Safety in High Power Rocketry

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NAR Representative to NFPA
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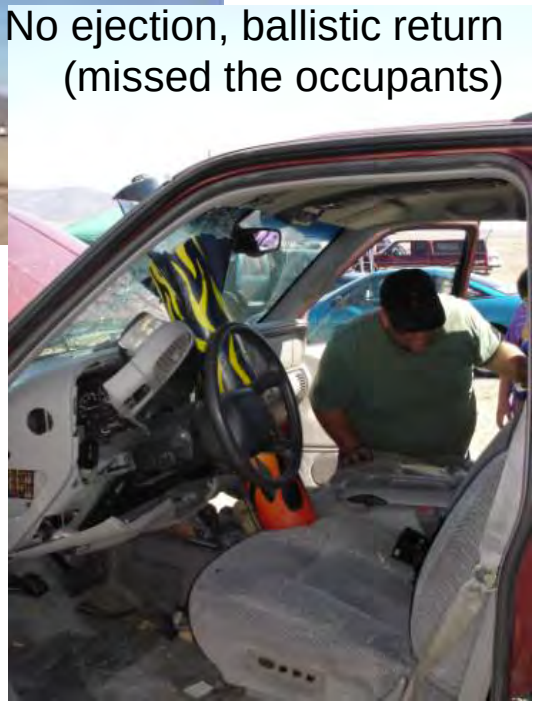
Outline

- Background
- Sharing the Sky
- Setting up the Range
- Inspecting Rockets
- Operating the Range

Bad Things Can Happen



Sparky-caused fire at NARAM

Person touching
a power line

Risk History

- Electrocution from power lines
  - Five *fatalities* in past 20 years due to attempts to retrieve rockets of all types from power lines (none at NAR or TRA launches)
  - Often overlooked, because “the safety code prohibits it”
- Fires
  - These happen far too often and usually result in loss of launch site; attention to prevention required – an increasing area of concern
- Damage or injury by rockets
  - Strikes on vehicles and buildings are too common
  - Probability has been on our side for strikes on people, but one death (from a model rocket) and several injuries (from HPR) have occurred
  - Several cases of burns from inadvertent ignitions of motors or charges

