Safety in Sport Rocketry

Training for RSO and Safety Check
2013

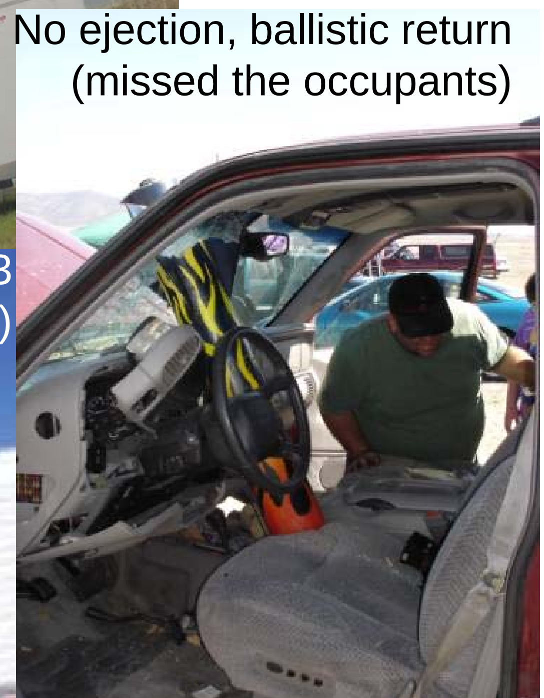
Overview

- Safety Response
- Safety Data
- Best Safety Practices

Near Misses Cause Concern

J forward closure failure (missed the car)

Late ejection in PMC (missed the truck; hit the trailer)



No ejection, ballistic return (missed the occupants)

No ejection, ballistic return of L3 rocket (missed the crowd)

Sparky-caused fire at NARAM

Clusters of Incidents Require *Action*

- The sort of incidents which occur on a sport rocket range (e.g., unstable rockets, failed recovery systems) do occasionally lead to accidents.
- This hobby has had an excellent safety record; *vigilance* is required to maintain it.
- NAR Safety Codes and National Fire Protection Association (NFPA) Codes were designed to minimize safety risks – *if they are followed!*
- When serious incidents or near-misses occur, vigilance requires ***action.***

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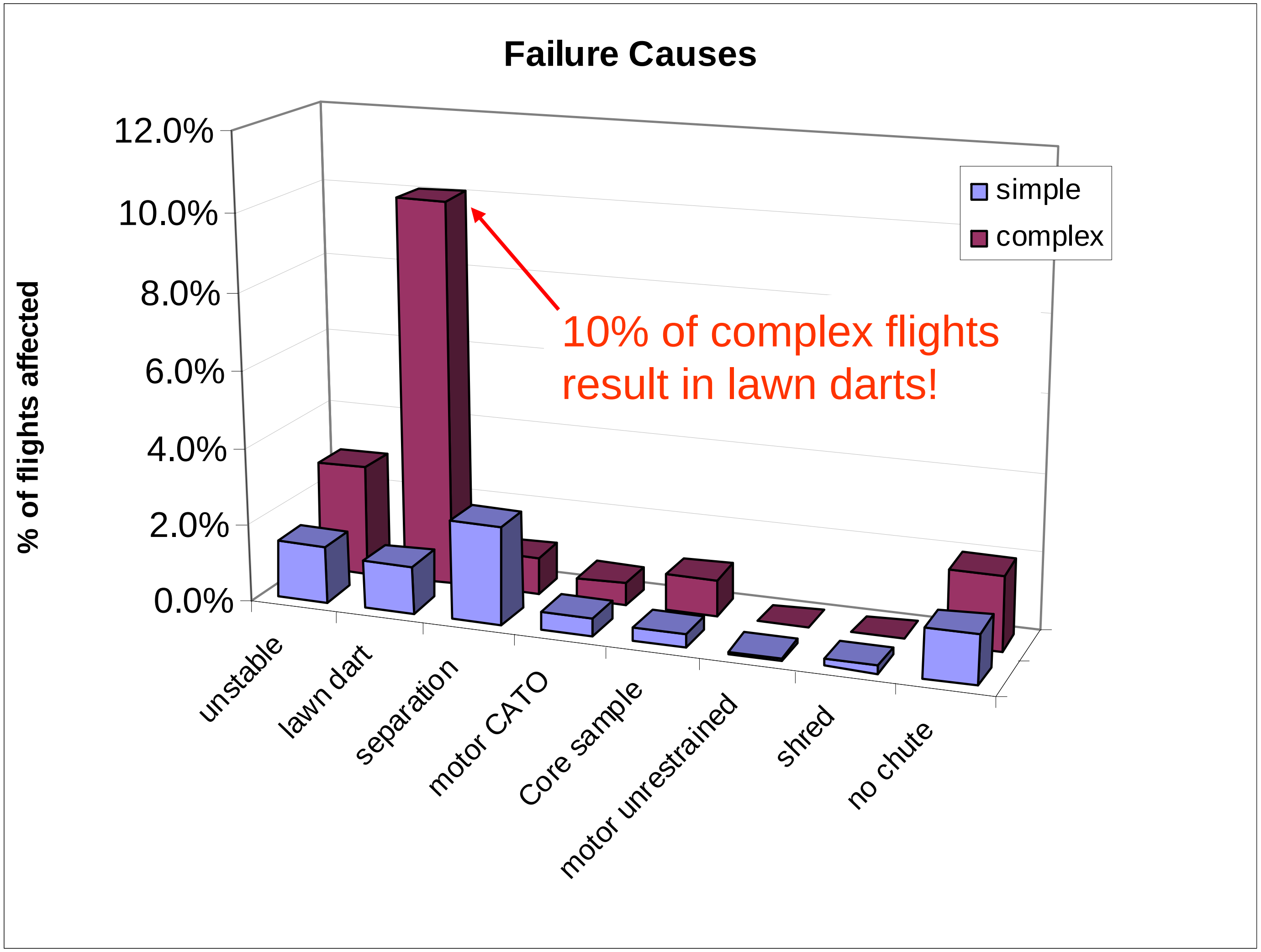
Failure Modes

