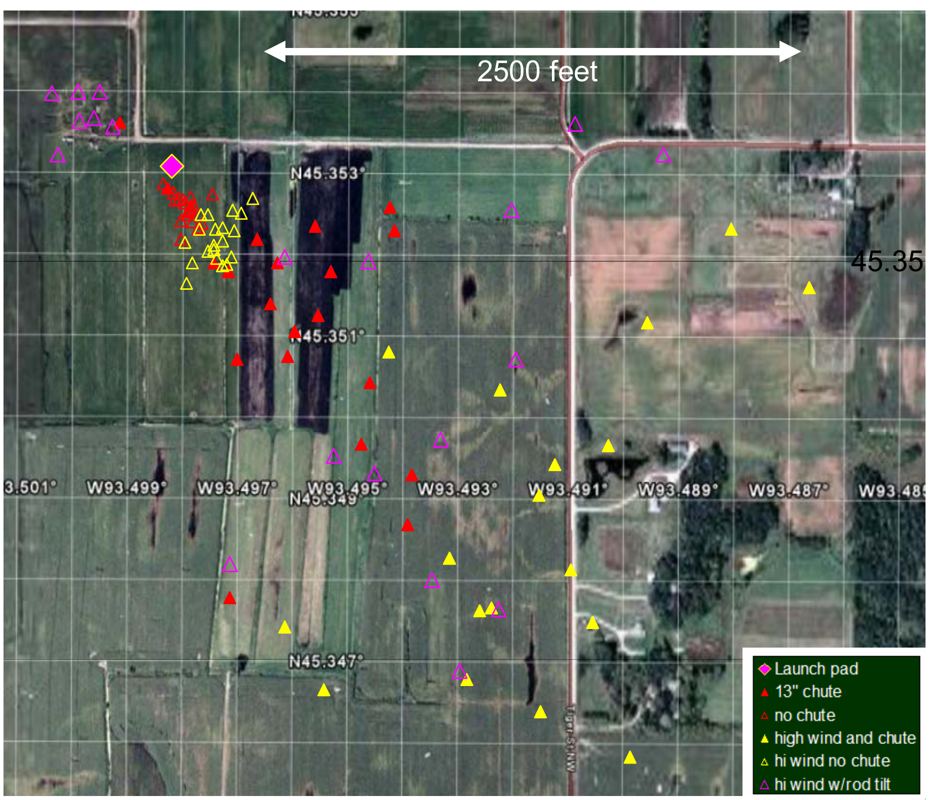


Figure 6. Splash patterns for a model rocket for various initial conditions.

Most of the landing points represent nominal recoveries, but note that several landing points are upwind of the launch pad. Some of these are lawn darts. If the club sets up the prep area along the road behind the launch pad, then the lawn darts could fall into the prep area. If the rockets are very small, the club may not care. If the rockets are larger, the club may restrict the prep area so that it does not extend upwind of the launch pad. If the rockets are still larger, the club may elect to take additional action, such as moving the launch pad.

If systematic data is collected, supplemented by judicious use of simulation programs, a set of splash patterns could be developed ahead of time for various combinations of wind direction, impulse, and rocket type. These data could be used in conjunction with historical failure rates and the parameters of each rocket to improve safety by ensuring that each flight falls within preset safety parameters. For example, in Figure 6 on page 9, a set of splash patterns for various initial conditions is shown, based on outputs from the *Splash* program. Nearly all of these are well clear of the road, which is the default prep area. However, there is a cluster of open purple triangles, all associated with recovery failures on flights launched with upwind rod tilt in fresh breezes. This cluster could be a signal for the club to modify its practices for those (and only those) conditions. Note that launches need not be entirely prohibited under those conditions; there are several alternative actions that could be taken to reduce risk under those conditions:

- The club could restrict rod tilt,
- The club could restrict the boundaries of the prep area,
- The club could launch rockets only with advance warning ("heads up")

The rockets that we should worry the most about are the ones that fail a lot, are dangerous when they do fail, or (especially) both.

Thus, when armed with accurate information, the RSO, knowing the experience of the flyer, the history of the model, the level of attention of the spectators, can if necessary modify the launch parameters for specific flights to reduce risk, without affecting the majority of flyers. To the extent that the club collects, reviews, and disseminates its own safety data, a fact-based club safety culture can emerge, and RSO decisions can be consistently made and socially enforced.

The example above describes the beginning of a fact-based safety policy based on past failure rates, risk potential, and predicted outcome given current conditions. This sort of policy is tailored to the risk presented by each flight, taking the rocket, the flyers, and the flying conditions into account. It allows resources to be focused where they are most useful, and enables the sharing of best practices throughout NAR.