Keeping Bad Things from Happening

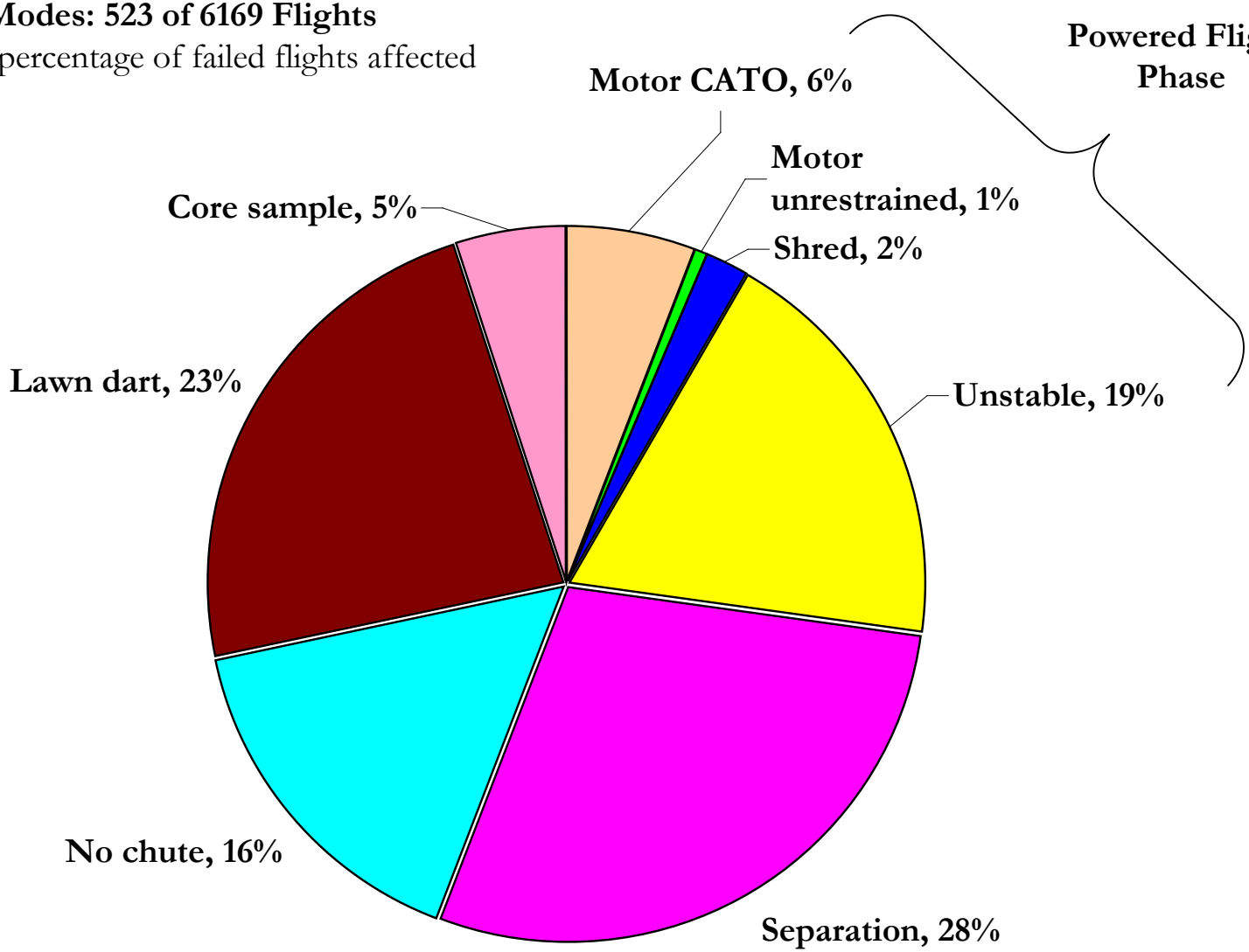
- Flight anomalies occasionally occur on a rocket range and can lead to accidents or near-misses unless care is taken.
- This hobby has had an excellent safety record; *vigilance* is required to maintain it and to keep our community safe and our insurance affordable.
- NAR Safety Code and National Fire Protection Association (NFPA) Code 1127 on HPR were designed to minimize safety risks – *if followed!*
- Risks can be minimized by careful layout of the launch site and good operating procedures.

Failure Modes

- NAR Safety Committee (chaired by Dr. Jay Apt) reviewed over 20,000 flight reports in 2006-2010
  - Largely model rocket flights, but HPR has same patterns
- Average flight failure rate was 8.5%
  - Complex (multi-motor) rockets twice as likely to fail as simple ones
  - ¾ of all failures were recovery system failures
- Key areas of concern:
  - Ballistic impact outside launch area or near people
  - Burn injuries from inadvertent ignition while loading
  - Range grass fires

Distribution of Failures

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



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Using U.S. Airspace

- Federal Aviation Administration (FAA) controls the use of all non-military airspace in the US
  - Federal Aviation Regulations (Title 14 CFR) provide FAA's rules
  - FAR Parts 101.21-101.29 cover "amateur rocket" flying
- High Power Rockets (per NFPA 1127 definition) are called "Class 2" amateur rockets by the FAA
  - Unlike model rockets ("Class 1"), they require prior authorization by FAA in order to fly
  - FAA authorization issued as a "waiver" for a given place and time
- FAA waiver provides authority to share controlled airspace, not exclusive use of it
  - Aircraft have priority but pilots are warned by a "Notice to Airmen" (NOTAM) that rocket-flying is occurring
  - Waivers are issued only up to 500 feet below any altitude at that spot that encompasses commercial air transportation/airport routes

