2019-2020

NASA's Space Grant Midwest High-Power Rocket Competition Handbook (version 3, posted 1/6/2020)

Photography/Altitude Challenge

Informational telecons: Tues. Sept. 24, 2019 (then repeated Thurs. Jan. 16, 2020) from 7 to 8 p.m. CST

(Contact James Flaten <flate001@umn.edu>, MN Space Grant, for call-in information)

Notice of Intent to Compete: Oct. 1, 2019

(Non-binding but for all institutions, including those not planning to start till the winter/spring.)

Registration Deadline: January 31, 2020

Launch Competition in Minnesota: Sat. & Sun., May 16-17, 2020** (Rain date: Mon., May 18, 2020)

** **If Minnesota has a particularly wet spring, the competition dates might shift – see details in handbook.**

Main contacts:

James Flaten, flate001@umn.edu, MN Space Grant Consortium, U of MN – Minneapolis
Gary Stroick, president@offwegorocketry.com, Technical Advisor, Tripoli Minnesota High-Power Rocketry Club

Web site:

http://dept.aem.umn.edu/msgc/Space_Grant_Midwest_Rocketry_Competition_2019_2020/

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Competition Objective

The Space Grant Midwest High-Power Rocket Competition is intended to supply student teams from colleges and universities around the nation with the opportunity to demonstrate engineering and design skills through practical application. Teams will conceive, design, document, fabricate, and fly custom high-power rockets to accomplish specific goals. The restrictions on rocket motors and dimensions are limited so that knowledge, creativity, and imagination of the students are challenged. The end result is a great aerospace experience for college/university students that would not otherwise be available in the region.

Rocket Design Objectives

The general objectives of this year's "Photography/Altitude Challenge" are as follows:

> *In this competition college/university student teams will design and construct a single stage (dual-deploy optional) high-power rocket that will fly twice in the competition. The target altitude for the first flight will be 2345 ft above ground level and the target altitude for the second flight will be 3456 feet above ground level. The flights can be on any Cesaroni or AeroTech I-class or J-class motor. The rocket must carry two low-cost cameras that interface with a non-commercial sensor suite described below (see later in this handbook for cost limits on cameras). The cameras are to be mounted on parts of the rocket that separate from one another in flight. Photography points during ascent (post-burnout) will be awarded for quality of footage and minimum rotation. (Active roll-control mechanisms encouraged, but not required.) Photography points during recovery will be for having each camera keep the other part of the rocket in view, especially during separation and during landing. Photography points post-landing will be awarded for the best 360º horizon panorama (video or a set of still photo(s)) from just one camera from an elevation as far off the ground as possible within 5 minutes of landing. The rocket must also carry a non-commercial data-logging sensor suite to characterize flight performance including (at least) axial acceleration, roll rate about vertical axis, av-bay ambient pressure plus forward-facing (stagnation) pressure (from which velocity can be determined). Sensor values must be logged at 10 Hz (minimum) and also text-overlaid on one video in real time (not post-processing). Computer/camera system likely to be Raspberry-Pi-based with Pi cameras, or something similar. All fabrication work on the rocket (except for possible machining of plastic and/or metal parts) must be performed by students.*

Judging Categories

Teams will be judged on their engineering acumen including, but not limited to, their design documentation, performance simulation, project construction and aesthetics, test plans and execution, launch and recovery operations including safety, as well as the demonstration of their rocketry knowledge and ability to communicate effectively. Teams will be evaluated based on their design reports, test flight results, presentations, competition flight, post-flight reports, as well as outreach activities.

The total score for each student team will be based on the following parameters. Note: Outreach (described later) is also expected and there will be a 10% overall deduction if not performed before the Flight Readiness (Written) Report due date.

Preliminary Design (Written) Report & Model Rocket Flight Documentation	30%
Flight Readiness (Written) Report	15%
Flight Readiness (Oral) Presentation	15%
Competition Flight Performance	20%
Post-Flight Performance Evaluation and Data Collection (Written) Report	20%
Total	100%

Competition Engineering Parameters

Student teams will be required to design and fabricate a rocket capable carrying out the challenge. The rocket must fly successfully at least twice on the competition date, at least once to each target altitude. Flights may be on different types of motors, though all motors must be Cesaroni or AeroTech I-class or J-class commercial motors.

The rocket must be fin-stabilized, with a static margin between 1 and 5 at launch, and designed to land safely. The rocket must use a commercial altimeter to produce rocket separation and the deployment of an "apogee parachute" at or just after apogee. If the rocket is dual-deploy (not required, but possibly advantageous to minimize drift on descent to help ensure the rocket lands on the sod), the second (AKA main) parachute must be deployed at least 500 feet above the ground. No drogue-less descent allowed, though achieving dual-deploy using a chute release is allowed.

