RIT Launch

Space Race Launch Vehicle Requirements (Annotated)

Abstract

This guide presents the minimum requirements for a safely launched and recovered Space Race rocket. This is not intended to exhaustively describe every detail of a safe rocket's design, but instead to be a concise reference for commonly forgotten-about considerations. The contents are a subset of similar guides to safe high-powered rocketry, including publications from the National Association of Rocketry and the Experimental Sounding Rocket Association, and are guided by the team leadership's experience in the considerations relevant to a Space Race team.

Nomenclature

The key words *must*, *must not*, *required*, *shall*, *shall not*, *should*, *should not*, *recommended*, *may*, and *optional* in this document are to be interpreted as described in RFC 2119 [3].

Drogue is equivalent to "first recovery event", *main* is equivalent to "second recovery event", even if the drogue and main parachutes are (such as in the case of a reefed descent) physically the same parachute.

Primary and *secondary* refer to redundancies of the same event, NOT to "main" and "drogue".

The launch vehicle's *ascent* starts at time from which the rocket is no longer fully constrained by the launch rail and ends at apogee.

Components are *safety-critical* if they are necessary to control energetics, the apogee separation event, trackers, or anything that can affect the stability during ascent.

Systems are *independent* if they do not share a necessary component; i.e. a failure in any necessary component of one system does not degrade the performance of the other(s).

Acronyms

AGL	Above ground level
ASL	Above sea level
COTS	Commercial off-the-shelf
DTEG	Design, Test, and Evaluation Guide
ESRA	Experimental Sounding Rocket Association
MARS	Monroe Astronautical Rocket Society
NAR	National Association of Rocketry
SRAD	Student researched and developed
URRG	Upstate Rocketry Research Group

1 Construction

1. The airframe shall be constructed of Blue Tube or stronger.
2. Each part of a joint separating in flight shall be reinforced to prevent the recovery harness from ripping into the body tube.
3. Each coupler section that must separate during flight must extend one caliber into the airframe section [1, p. 28].

   The joint should be long enough to not tilt or bind while separating.
4. There shall be two rail guides, placed on opposite sides of the center of gravity.

   Extra rail guides over-constrain the line; they have to be perfectly in line if there are three.
5. The rail guides shall not be placed in line (or close to in line) with ports that need to be externally accessible (e.g. screw switches) on the pad [1, p. 29].

   This is an easy mistake to make; we made it during IREC 2021 with *VOID*, and we at least part of the reason this is in the DTEG.
6. If a mission incorporates an object containing liquid, the object shall be separated from the avionics bay by a liquid-tight bulkhead.
7. The motor shall be positively retained.

   It can't fall out while moving around the launch site or on the way down after burnout.
8. Coupler joints that separate in flight shall be held together by shear pins which can collectively hold at least the fully-loaded weight of the rocket.

   Shear pins prevent drag separation in flight by requiring substantial force (provided by black powder or some other pressurant) to separate. You should also be able to carry the rocket around without the shear pins breaking.

2 Trajectory

1. The launch vehicle shall have a static stability margin between 1 and 4 body calibers for the entire ascent, under the maximum wind condition in which the team plans to launch. This must be verified by a plot of the static stability margin over the entire ascent [1, 2].

   Immediately on leaving the launch rail, the rocket has an angle-of-attack due to a non-zero wind. This moves the center of pressure forward, substantially reducing stability at the start of the flight. On the other hand, as the motor loses mass, the center of gravity moves forward, and as the rocket accelerates, the center of pressure moves forward. For subsonic rockets, the CG effect dominates, and the static stability margin skyrockets. The "stability" figure in OpenRocket's editor is representative of neither case: it is calculated in the fully-loaded state, at 0.1 or 0.3 Mach, and no angle of attack.
2. The maximum launch wind speed should meet or exceed the average wind gust speed at the launch site at the time of year the launch is scheduled to occur.

   If you simulate at no wind, you have to launch at no wind, which almost never happens.
3. The launch vehicle's fin-flutter velocity shall be no less than 25% greater than the maximum velocity during ascent.

   At high velocities, rocket fins are subject to aeroelastic flutter. The Flutter Boundary Equation calculates the velocity at which this happens. However, it should be used with caution because the flutter dynamics of composite fins (which is almost all of them) are much more complicated and a shear modulus may be hard to come by.

4. All launched bodies shall be recovered.

   This is especially important for our launches with URRG in Potter, which is an active field; rocket components can get caught in and damage the combine harvesters, and this directly jeopardizes URRG's permission to use that field.

3 Recovery

3.1 Hardware

1. All non-redundant components in the load path from the parachutes to the body tubes shall be tested, calculated, or rated by the manufacturer to withstand the maximum snatch force expected from that recovery event.

2. The recovery harness shall be at least five times as long as the launch vehicle (measured tip-to-tip).

   Experience-based best practice indicates this is a safe length to mitigate snatch loading.

3. Before launch, the team must conduct a separation test to ensure that the chosen charge masses and shear pin dimensions will successfully separate each recovery bay.

3.2 Electronics

1. The rocket shall use a dual-event recovery.

   The drogue event prevents excessive drift.

2. The drogue events shall slow the rocket to between 100 and 50 feet per second.

   A minimum speed prevents excessive drift, and a maximum speed prevents excessive shock at main.