Filing for a Waiver

- Launching HPR requires filing for a “waiver” for the site
  - Requested from the applicable FAA regional office >45 days in advance
  - Specific form (7711-2) required
  - Must describe number of rockets, altitude, recovery systems, launchers
  - Must include topographic map of operating area
  - Can cover an extended period of time (a year), not just a single day
- Detailed procedures and advice for submitting a waiver request are on the NAR website
- Waivers will not be granted by FAA if the flight altitude requested conflicts with air traffic or would force rerouting
  - Check your site first on aviation charts to see where air traffic routes are so you do not request something that will not be granted
  - “Windows” of higher altitudes may be obtainable, will require significant real-time communication with FAA air traffic control

Conducting Flights

- FAR 101.25 requires that HPR must not be flown:
  - In a manner that creates hazard to persons, property, or aircraft
  - Into any cloud or any altitude where cloud coverage is more than 50%
  - Between sunset and sunrise unless specifically authorized
  - Within 5 NM of any airport boundary unless specifically authorized
  - If uninvolved people are within 25% of expected altitude
  - Unless there is an RSO in charge & fire control measures are available
- Waiver requires notifying applicable air traffic control facilities
  - Regional facility (TRACON) 24 to 72 hours in advance so they can look up your approved waiver and issue a NOTAM
  - Both TRACON and control tower of any nearby airport prior to initiating launch operations and upon completion of operations

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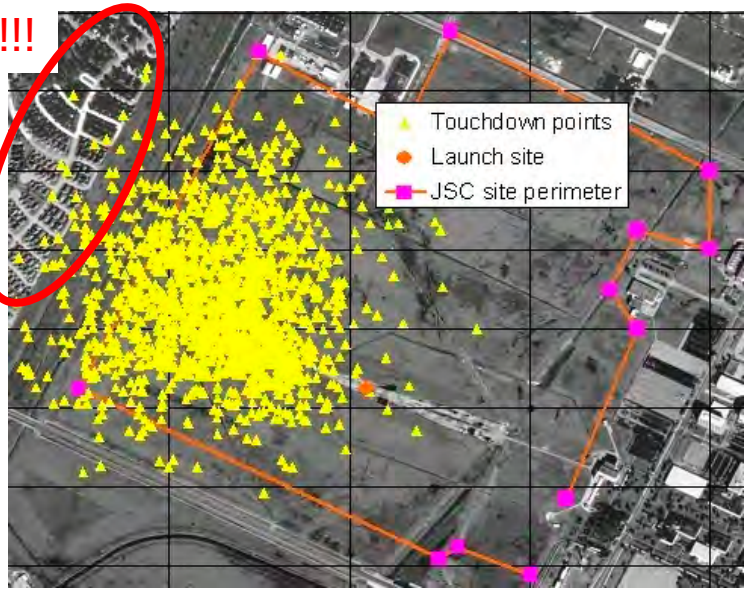
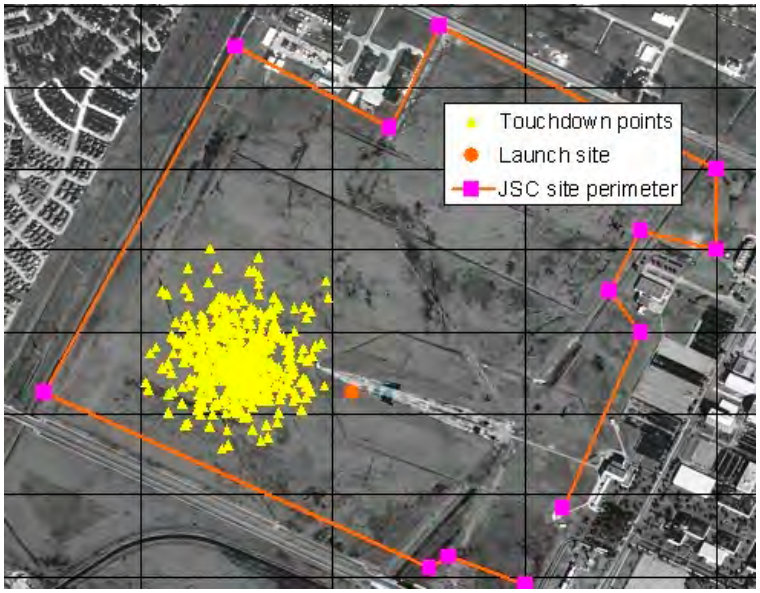
Keep Rockets on the Field