The recovery system must safely land the vehicle at a descent speed not to exceed 24 ft/sec. Post-landing release of parachutes is allowed but failure to recover all parachutes if they blow away will result in flight disqualification (so be careful!). The motor ejection charge must either remain in place to serve as a back-up to the electronic separation for the deployment of the apogee parachute, or else a second, fully-independent, commercial altimeter system (including independent power, wiring, and ejection charge(s)) must be used to back up deployment of the apogee parachute. If using motor eject, use simulations to ensure the delay grain is long enough for the rocket to reach apogee before the motor eject fires.

All structural components and materials must be obtained from reputable high-power rocketry vendors or an engineering analysis demonstrating their suitability must be included with the design.

The winner of the flight portion of the competition will be the team whose rocket completes a minimum of two safe and successful flights under the following conditions (see more details later in this handbook):

- Flight 1: Flies stably aiming for 2345 feet above ground level (disqualification if its apogee altitude differs from the target altitude by more than 500 feet) and is recovered in re-flyable condition. See Figure of Merit calculation #1 below.
- Flight 2: Flies stably aiming for 3456 feet above ground level (disqualification if its apogee altitude differs from the target altitude by more than 500 feet) and is recovered in re-flyable condition. See Figure of Merit calculation #2 below.

On the competition date teams may make multiple attempts at each type of flight and may select which two flights are to be judged (within reason – the launch waiver closes at 4 p.m.) Bear in mind that rocket motors can vary ±10% from the manufacturer, so consider designs and motor selections that can deal with variation in motor impulse from nominal values.

The rocket must also carry a non-commercial data-logging sensor suite to characterize flight performance including (at least) axial acceleration, roll rate about vertical axis, av-bay ambient pressure plus forward-facing (stagnation) pressure (from which velocity can be deduced). Sensor values must be logged at 10 Hz (minimum) and also text-overlaid on one video in real time (not post-processing). Computer/camera system likely to be Raspberry-Pi-based with Pi cameras, or something similar. In this context "non-commercial" means "not intended/sold for use in rocketry" as opposed to the on-board electronics for firing ejection charge(s), which must be a commercial rocketry altimeter.

Be aware that motors from different companies need to be assembled in different ways and AeroTech motors are (typically) more complicated than Cesaroni motors (except for "disposable (case-less)" AeroTech motors). (Work with your mentor to learn how to assemble the motors you select – assembly errors often lead to motor CATO events!)

Note that AeroTech "single use" motors (AKA "the AeroTech disposable motor system") don't require external motor cases – they slide directly into the motor-mount tube and have a thrust ring to keep them from going in too far (but they still require motor retention to keep them from coming out). Although such motors are easier to use, the selection of single use motors is much more limited than reloadables.

Please contact Gary Stroick with any questions. Remember that motor orders for the competition itself must be placed with Gary Stroick (and paid for, if the total motor cost exceeds $100 covered by a portion of your registration fee) no later than March 13, 2020, in conjunction with submitting your PDR. Motors for test flights should be ordered even earlier – from a high-power rocketry vendor such as one who serves high-power launches in your part of the country.