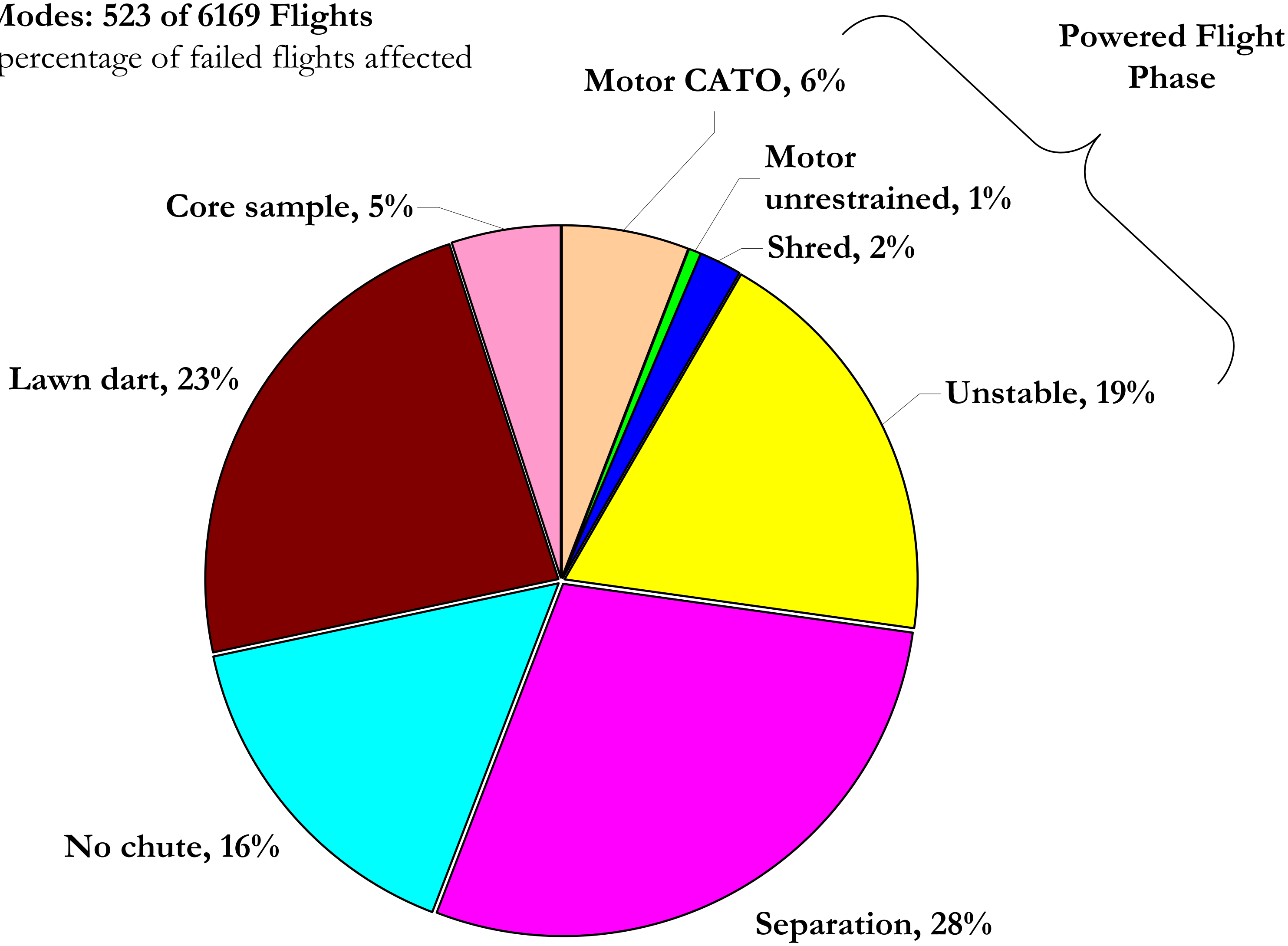
- NAR Safety Committee in 2005 reviewed 6169 flights
  - Validated against 2 independent data sets of 4546 and 9622
  - NOVAAR section also collected 3 years of data, 5092 flights
- Average flight failure rate was 8.5%
  - Complex (multi-motor) rockets twice as likely as simple
- ¾ of all failures were recovery system failures
- ¼ were powered flight phase failures, mostly instability
- Collecting data on flight failures is key to recognizing and reversing adverse safety practices
- Recent safety incidents have highlighted some concerns
  - Ballistic impact outside established launch area
  - Burn injuries from inadvertent ignition while loading
  - Range grass fires

Likelihood of Failures



Distribution of Failures

Failure Modes: 523 of 6169 Flights
Showing percentage of failed flights affected



NOVAAR Safety Data

- Flight card data was collected and analyzed for all 5092 of the 2007-2009 flights on NOVAAR's range
- 374 flights (7%) were recorded as "unsafe"
  - 230 for recovery issues ranging from ballistic return to separated recovery system (61% of all unsafe flights)
  - 41 were unstable
  - 26 shredded
  - 54 experienced a motor CATO (1% of all flights)
- Types of rockets most likely to experience safety issues: D through G power (TARC!) and multi-stage

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Best Practices Concept

- Best practices *start* with Safety Codes and add experience-based practices tailored to specific local circumstances and individual rockets/fliers
- When a safety problem occurs, change the practice that let it happen
  - ***STOP*** and conduct a post-event review of significant safety incidents (including frightening near-misses)
  - Lessons forgotten or unimplemented from safety incidents may be relearned the hard way at the wrong time
  - Communicate the incident and lessons to others

Range Safety Officer

- The RSO is the single person responsible for ensuring that fliers' "right to fly" is limited by their "duty of safety" to others
  - Must just say NO: if a rocket is not safe don't let it fly; if a situation does not look safe, ***STOP*** ***and take action*** to change it
  - Don't get "launch fever" and tunnel vision
- Bigger safety decisions are made at safety check-in than at the point of flight control
  - Focus safety expertise and attention at both
  - HPR rockets must be checked in by an HPR certified RSO

Historical Risks

- Electrocution from power lines
  - Five *fatalities* in past ten years due to attempts to retrieve rockets from power lines
  - Often overlooked, because "the safety code prohibits it"
- Fires
  - These happen too often; attention to prevention required
- Being struck by rockets
  - Strikes on vehicles and buildings are too common
  - Probability may be on our side for strikes on people, but adverse consequences in the event of injury are huge!