Both parachute recoveries and ballistic trajectories can land farther away than vertical-flight apogee altitude. It is unacceptable for these to occur outside the boundaries of the launch site

Houses!!!



Standard Apogee Deployment
Many flights out-fly the site

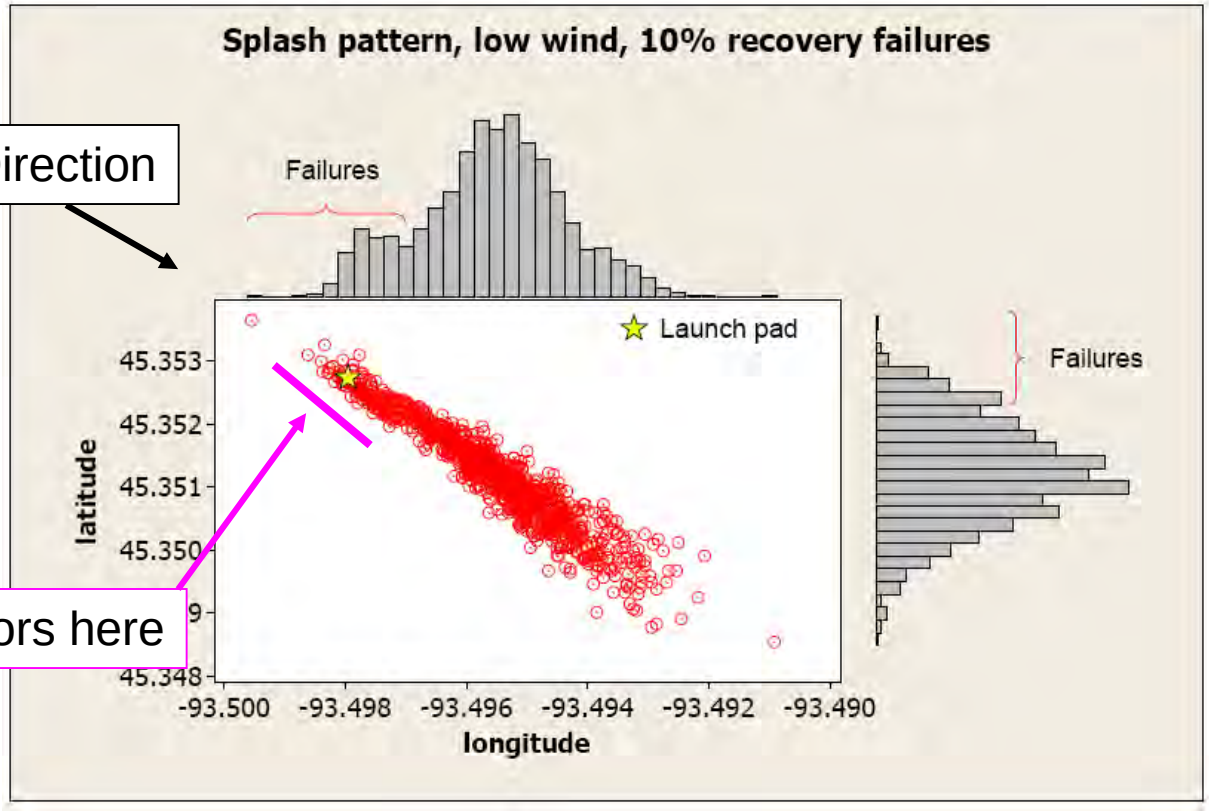