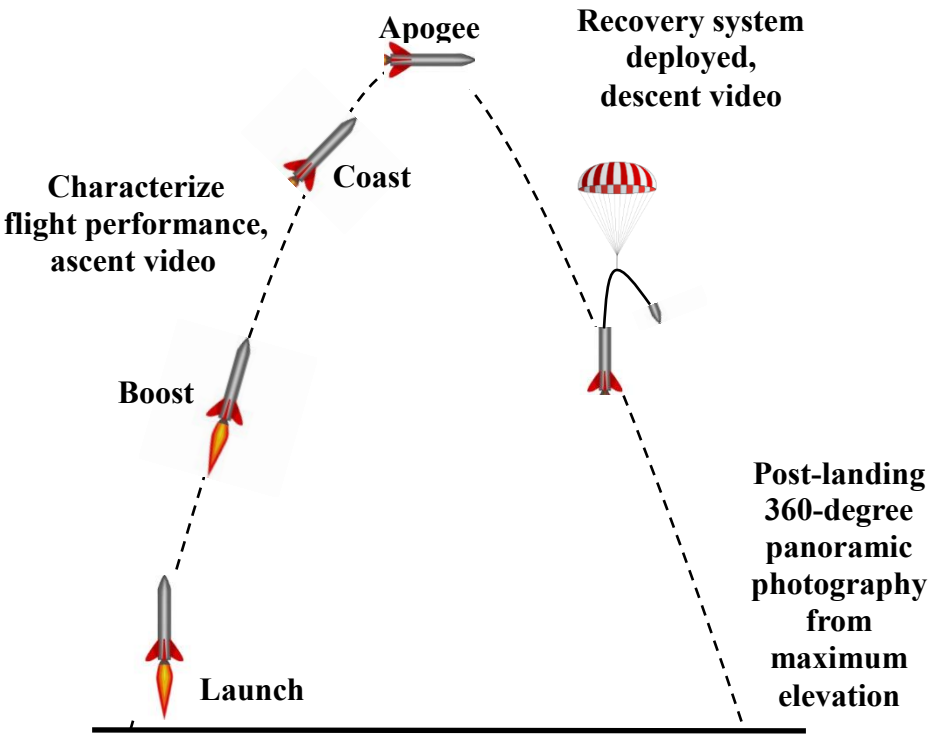


Figure 1: Generic rocket flight profile.

Flight Mission	Minimize rotation during ascent (post-burnout) to help collect high-quality video during ascent. Achieve specific apogee altitudes. Take video from two cameras in different parts of rocket that separate at apogee and have cameras keep each other in view during descent and landing. Take post-landing 360º panoramic photo from maximum altitude (i.e. aim for at least one foot – possibly more – off the ground) within 5 minutes of landing.
Recovery System	⊢ Electronic ejection of an "apogee parachute" no earlier than apogee using a commercial rocketry altimeter ⊢ An ejection back-up for the apogee parachute is required. Either use motor eject or else use a second, independent commercial altimeter system ⊢ A dual deployment recovery system is optional, but may assist in ensuring the rocket lands on sod (probably better for post-landing photography). If dual deploy is implemented the main parachute must be deployed at least 500 feet above ground level.

Rocket Constraints

- Each team must prepare a mounting location for a competition-provided "Altimeter Two" data recorder. Make the location accessible! Competition judges may want to clear the device memory prior to each flight and will definitely want to see the device read-out after each flight. If yours team owns either an Altimeter Two or an Altimeter Three (from Jolly Logic) you may consult with competition organizers about potentially using your own device for competition flights.
- Each team must be able to fully prepare their rocket for flight within **one hour** and fly at least twice during the launch window, which will run from 9 a.m. to 4 p.m. Wait-time in the RSO line will not count against this one hour limit. All rockets are expected to be ready for RSO inspection within one hour of the range opening in the morning. The second one-hour period will begin after the rocket has been recovered, passes a post-flight inspection, and requested flight data has been extracted. Modest point deductions will be made for taking longer than one hour to prep a rocket but DO NOT JEOPAR-DIZE SAFETY FOR TIME. The way to make this work is to have checklists, assigned roles, and to practice. Be organized and efficient but don't rush, lest you make mistakes! The last flights of the day need to be in the RSO line no later than 3 p.m. so as to be launched by 4 p.m.
- The static margin of the rocket must be between 1 and 5 at launch (i.e. at rocket maximum weight).
- The thrust-to-weight ratio for each flight must be no less than 3 to 1 at launch (i.e. at rocket maximum weight).
- Specific points will be awarded for "avionics bay design: tough, but user friendly." No more comments from judges like "It looks like it was thrown together with parts from the junk drawer!" This will entail a careful presentation of the AV-bay design in pre-competition written reports as well as possible in-person judging of open AV-bays at the competition itself. Judges will be evaluating component organization (including battery orientation), wiring layout, switch positioning, ease of use, and methods of securing components and the sled itself within the AV-bay, etc.
- Max value of 2-video camera system capable of text overlay: $200 (not including SD cards, batteries, other sensors). This should be adequate to purchase two Raspberry Pi video-camera systems though you are allowed to select other camera systems if they have the right capabilities and stay under this total cost limit.

NEW: Draft of Design

- NEW: Before you begin to build you must generate a "Draft of Design" which includes an OpenRocket or RockSim simulation of the design basics plus details about airframe materials and planned commercial altimeter(s). See Appendix A-6 for required details. This document should be shown to your team's mentor and also to Gary Stroick, the competition technical adviser. Heed any feedback they provide!

Model Rocket Demonstration Flight

- Each team must purchase, assemble, fly, and successfully recover a "model" rocket. Pictures of the team at their launch site with the rocket, before and after their launch, must be included with the Preliminary Design Report. Teams whose members all have previous high-power rocketry experience may request a waiver of this requirement from the competition's Technical Advisor. Teams may satisfy this requirement by building and flying and successfully recovering a (non-competition) high-power rocket, rather than a model rocket, if they wish.