Power lines: Follow the Safety Code!

STAY AWAY!

Call the power company; let them recover the rocket (even the models you don't want back might attract kids.) Even if it costs you, it is money well spent!

Shorted power line causes arc

Fires: Prevention is Key

- Have adequate firefighting equipment, and *know how to use it!*
  - Fire extinguishers alone will not stop a grass fire – tools needed.
  - Observe burn bans: If dry & windy, fires may be unstoppable –don't fly.
- Clear the area around the pads
  - NFPA requires blast deflector and cleared area near launch pads.
  - Specific cleared distances specified for HPR (extra for "sparky" motors).
  - Pad blankets, pre-soaking of ground can also help
  - If it's too dry, <u>don't fly</u>
- Assign a fire watch for the pads; don't just watch the flights.
- Fires at crash sites get momentum if people do not hurry to the site expecting to find one.

NARAM-47

Injury Risk From Being Struck

A potentially lethal event: Failed L3 attempt with ballistic return to range head.

Three frames from:
http://www.youtube.com/watch?v=bfcud62ct6M

Injury Risk From Being Struck

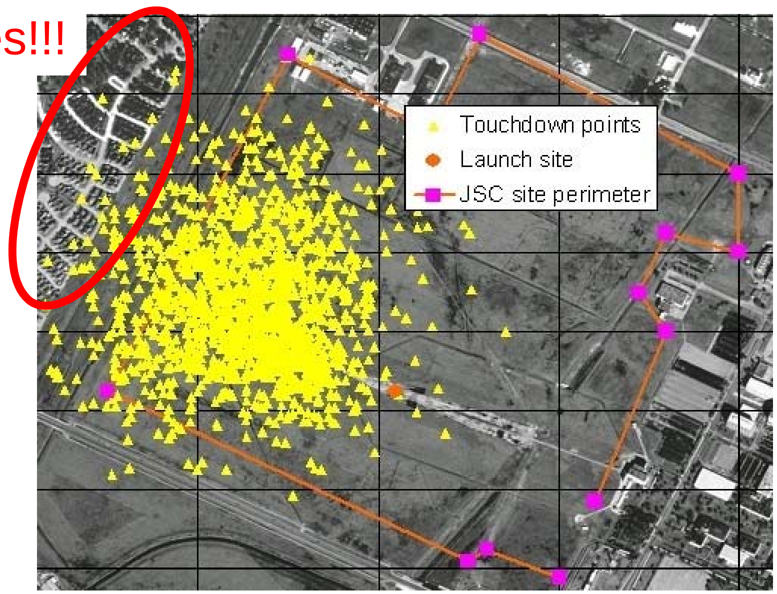
- Risk of injury depends on kinetic energy and how it is absorbed by body: No fixed danger level.
  - Batted baseball: ~150 joules *
  - .357 Magnum: ~750 joules
  - 40-pound rocket under chute at 30 ft/sec: 759 joules
  - Adult falling out of a second story window: ~3,500 joules
  - The rocket that penetrated the SUV: ~7,700 joules
  - The rocket on the previous page: >15,000 joules
- Impacts ***must*** occur where people are not.
- Recoveries of heavy rockets ***must*** occur at slow speeds and only in safe places !

*Kinetic energy = $\frac{1}{2}MV^2$, is measured in joules. A 1-pound object impacting at 100 feet per second (68 mph) has a kinetic energy of 210 joules.

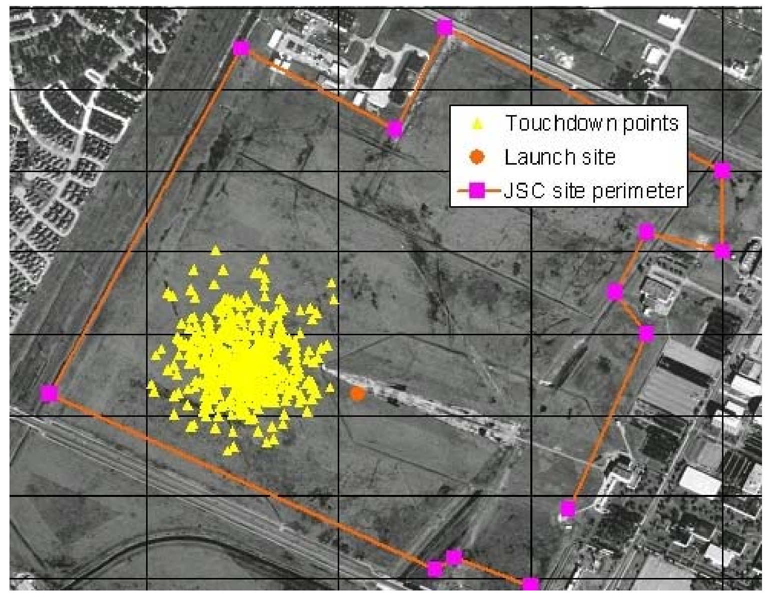
Keep Rockets on the Field

SPLASH-predicted landing location for HPR on an I453 to 2580 ft. Both parachute recoveries and ballistic trajectories can impact over 2580 ft. away!

Houses!!!



Standard Recovery
Many flights out-fly the field



Smaller Parachute or Dual Deploy
All flights stay within the boundary

1500 runs, with winds varying from 0-20 mph, from 320 degrees with a 1-sigma variability of 45 degrees

Mitigation Example

NASA Houston Section

Wind speed/direction vs. Altitude Pie Charts

-Sectors represent direction wind is from. -Use steady state winds + ½ the gusts

Rings represent speed:
Inner = 0-7 MPH
Middle = 8-11MPH
Outer = 12-15 MPH

Color indicates safety :
Red…..No Go
Green…OK
Blue …Angle 8⁰ North or Notify R/C fliers
Yellow…Angle 8⁰ angle into wind (or weathervane)

Add 5-10 mph to reported winds for higher winds aloft (check bldg. 30 winds)

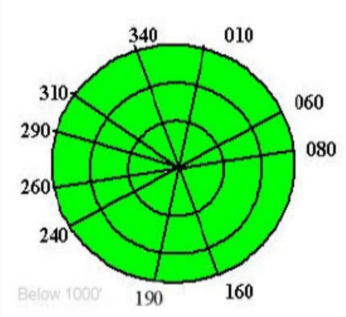
Wind drift distance per 1000' altitude

-Be sure to account for winds aloft!