3. The secondary drogue event shall occur on a delay from the primary drogue event.

   The two pressurization charges each have enough powder to separate the rocket, so detonating them at the same time over-pressurizes the rocket, which flies apart much faster, exerting a larger snatch force.

4. The configured delay for any drogue event shall not exceed two (2) seconds.

   Otherwise, the secondary event might occur with the rocket having accelerated down a significant amount, increasing the snatch loading.

5. The main events shall occur between 1500 and 500 feet above ground level and shall slow the rocket to less than 30 feet per second.

6. If the main event uses a pressurization of the recovery bay, the redundant main event shall occur on a delay from the first (in altitude or time).

7. Drogue deployment shall be controlled by two independent commercial off-the-shelf (COTS) flight computer systems.

   The drogue event is critical to a safe flight, so the flight computers, batteries, screw switches, and igniters need to be fully redundant.

8. Main deployment shall be controlled by two independent flight computer systems, at least one of which must be COTS.

   The main event is very important to a safe landing, which is why at least one computer must be COTS, but no-main is much less of a hazard than no-drogue.

9. The team's power drain timeline shall assume no less than 90 minutes of drain time for flight computers and no less than 240 minutes of drain time for GPS trackers.

10. The flight computers and trackers shall be tested with the batteries to be used in the field to comply with the power drain timeline.

11. All electronics controlling energetics shall have arming switches that are externally accessible while the vehicle is fully integrated and vertical on the launch rail.

    Energetics should be armed as late as possible, to minimize the chance of a failure, and should be armed (and disarmed in the event of a scrub) with the rocket vertical because some flight computers might interpret movement from vertical to horizontal (or the other way around) as a nose-over event and set off the charges while surrounded by personnel.

12. Switches (arming or otherwise) which control safety-critical electronics that rely on a spring contact shall be rated by the manufacturer to high vibration and G-force.

    Some switches, like key arming switches and electromechanical relays, have a spring inside them. This spring may depress on launch, browning out electronics that are not resistant. Some flight computers incorporate a capacitor for exactly this reason, but do not rely on this as a primary safety system.

13. The launch vehicle shall be tracked in real-time, from launch to recovery, by an independent COTS GPS tracker.

    This aids recovery if the rocket drifts a long way (especially for main-at-apogee failures)

3.3 Wiring harness

1. All safety-critical wiring shall be stranded [1, p. 37] and no smaller than 24 AWG, unless a COTS component requires otherwise.

   Safety-critical is *typically* synonymous with "sets off an e-match". With that in mind, 24 AWG can safely carry 2 amps [5], which is more than enough required for e-matches. Stranded wire is more flexible and therefore less likely to fail to fatigue during repeated assembly, disassembly, and tight bend radius.

2. All wiring shall be labeled and should be color-coded to easily identify the subsystem to which it is attached [1, p. 21].

   Connecting recovery devices to the wrong terminals is potentially catastrophic. Labeling the wiring harness makes this less likely, eases the mental load during launch preparation, and makes the assembly easier for someone else to verify.

3. All wiring must be rated to at least the largest current it is expected to carry.

3.4 Electrical connections

1. Connectors shall be resilient to high G-force and vibration, either by having a latch, a high mating force (e.g. XT-30/60/90), or an external means of retention (e.g. zip tie).

2. Stranded wire crimped into a contact or retained in a terminal block or by other mechanical means (i.e. squeezed in any way) must not be tinned, except to the extent that individual strands are tinned by the manufacturer [4].

   Solder will crack and creep, leading to a much worse connection in a crimped joint.

3. Safety-critical connectors shall be crimped, not soldered [1, p. 39], unless made impossible by the connector installed by the manufacturer.

   Good-quality crimped connections are easier to make and inspect.

4. All stranded wiring terminating in a terminal block should use a crimped ferrule.

   Stranded wires are useful because they are flexible, but into a terminal block, loose strands can cause shorts in other components. A crimped ferrule groups all of the strands together.

5. In any connector pair, the connector providing power shall use whichever gender physically isolates the pins, unless made impossible by the connector installed by the manufacturer.

   XT-style connectors are a good example: it is possible to drop a piece of metal into the male-keyed (pin) connector and short the pins together, but because the plugs are physically isolated in the female-keyed (plug) connector, the same is not possible. The "connector providing power" is not limited to batteries; this would include the computer side of computer and igniter because the connector on the computer will be the one energizing. Some connectors, like Tamiya style, isolate the pins in both cases, in which case the decision is arbitrary.

6. Power connectors shall be keyed to prevent reversed-polarity insertion [1, p. 39], unless made impossible by the connector installed by the manufacturer.

7. Crimped connections are recommended over soldered connections, when such a choice exists.

8. Solder joints shall not have obvious gaps where the pad or cup is not fused with the solder.

Revision history

Version	Date	Author(s)	Notes
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References

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[4] *When to Tin and Not Tin Wires.* URL: `https://www.eptac.com/faqs/ask-helena-leo/ask/when-to-tin-and-not-tin-wires`.

[5] *Wire size and Current Rating (A) Guide.* URL: `https://www.jst.fr/doc/jst/pdf/current_rating.pdf`.