Pre-Competition Test Flight

- Each team must assemble, fly, and successfully recover their fully-functional competition rocket at least once on a high-power (i.e. H-class or above) rocket motor prior to attending the competition. (Note – teams that do not satisfy this requirement may still compete, but will lose a set amount of points in the Flight Readiness report and the oral presentation.) If you elect to fly but without all of the electronics (e.g. you might elect to fly the sensor suite, but skip the actual camera system), replace them with dummy weights so the rocket's performance is as realistic as possible.

- Teams are strongly encouraged to fly an Altimeter Two data recorder (the competition organizers will lend you one in advance, upon request) on the test flight(s), to become familiar with how they work.

Rocket Design and Safety Reviews

- In addition to a faculty adviser, every team is required to have a non-student mentor with high-power rocket experience (i.e. a Tripoli or NAR member with a Level 2 or higher certification). This mentor must evaluate the safety of your design both prior to and during the build process, preferably more than once, using a competition-provided checklist and also provide some brief written commentary to the competition organizers, due at the same time as the team's two pre-competition

written reports. The faculty adviser and the rocketry mentor (this potentially could be the same person, if the faculty adviser is certified appropriately) are encouraged, though not required, to attend the competition itself in Minnesota in May of 2020.

- Analysis of non-"pre-qualified" components must be included in written reports and also must be made available at all safety reviews.
- Each team, with their rocket, must participate in the Safety Review by Tripoli MN on the day before the competition launch – the same day as the oral presentations to the judges.
- Each rocket must also pass the Range Safety Officer's Inspection on the day of the launch (repeated before every flight) before it will be allowed to fly.

Educational Outreach

- Each team must share information pertinent to their competition rocket design/build/fly experience with at least 10 individuals (typically in group setting) who are not themselves involved in the competition. For purposes of this competition, Outreach will be scored simply as "completed" or "not completed". Teams that do not complete the Outreach task and submit the required documentation by the scheduled due date, as verified by their state's Space Grant, will receive a 10% deduction from their final overall score.

Successful Flights

- Two flights, both deemed "successful" based on the criteria listed below, are required at the competition.
- Rocket flies vertically
- Rocket is stable throughout the ascent
- "Apogee parachute" is deployed at (or just past) apogee, preferably by electronics but no flight deduction if the motor eject back-up is required instead
- The main parachute, if rocket is dual-deploy, must be deployed no lower than 500 feet AGL
- Landing descent rate is deemed reasonable (≤ 24 ft/sec)
- All rocket components remain attached together throughout the flight (e.g. no disassembly or shedding of components – exception: possible auto-disconnect of parachute(s) after landing)
- Rocket is recovered in re-flyable condition
- Notice that failure of the non-commercial sensor suite and/or the video cameras to collect data is not flight-critical so will not result in an "unsuccessful" rating
- Note that "landing without damage" is NOT the same thing as "successful flight" – judges may disqualify a

rocket based on safety reasons, like failure to do one or more of the things listed above, even if it is recovered in reflyable condition. Rockets that are disqualified may be proposed for reflight, if undamaged, as long as the RSO is convinced that the safety issue(s) is(are) resolved.

Required equipment:

Competition Rocket Motors (two provided; team pays overage if total cost exceeds $100)	▪ Teams must fly their flights on either a Cesaroni or an AeroTech I-class or J-class motor. Different motors may be used for the two flights. Thrust curve data can be found at: http://www.thrustcurve.org/searchpage.jsp
Radio Tracking	▪ The Tripoli MN club requires on-board tracking electronics (not just an audio beeper) on all flights that go higher than 3000 feet AGL. We will require such tracking on ALL competition flights, even those not expected to reach 3000 feet AGL. Tracking must include at least one commercial tracking device that may be either a radio "beeper" or else a commercial GPS tracking unit (rugged enough for rocketry) that transmits GPS location to a ground station or to the internet. (There is fairly good cell phone service at the North Branch launch site to get on-line with smart phones to check for data posted to the internet.) The Tripoli MN rocket club can lend teams directional ground receivers for radio beepers operating in the 222MHz to 224MHz range from Communication Specialists < http://www.com-spec.com/rcplane/index.html>. ▪ Note: Even though the launch field is on a sod farm, there are woods and fields of corn and soybeans (which will be planted and actively growing in May) near the launch site which rockets sometimes drift into, making them hard to find without radio tracking. An audio siren is also a good idea, but optional for this competition. If the competition happens to shift later than May due to weather issues, audio sirens become a genuine must.
Competition Flight Data Recorder (for Flight 1, at least)	▪ Jolly Logic "Altimeter Two" (just a data logger – not capable of firing ejection charges; has an internal battery) ▪ 1.93" long x 0.64" wide x 0.47" high ▪ 0.24 ounces (6.7 grams) ▪ This data recorder will be independent from the team's required commercial rocketry altimeter(s) controlling the electronic deployment system(s). This data logger will be

inserted just prior to each launch to record max altitude (and other data).