	Descent Rate			
Wind	15fps	20fps	25fps	70fps
7 mph	685'	510'	410'	145'
11 mph	1075'	800'	645'	230'
15 mph	1460'	1100'	880'	315'
20mph	1935'	1465'	1170'	420'

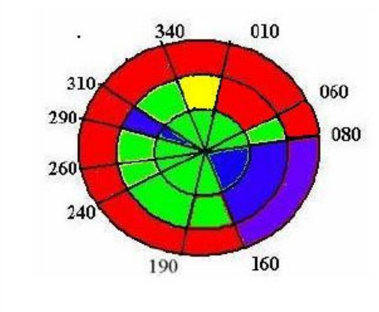
All Flights

Below 1000'

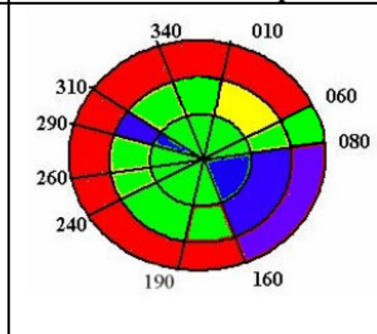


Single Parachute 1500'-2000'

Descent rate 15-20fps

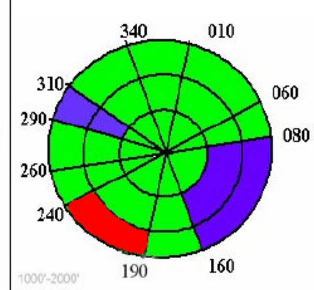


Descent rate > 20 fps

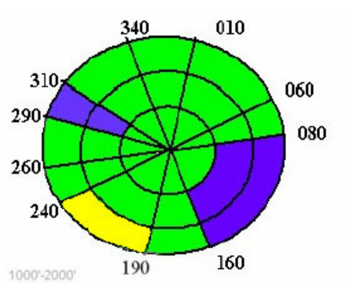


Dual Deploy

1500-2000'

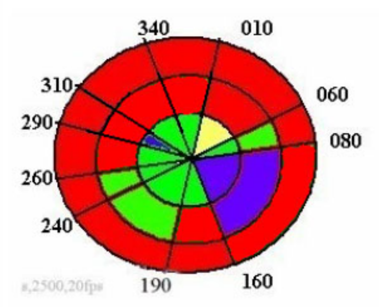


1000'-1500'

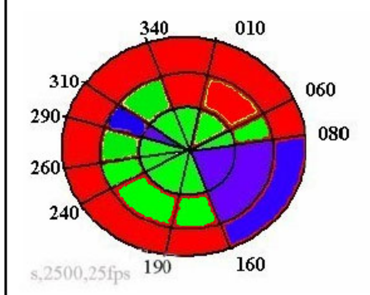


Single parachute 2000'-2500'