Dual Deploy (or lower apogee)
All flights stay within the launch site boundary

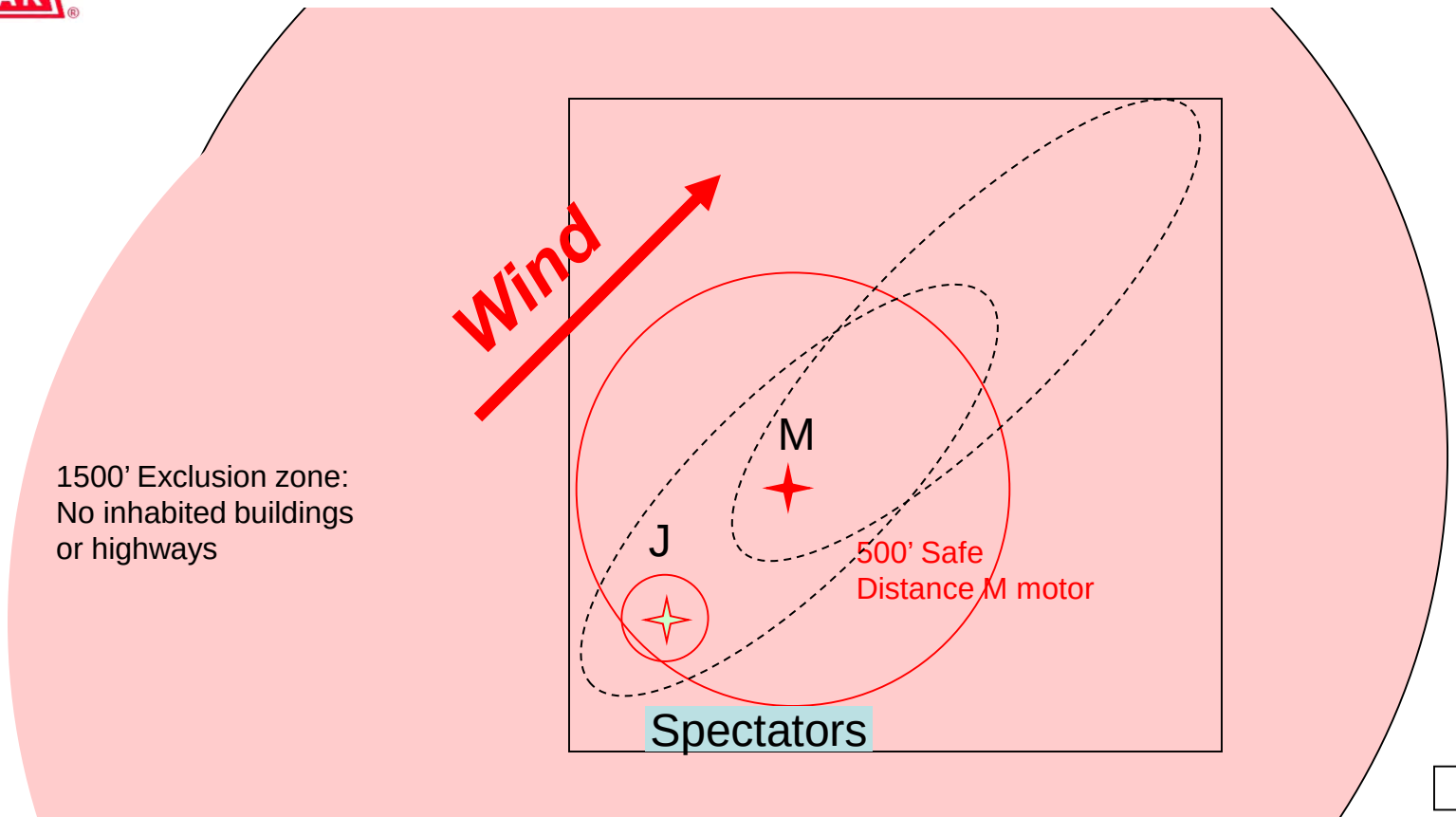
1500 runs on an I453-powered rocket flying to 2580 feet at Johnson Spaceflight Center , with winds varying from 0-20 mph, from 320 degrees with a 1-sigma variability of 45 degrees