Additional Comments:

Interested students with questions about the capabilities of the launch motors or seeking help in getting started are highly encouraged to contact the competition's Technical Advisor **Gary Stroick** (president@OffWeGoRocketry.com) of Tripoli Minnesota Association (a high-power rocketry association); or a high-power rocket association near them. Students interested in gaining information or experience by observing high-power rocket launches are encouraged to contact Gary or to attend one of the regular high-power rocket launches held in North Branch, MN, by Tripoli MN, or a comparable launch in their state. More information and launch schedules are posted at http://www.tripolimn.org and comparable websites.

Competition Schedule

- September 1, 2019 – Announcement of competition
- September 24, 2019, 7 to 8 p.m. CST – Informational telecon (for teams starting in the fall and faculty advisers (at least) who expect to form teams later in the year) and posting of handbook
- October 1, 2019 – (Non-binding) Notice of Intent to Compete and "sponsorship" by a Space Grant required of all teams, including those starting later in the school year
- BEFORE YOU START TO BUILD – Submit Draft of Design (specs & sim)
- January 16, 2020, 7 to 8 p.m. CST – Repeat of informational telecon (for teams starting in the spring)
- January 31, 2020 – Formal Team Registration and payment of $400* registration fee due (*tentative value – might possibly go up or down (a little) depending on the number of teams that sign up and depending on our success in raising funding from outside sponsors)
- February 7, 2020 – Declaration of Competition Attendance due
    - Specify Number of Team Members Attending Launch
    - Specify Number of Hotel Rooms and Dates Required
- February 14, 2020 – Last possible date to get credit for Draft of Design
- Mid-February – Suggested last date to order motors for April test flights.
- March 13, 2020 – Preliminary Design (Written) Report due (see rubric below)
    - Must include the type and number of motors desired for the competition date. The registration fee covers the cost of two competition motor reloads for the competition flights costing up to $100. Teams whose two competition motors cost more than $100 total and/or who want to purchase additional motors from Off We Go Rocketry (the vendor that serves Tripoli MN launches) to possibly fly more than twice at the competition must submit the extra funds with this report. Generally speaking, purchasing additional motors are the responsibility of the team and must be purchased from a high-power rocketry vendor and paid for in advance.
    - This report must also include the Model Rocket Demonstration Flight documentation
- March and April 2020 – likely times for test flight(s), at least one of a "fully-functional" rocket. However it is strongly recommended that teams conduct test flight(s) **well before the end of April** – early enough to reschedule if weather is not cooperative and also early enough to have time to repair and re-fly the rocket prior to the FRR due date (see below) if things don't go as planned.
- May 4 (NOT May 11 which was suggested during the kick-off telecon), 2020 – Flight Readiness (Written) Report and Educational Outreach form due
- May 16-17, 2020 – Competition**
    - Saturday, May 16 – Mid-afternoon into the evening: Flight Readiness (Oral) Presentations and Safety Checks
    - Sunday, May 17 – Competition launch all day (North Branch, MN) and evening social event with announcement of partial results[1]

[1] At this event we expect to announce, and celebrate, the top teams in selected categories. This may include peer-judged awards like "Best Anti-Roll Design" and "Best Av-Bay Design" and "Coolest-Looking

    - Monday, May 18 – Alternative competition launch (Rain Date)
- May 31, 2020 – Post-Flight Performance Evaluation and Data Collection Report due
- Final competition results will be reported on or before June 12, 2020.

** If Minnesota has a particularly wet/snowy winter and it becomes apparent that rocket flights won't be possible even by mid-May, much less earlier than that (for test flights), the competition organizers reserve the right to unilaterally shift the competition dates (possibly as late as mid- or late-September). Such a drastic decision will be made no later than the end of April, 2020. If teams assemble in May and do oral presentations but are unable to launch due to wet conditions the competition organizers will provide an alternative mechanism (which will not require a second trip to Minnesota) for teams to finish the competition at their home fields and submit their final report remotely.

Note that reports, motor requirements, forms, etc. are due to the Technical Advisor by e-mail at 5:00 p.m. Central Time on the dates specified above. Scores for late reports will be reduced by 20% for each portion of a day that they are late so DON'T BE LATE!