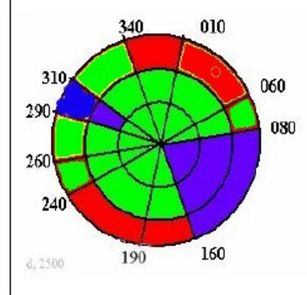
15-20 fps



>20fps

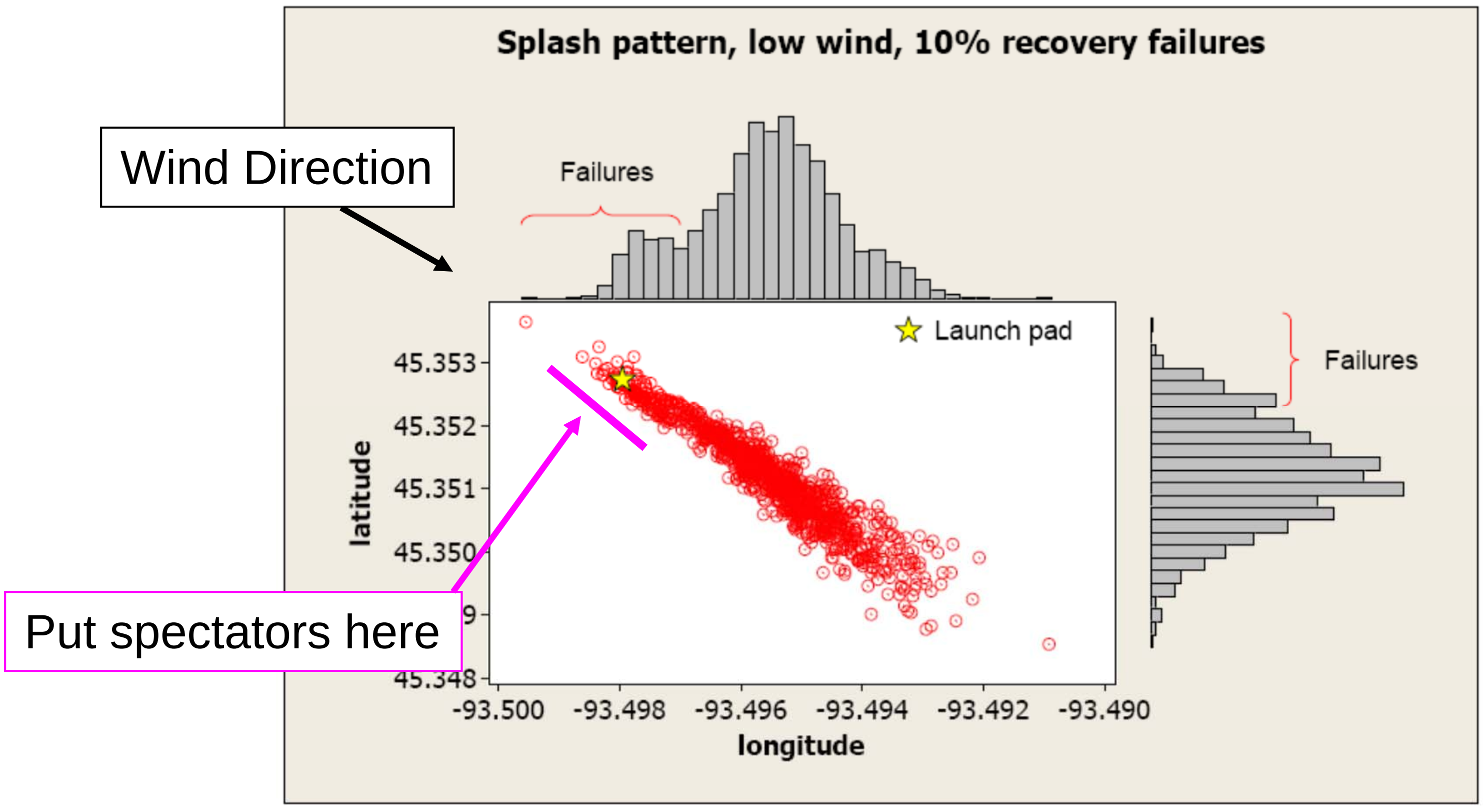


2000'-2500'

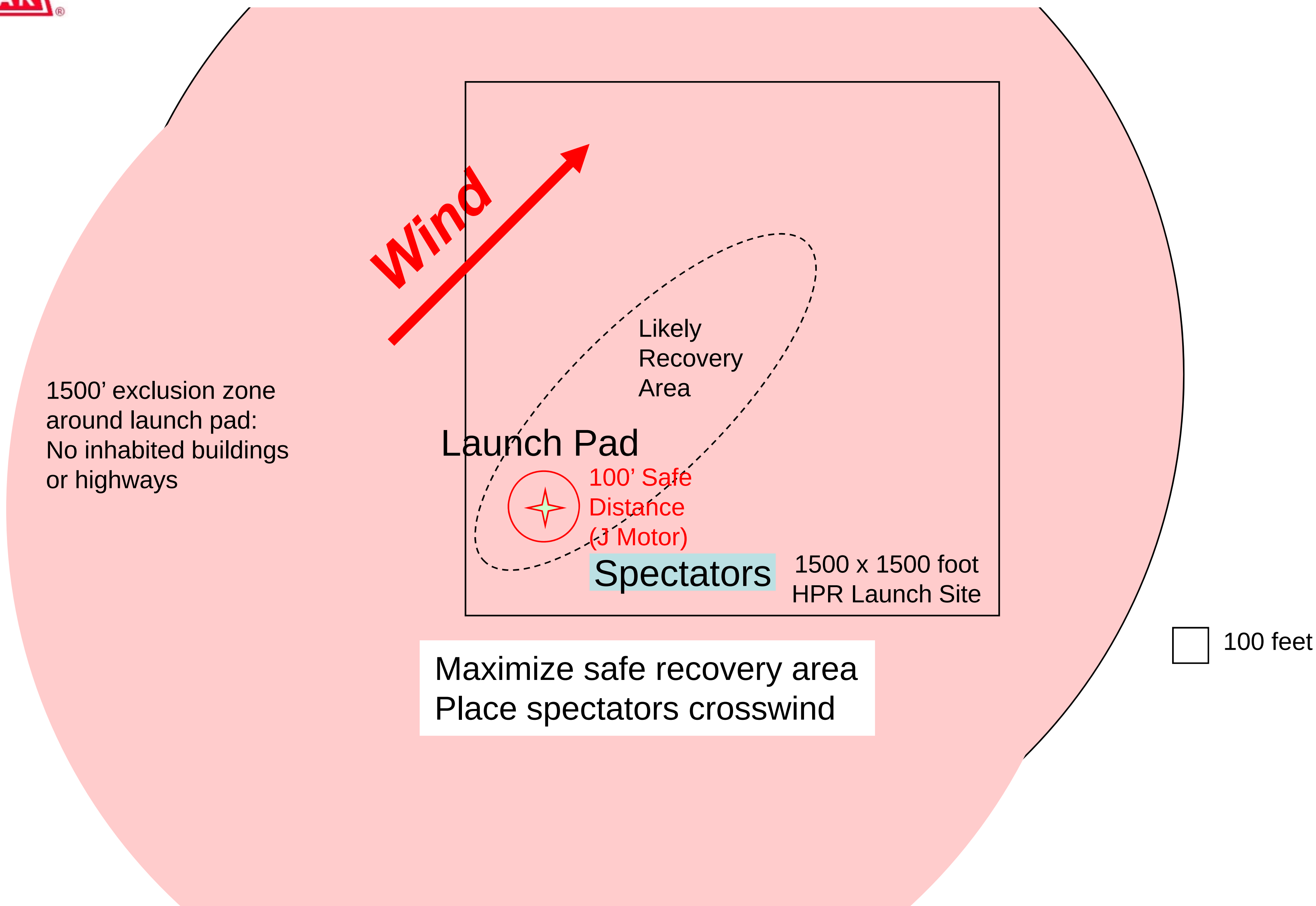


Keep Spectators Safe

Very significant risk reduction can be achieved by positioning people and vehicles crosswind from the launch pads.



Ideal launch site layout for small fields



Crowd Safety

- Launch standoff ranges apply to spectators, photographers, and to people returning with rockets.
  - Use flag line liberally.
- Make sure launch rods and flight paths (with weathercocking) point away from the crowd.
  - Ensure heavy rockets are landing only within launch site.
  - Don't let boost trajectories over-fly spectator/parking areas.
  - If a rocket does over-fly spectators, ***STOP*** and FIX THE PROBLEM!
- Use RSO "heads up" calls, but don't abuse them.
  - Ensure they are audible in the spectator area (PA/FM).
  - Have people point to the hazard to cue everyone else.
- Know who to call and what to do if an accident or injury (of any kind or cause) happens.