Keep Spectators Safe

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



Ideal Launch Site Layout

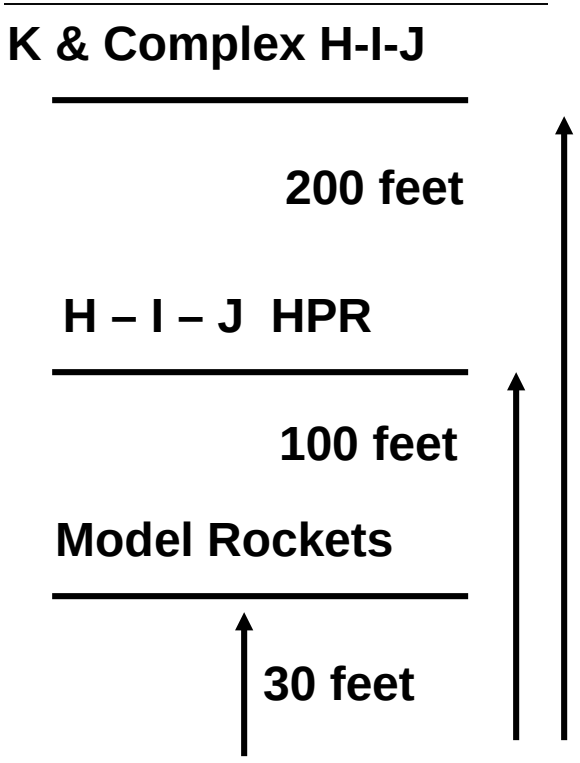


1500’ Exclusion zone:
No inhabited buildings
or highways

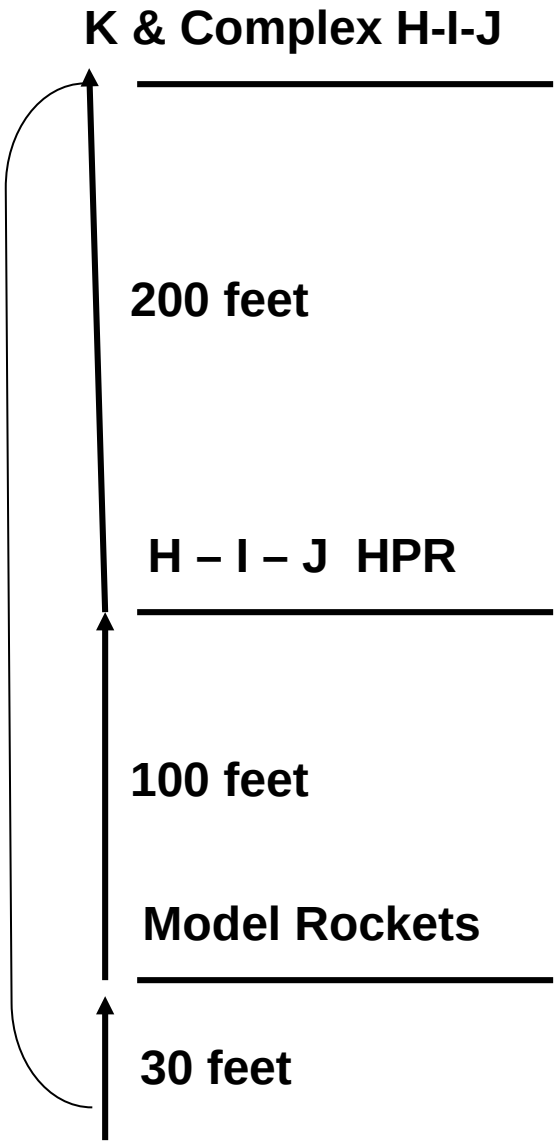
Maximize recovery area
Place spectators cross-wind