Rocket". All teams are strongly encouraged to stay into the evening following the primary launch day so they can attend this event and also just in case we need to launch on the alternate/rain date. If the launch needs to be held on the alternative date, teams that don't stick around will be disqualified from eligibility for judged prizes, but will still be encouraged to complete their flights at their home field and submit their results for judging. If we are unable to fly at all, even on the alternative date, teams will be given a specific deadline during which to complete their flights at their home field and submit their results for judging.

Safety and Construction

Setting the Tone

It is understood that this experience may be the first time many of the competitors have designed, built and flown a high-power rocket. To aid in making it a safe as well as educational aerospace opportunity, attention to safety will be held paramount. All teams will therefore be held to Code for High Power Rocketry as laid out in NFPA 1127 and further enhanced by the Tripoli Rocketry Association.

Table 1. FAA Model Rocket Classification

Limitation	**Class 1**	**Class 2**
Rocket weight	1500 grams (3.3lbs)	No limit
Motor limit	4.4 oz. of fuel (mid-size H motors)	40960 N-sec total thrust
Altitude limit	None - may be set by local agreement.	No Limit FAA Waiver Required
Other	Clear of clouds (all classes)	5 miles visibility, Clouds less than 5/10ths coverage (Clear of clouds) FAA Waiver required and Notice to Airmen filed (NOTAM) Between Sunrise and Sunset

Table 2. Tripoli Certification Requirements and Limitations

	Rocket / Motor Limitations			
Certification required	None	Level 1 HPR	Level 2 HPR	Level 3 HPR
Total Combined Impulse	320 N-sec (2 G Motors)	640 N-sec (H,I)	5120 N-sec (J,K,L)	40960 N-sec (M,N,O)
Combined propellant mass	125 grams (4.4 oz.)	No Limit		
Single Motor Impulse	160 N-sec (G motor)	No Limit		
Single Motor propellant mass	62.5 grams (2.2 oz.)	No Limit		
Single Motor Average Thrust	80 N-sec	No Limit		
Sparky Motors	Not allowed	Allowed		
Total Rocket Mass	1500 grams (3.3 lbs)	No Limit		
Field distance requirements	Per Model rocket safety code	Per HPR safety code		

The purpose of NFPA 1127 the Tripoli Safety Code and the NAR Safety Code are to:

- Provide safe and reliable motors, establish flight operations guidelines and prevent injury.
- Promote experimentation with rocket designs and payload systems.
- Prevent beginning high power hobbyists from making mistakes.

NFPA 1127 Code for High Power Rocketry
National Fire Protection Association
http://www.nfpa.org/1127

Tripoli Code for High Power Rocketry
Tripoli Rocketry Association
http://www.tripoli.org/LinkClick.aspx?fileticket=vF%2f34Qq57zg%3d&tabid=185

I. All Launches:
   A. Must comply with United States Code 1348, "Airspace Control and Facilities", Federal Aviation Act of 1958 and other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.
   B. A person shall fly a rocket only if it has been inspected and approved for flight by the RSO. The flier shall provide documentation of the location of the center of pressure and the center of gravity of the high-power rocket to the RSO if the RSO requests same.
   C. The member shall provide proof of membership and certification status by presenting their membership card to the LD or RSO upon request.
   D. A rocket with a predicted altitude in excess of 50,000 feet AGL requires review and approval by the TRA Class 3 Committee.
   E. Recovery.
      1. Fly a rocket only if it contains a recovery system that will return all parts of it safely to the ground so that it may be flown again.
      2. Install only flame-resistant recovery wadding if wadding is required by the design of the rocket.
      3. Do not attempt to catch a high-power rocket as it approaches the ground.
      4. Do not attempt to retrieve a rocket from a power line or other place that would be hazardous to people attempting to recover it.
   F. Payloads
      1. Do not install or incorporate in a high power rocket a payload that is intended to be flammable, explosive, or cause harm.
      2. Do not fly a vertebrate animal in a high-power rocket.
   G. Weight Limits
      1. The maximum lift-off weight of a rocket shall not exceed one-third (1/3) of the average thrust on the motor(s) intended to be ignited at launch.
   H. Launching Devices
      1. Launch from a stable device that provides rigid guidance until the rocket has reached a speed adequate to ensure a safe flight path.
      2. Incorporate a jet/blast deflector device if necessary to prevent the rocket motor exhaust from impinging directly on flammable materials.
   I. Ignition Systems
      1. Use an ignition system that is remotely controlled, electrically operated, and contains a launching switch that will return to "off" when released.
      2. The ignition system shall contain a removable safety interlock device in series with the launch switch.
      3. The launch system and igniter combination shall be designed, installed, and operated so the liftoff of the rocket shall occur as quickly as possible after

actuation of the launch system. If the rocket is propelled by a cluster of rocket motors designed to be ignited simultaneously, install an ignition scheme that has either been previously tested or has a demonstrated capability of igniting all rocket motors intended for launch ignition within one second following ignition system activation.