Recovery System Safety

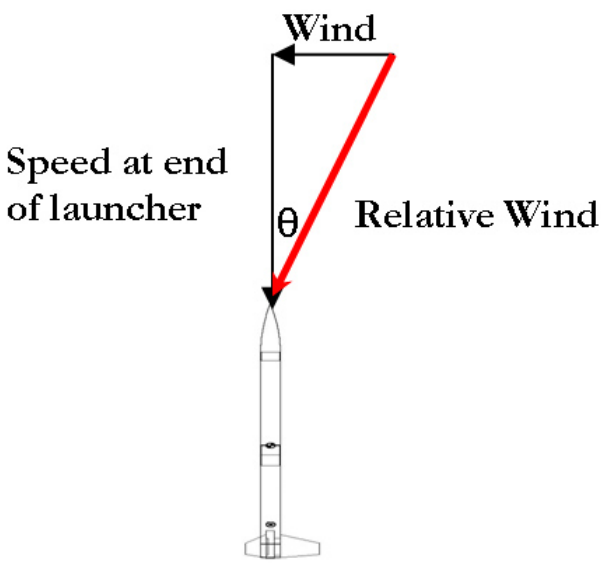
- Recovery system failure is the hardest mode to prevent – and the most dangerous!
  - Rockets normally have system already packed at check-in.
  - Do “peer review” of packing and structural integrity before check-in – and if in doubt, disassemble.
- Common failure causes are detectable & preventable:
  - Drag separation of heavy nose at burnout or failure of a tight-fitting nose to separate at all.
  - Weakness in shock-absorbing/anchoring system.
  - Inappropriate delay time and/or trajectory = excessive ejection velocity.
  - Electronics malfunction (usually user-induced) for HPR.
  - Failure to adequately restrain motor at ejection.

Stability Safety

Significant reduction in risk of having unpredictable trajectories can be achieved by:

- Use of existing simulation tools to determine rocket static/dynamic stability before flight.
- Using long-enough, stiff-enough rods (better yet, rails!)
- Compensating for effect of wind in reducing stability and causing non-vertical flight.
  - Crosswind moves Center of Pressure forward
  - Increased velocity off the launcher required in wind

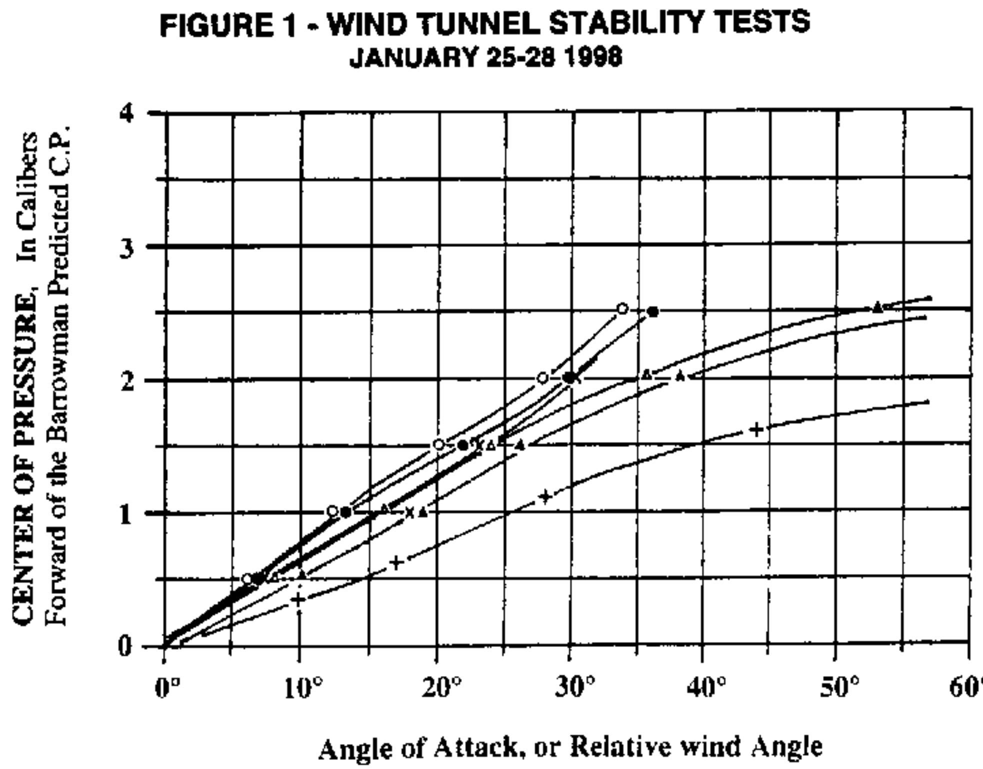
Stability vs Wind



A 30 ounce, 2.6” diameter HPR design powered by an H180 reaches 45 mph from a 3’ rod and 60 mph from a 6’ rod.

If the wind is 10 mph, the angle of attack θ is 13 degrees if a 3 foot rod is used, and 9 degrees with a 6 foot rod.

A rule of launch velocity at least 4 times the wind speed (14° AOA) limits the CP shift to ~ 1 caliber.