[This article is an abbreviated version of my NARAM R&D report].

New products

Manufacturers' Forum

More cool stuff on the way

Alan Estenson

Here are some highlights from the NARAM manufacturers' forum:

Aerotech. The F20 LUR (Limited Use Reloadable) has been NAR certified, but Aerotech isn't going straight into full production. They're going to do an extensive real-world beta-test first. They plan to get 50 sets out into rocketeer's hands to try them out. Cost per flight will be about 30% cheaper than the regular F20 single-use Econojet. Aerotech also plans to

- release a single-use Redline propellant G motor, hopefully by the end of this year,
- release a new Estes E9-sized 24mm consumer RMS casing. It'll be something like a 24/40-60, and have all-new reloads in the E and F ranges,
- produce BlackMax propellant reloads for nearly all of their high power RMS casings,
- bring back the 24mm non-standard single-use motors, if they can find a supplier for the casings.

Boostervision has a variety of products for live video downlink. Looks like a great way to go for high quality in-flight video (especially if you already own a good camcorder for recording the video on the ground).

BMS is working on a new machine that Bill hopes will allow him to make the smaller standard balsa cones more economically and thus let him drop the prices.

Fliskits. Jim talked about their newest kits, their expansion into MicroMaxx, and their planned launch controller.

Alan Estenson

Field trip to the Air Force Museum: Priceless!

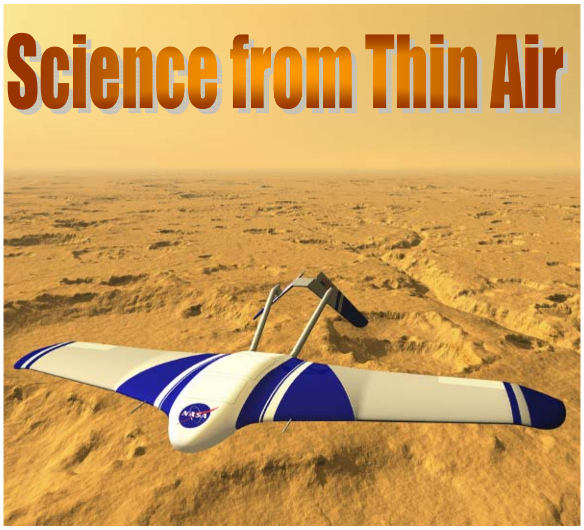
Outreach

Rocket League Wrap-Up

Fifteen teams, five trophies, fifty -three medals

Ted Cochran

Innovations in Science and Technology Education (INSciTE), assisted by MASA and Hub Hobby store of Little Canada, sponsored the fourth year of Rocket League this spring.



http://marsairplane.larc.nasa.gov/platform.htm

The goal of the program is to use an intrinsically interesting activity to challenge kids to do real science. This year, 190 kids on over 60 teams from eight schools built and flew boost gliders. Because the planned final launch had a late start because of passing thunderstorms, additional launches were held, making for a busy week.

Winning in Mercury Division was the Purple Rhino team from Field School (see pictures this page), with Pillsbury's Rocket Girls a mere one second behind. Purple Rhino used a White Wings glider attached to an Estes Alpha, while Rocket Girls used an Edmonds Deltie glider on an Air Show booster.

In Gemini Division, which required more research and development, a team from Highland Park, also called Rocket Girls, took top honors, and Anwatin Team 33 came in second. In Apollo Division, the Juggernauts, an independent team, won first place, with the Air Falcons from Highland Park close behind.

Photos by Carol Marple

The *MASA Planet* is the official newsletter of the Minnesota Amateur Spacemodeler Association, Section 576 of the National Association of Rocketry. It is published bimonthly as a service to its members. MASA authors and photographers retain rights to their submissions, which are used by permission. The *Planet* is available in color on MASA's web site:

http://www.mn-rocketry.net/masa/

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Submissions may be made to the editor at: masa.planet@mn-rocketry.net. (Volunteer quickly, lest you be assigned to collect data for a safety study.)

If your email address, U.S. Mail address, or phone number changes: Please send notice of your change to masa@mn-rocketry.net. Include your name, old email address, and new address. We depend on email for communicating important information. When an email address starts "bouncing", we lose contact with you.

Web Gem

See: http://www.isas.ac.jp/e/enterp/rockets/vehicles/m-v/index.shtml

The Japan Aerospace Exploration Agency's three stage, solid fuel M-V-6 rocket launched the Astro-E2 observatory from the Uchinoura Space Center on July 10 at 12:30 JST

MASA Planet

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