Range Layout Efficiency

Efficient in space, but not throughput



Efficient throughput: any can load safely while others fly – but watch where people walk



Launch Control / Spectators

Fires: Prevention is Key

- Have adequate firefighting equipment, and be ready *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 totally cleared area near launch pads.
  - Cleared radius specified for HPR (50% extra for "sparky" motors).
  - Pad blankets, pre-soaking of ground can also help
  - If it's too dry, don't fly
- 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

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Safety Checkin

- Put your most experienced and safety-conscious range crew at check-in: the most important position on the team
- Provide them with the tools they need, clear guidance on procedures, and full support if they say something cannot fly
- Conduct a careful physical inspection to ensure rocket is stable, structurally sound, and has an appropriate recovery system
- Check to see if the motor is on the NAR certification list
- Verify certification level and NAR/TRA membership of flier
- Check to see if the motor has enough thrust to provide safe liftoff thrust:weight ratio (typically 5:1, 3:1 required by NFPA)
- Check to be sure the motor is adequately restrained

Recovery System Safety

- Recovery system failure is the hardest mode to prevent – and the most common and most dangerous.
  - Rockets normally have system already packed at check-in.
  - Encourage “peer review” of packing and structural integrity before check-in –and if in doubt at check-in, disassemble.
- Common failure causes are detectable & preventable:
  - Drag separation of heavy nose at burnout or failure of a friction-fit nose to separate – no HPR rocket should fly without shear pins
  - Weakness or damage in shock-absorbing/anchoring harness system – use no elastic or non-forged eyebolts, plenty of nylon/Kevlar shock line
  - Electronics malfunction (usually user-induced) – have a conversation with the flier about what is supposed to happen in flight and where; and ensure that batteries are fresh and will not move under high-g’s
  - Poor packing of parachutes or rigging of their deployment sequence
  - Inadequate pyrotechnic charges or igniters that require too much current

Stability Safety

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

- Use of simulation tools to determine rocket static/dynamic stability before flight.
- Using long-enough, stiff-enough rails (not rods for HPR!) mounted on bases that will not wobble or move sideways when the rocket moves up to the top under thrust
- 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
  - Limit upwind angles on launcher – adds to weathercocking

Physical Inspection Guide

Use forged eyebolts – or use U-bolts

Use long non-elastic “shock cords” of sufficient strength to connect heavy sections at deployment

Do not use thin (1/4-inch) plywood on bulkheads where recovery anchors are attached

Inspect recovery system connections – are they strong enough?

Physical Inspection Guide

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

Physical Inspection Guide

- Is the recovery system big enough to bring the rocket down safely once main deploys (~20 ft/sec)?
- Is it packed carefully and protected from ejection flame damage with a flame-proof blanket or a piston?
- Are separation points shear-pinned rather than friction-fit?

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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

Launch Control/Pad Safety

- Test every pad before a launch, measure firing battery charge, clean all clips and rails, ensure the pad bases are not wobbly and won't move.
  - Know if the launch system is "electric match" safe
- Take care in using safety keys, interlocks, and pad selection.
  - It can be 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 – no spectators, children, or family members
- Igniters not installed and onboard pyro recovery/ignition systems not energized until rocket is in the launch position on pad.
- Make sure spectators and those recovering previous rockets within rocket's ballistic range are aware of impending launches and can be warned instantly if a dangerous event occurs.

Crowd Safety

- Launch standoff ranges apply to spectators, photographers, and to people returning with rockets.
  - Use flag line liberally.
- Make sure launch rails and flight paths (with weathercocking) point away from the crowd.
  - Ensure HPR rockets are landing only within launch site.
  - Don't let boost or recovery 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.

Power lines: Follow the Safety Code

IF ONE LANDS THERE, STAY AWAY!

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

Shorted power line causes arc

Summary

- Our hobby's survival in a 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.
- Energy levels of HPR make safety incidents particularly dangerous, so they must not happen
- Our hobby's safety is in our hands.