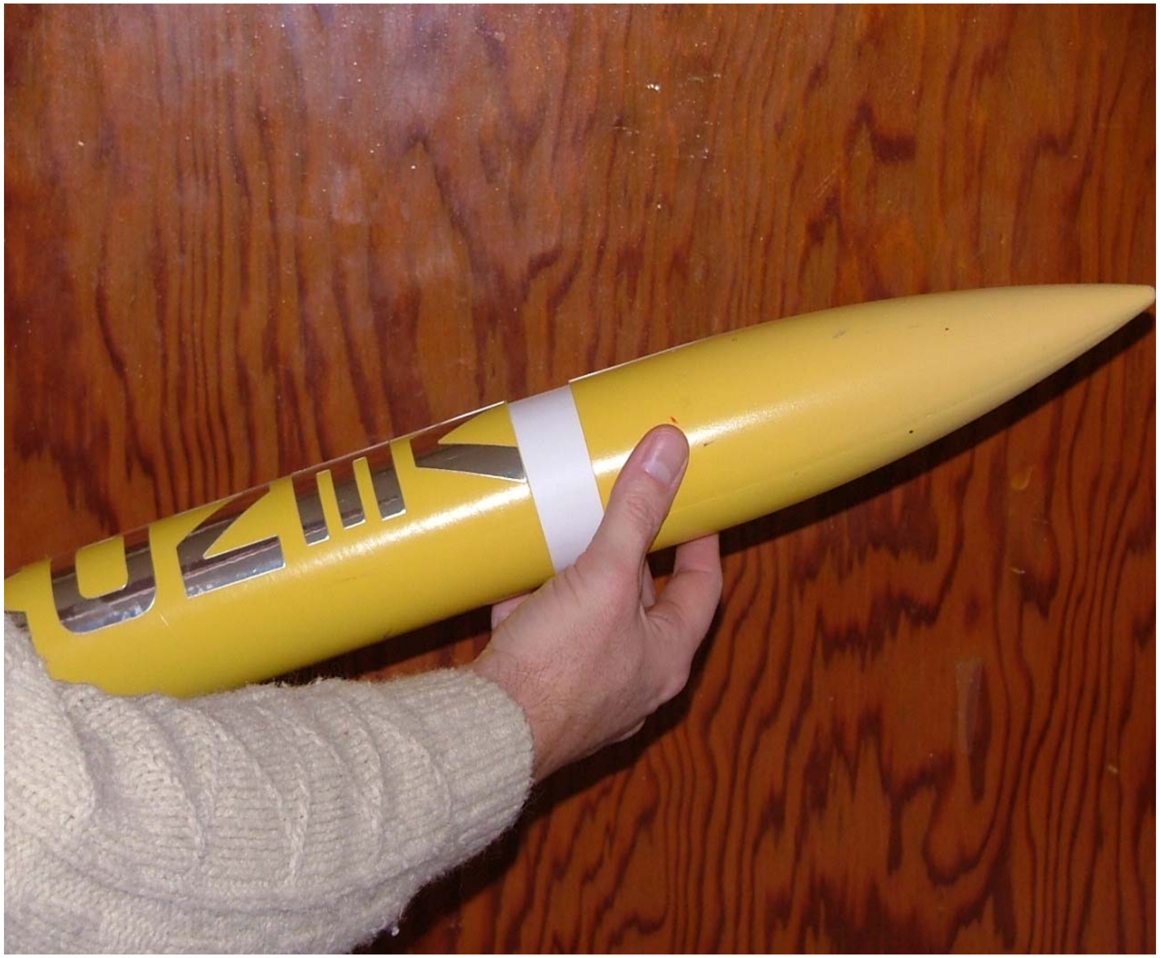
Launch Control Safety

- Test every pad before a launch, measure battery charge, and clean/replace all clips.
  - Know if the launch system is "electric match" safe – NOVAAR's is
  - Know what happens to launch voltage if a relay fails.
- Take care in designing safety keys, interlocks, and pad selection.
  - It is very dangerous to fire one pad on a system when other pads controlled by that system are still loading.
  - Make sure LCOs understand the system each shift.
- Minimize number of people out at pads when loading
- Make sure spectators within rocket's ballistic range are aware of impending launches and can be warned instantly if a dangerous event occurs.
  - Loud horn used only for seriously dangerous situations
  - Public address and/or FM radio announcement.

Safety Checkin

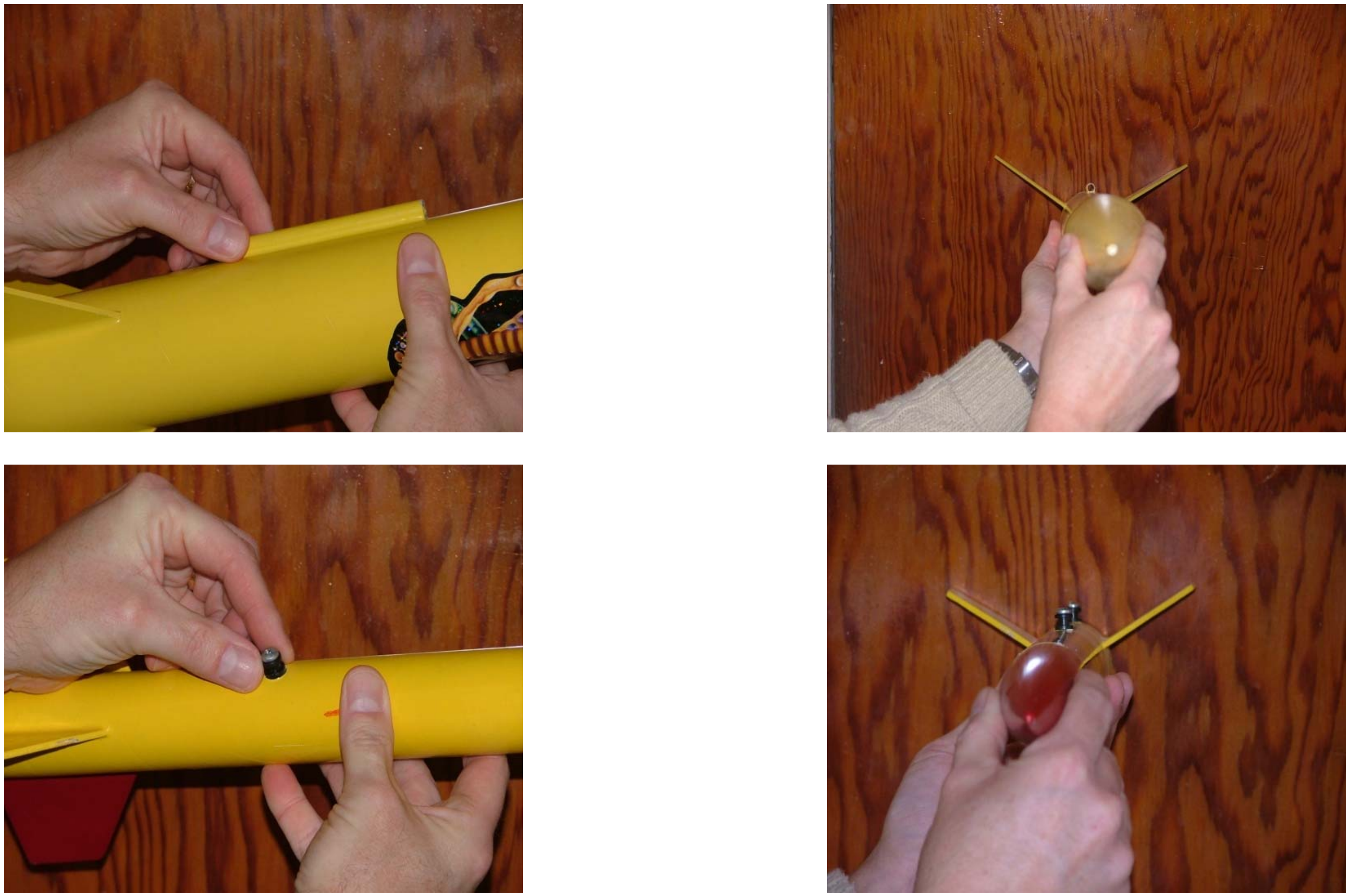
- Conduct a careful physical inspection to ensure rocket is stable and structurally sound
- Check to see if the motor is on the NAR certification list – and is not a sparky motor (if HPR)
- Verify certification level and NAR/TRA membership of HPR fliers, and ask who did their “peer review” of their prepping
- Check to see if the motor has enough thrust to provide at least a 5:1 liftoff thrust:weight ratio
- Check to be sure the motor delay time is not too long and the motor is adequately restrained
- Verify that the nose is neither too loose nor too light and the recovery system is deployable