4. A rocket motor shall not be ignited by a mercury switch or roller switch.

J. Install an ignition device in a high-power rocket motor only at the launch pad.

K. Launch Operations

1. Do not launch with surface winds greater than 20 mph (32 km/h) or launch a rocket at an angle more than 20 degrees from vertical.
2. Do not ignite and launch a high-power rocket horizontally, at a target, in a manner that is hazardous to aircraft, or so the rocket's flight path goes into clouds or beyond the boundaries of the flying field (launch site).
3. A rocket shall be pointed away from the spectator area and other groups of people during and after installation of the ignition device(s).
4. Firing circuits and onboard energetics shall be inhibited until the rocket is in the launching position.
5. Firing circuits and onboard energetics shall be inhibited prior to removing the rocket from the launching position.
6. When firing circuits for pyrotechnic components are armed, no person shall be allowed at the pad area except those required for safely arming/disarming.
7. Do not approach a high-power rocket that has misfired until the RSO/LCO has given permission.
8. Conduct a five second countdown prior to launch that is audible throughout the launching, spectator, and parking areas.
9. All launches shall be within the Flyer's certification level, except those for certification attempts.
10. The RSO/LCO may refuse to allow the launch or static testing of any rocket motor or rocket that he/she deems to be unsafe.

II. Commercial Launches

A. Use only certified rocket motors.

B. Do not dismantle, reload, or alter a disposable or expendable rocket motor, nor alter the components of a reloadable rocket motor or use the contents of a reloadable rocket motor reloading kit for a purpose other than that specified by the manufacture in the rocket motor or reloading kit instructions.

C. Do not install a rocket motor or combination of rocket motors that will produce more than 40,960 N-s of total impulse.

D. Rockets with more than 2560 N-s of total impulse must use electronically actuated recovery mechanisms.

E. When more than 10 model rockets are being launched simultaneously, the minimum spectator distance shall be set to 1.5 times the highest altitude expected to be reached by any of the rockets. Tripoli Rocketry Association Safe Launch Practices

F. When three or more rockets (at least one high power) are launched simultaneously, the minimum distance for all involved rockets shall be the lesser of:

1. Twice the complex distance for the total installed impulse. (refer to V. Distance Tables)
2. 2000 ft (610 m)
3. 1.5 times the highest altitude expected to be achieved by any of the rockets.

G. When more than one high power rocket is being launched simultaneously, a minimum of 10 ft (3 m) shall exist between each rocket involved.

MINIMUM DISTANCE TABLE

Installed Total Impulse (Newton-Seconds)	Equivalent High-Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 -- 160.00	G or smaller	N/A	30	30
160.01 -- 320.00	H	50	100	200
320.01 -- 640.00	I	50	100	200
640.01 -- 1,280.00	J	50	100	200
1,280.01 -- 2,560.00	K	75	200	300
2,560.01 -- 5,120.00	L	100	300	500
5,120.01 -- 10,240.00	M	125	500	1000
10,240.01 -- 20,480.00	N	125	1000	1500
20,480.01 -- 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Design and Safety Review

Endeavoring to have all teams perform their flights in a safe and controlled manner, each team must have a non-student mentor that reviews the design and construction of their rocket in advance of the competition flight by a person holding at least a High-Power Rocket Level 2 Certification with Tripoli or NAR. If you need assistance in finding a rocketry mentor, please contact the competition Technical Advisor and they will help you with this task. A Safety Review Meeting will occur the evening before the competition launch date that will be mandatory for all teams.

Interacting with the mentor is required, not optional. The mentor must submit a form (see APPENDIX A-5) discussing their interactions with the team along with each of the first two written reports. Teams – make sure they have something to say (and make sure it is positive)!

The teams must be prepared to discuss the design of their rocket and its systems. In addition, the teams must be able to demonstrate:

- Their rocket in various state of assembly including full exposure of the AV-bay internal structure
- A diagram of the rocket indicating the configuration of its main components
- Flight simulation showing max altitude and launch rail departure velocity (speed at 8 ft – this should exceed 45 ft/s)
- Commercial rocketry altimeter(s) for ejection charge deployment (user manual)
- Pre-flight Checklist
- Launch Pad and Flight Arming Checklist
    - Must include the altimeter(s)' ready/standby tones
- Recovery/Post-flight Checklist
    - Must include procedure to "safe" unexploded deployment charges (if any) and turn off payload (if needed for safety reasons)