Physical Inspection Guide



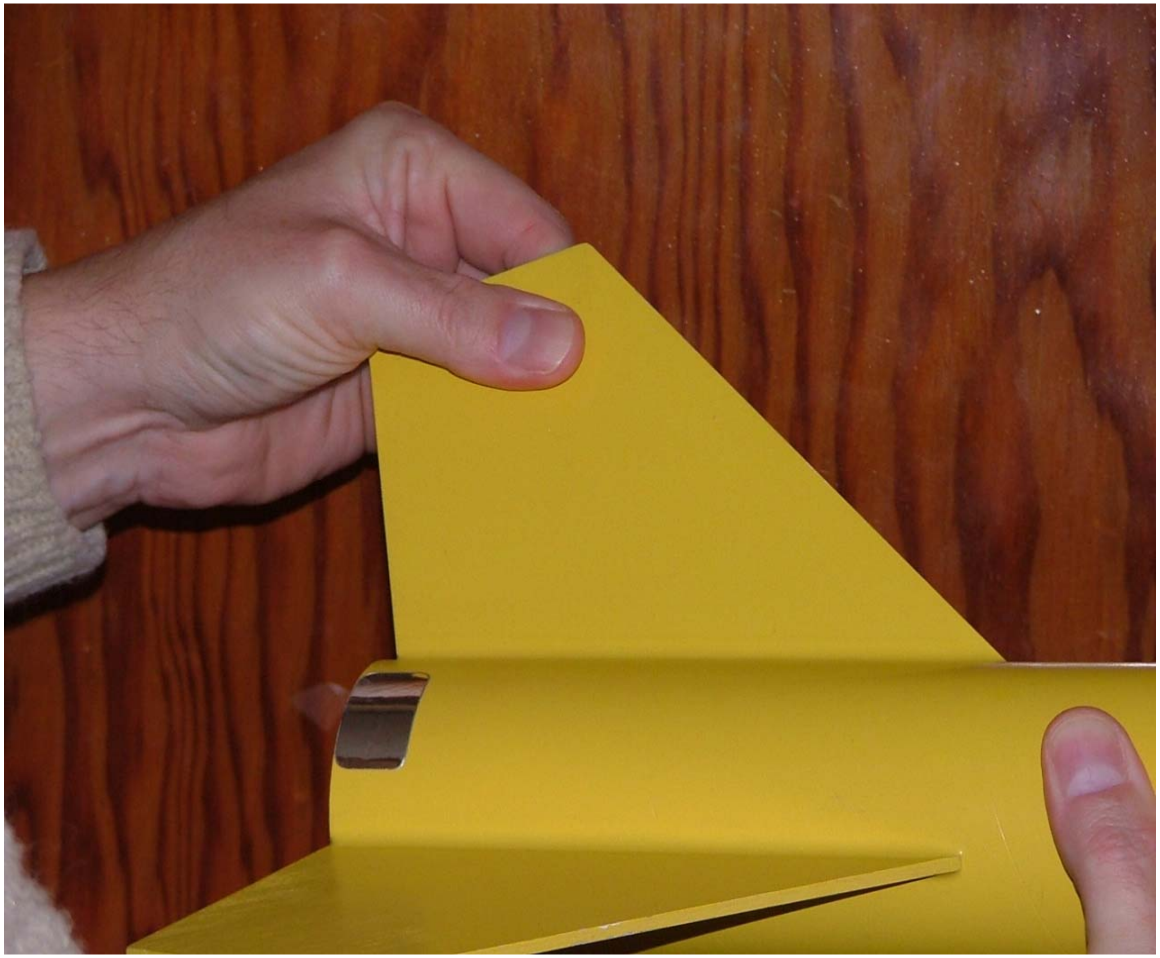
Examine all slip fits. Too tight? Too loose – falls off of its own weight?

Physical Inspection Guide



Inspect lugs or buttons. Are they secure (not taped)? Are they straight?

Physical Inspection Guide



Are the fins secure? Are they straight? Are the fillets intact?

Physical Inspection Guide

Is the motor secure? Will it “fly through” the model or pop out at ejection?

Physical Inspection Guide

Is the model stable? Check that CG is well ahead of fin leading edge.

Physical Inspection Guide

- Is the recovery system big enough to bring the rocket down safely?
- Is it packed carefully and protected with flame-proof wadding?

Summary

- Our hobby's survival in our litigious society depends on its real and perceived safety.
- Safety occurs only when responsible people understand the risks of their activities and make mature, informed decisions to manage them.
- Our hobby's safety is in our hands.