Pre-flight Safety Inspection

On flight competition day, all teams must have their rockets inspected before they will be allowed to proceed to the launch pad. The teams must be prepared to discuss their rocket's design and its deployment systems. In addition, the teams must display:

- Team's rocket, readied for launch
    - Center of Gravity (CG) for each flight and Center of Pressure (CP) must be clearly marked on the rocket's exterior
- Pre-flight Checklist (showing that all steps have been completed up to launch)
- Launch Pad and Flight Arming Checklist
    - Must include the altimeter(s)' ready/standby tones
- Recovery/Post-flight Checklist
    - Must include procedure to "safe" unexploded deployment charges (if any) and turn off payload (if needed for safety reasons)

Post-flight Check-in

Following the team's competition flights the team must follow their Recover/Post-flight Checklist to insure a safe recovery. The team then proceeds to the recovery check-in with:

- The team's rocket
- Recovery/Post-flight Checklist
    - Must show that all steps in the recovery procedure were completed before approaching the check-in station

At this check-in the rocket will be inspected and flight data, including flight video (if any) will be downloaded before the rocket is released to be prepped for additional flight(s). The one-hour prep timer (for successful flights only) will start when the rocket is released from the post-flight check-in. If a rocket has an unsuccessful flight but is reparable and re-flyable, the timer will begin after the rocket has been repaired – don't rush that!

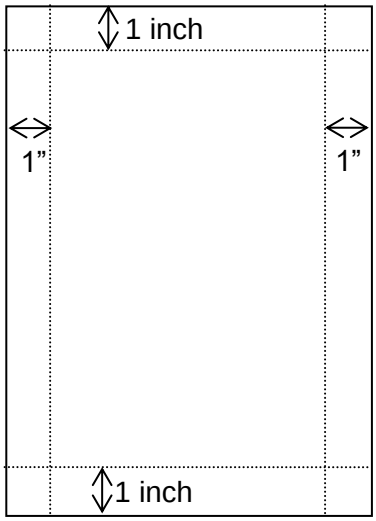
Preliminary Design (Written) Report

Design Report Objective

The purpose of this design report is to evaluate the engineering effort that went into the design of the rocket and how the engineering meets the intent of the competition. The document that illustrates the best use of engineering principles to meet the design goals and the best understanding of the design by the team members will score the highest.

Report Format

The design report can be no longer than twenty five (25) single-sided pages in length. It must be in a font not smaller than 12 pt and no less than single-spaced. All margins must be no less than 1 inch from the edge of the page. All pages (except for the cover page) must be numbered in the upper right hand corner. Each section of the report must be clearly delineated with a heading. All section headings must appear in a table of contents. Reports must be submitted electronically in *.pdf* format.



Material that must be included, as a minimum:

- Separate Cover Page (counts toward page limit)
- Team Name, School Name, Team Mentor, Team Faculty Adviser (with contact information including both e-mail and cell phone), Student Team Lead (with contact information including both e-mail and cell phone), and a listing of all Student Team Members – this information can all go on the Cover Page
- Separate Table of Contents page (counts toward page limit)
- Separate Executive Summary page (1 page max, counts toward page limit)
- Design Features of Rocket Airframe, including mounting of cameras
- Design Features of Electronics/Payload (i.e. video text overlay, commercial altimeter, non-commercial system to monitor and log acceleration, pressures, etc.)
    - Usability and Reliability Design Features of the Avionics Bay (i.e., ease of assembly, sled layout, power layout, wiring layout, switch positions, etc.)

    - Details about the wiring of the video cameras including details about post-landing operations (which might involve lifting one camera off the ground for panoramic photography)
    - Details about superimposing sensor data onto video footage from at least one camera in real time
- Diagram of Rocket Identifying the dimensioned locations for the:
    - CP (center of pressure)
    - CG (center of gravity when fully loaded (i.e. with rocket motor installed))
- Analysis of the Anticipated Basic Flight Performance – including information about how each were estimated
    - Estimated Maximum Altitude
    - Estimated Peak Velocity
    - Estimated Peak Acceleration
    - Estimated Descent Speed under "Apogee Parachute"
    - Estimated Main + Drogue (AKA Landing) Speed, if implementing dual deploy
- Budget (planned, including (value of) Registration fee and Competition Travel)
    - For two-camera system, must include actual cost of new equipment even if your team didn't need to spend that much - $200 max
- Required Mentor Report Form (see Appendix A-5)

Evaluation Criteria

Reports and design will be evaluated on content, organization, clarity, completeness, and professionalism of the material. The criteria are detailed in Appendix A-1 "Preliminary Design Report Judging."

Scoring Formula

The scoring of the Preliminary Design Report is based on the average of the Preliminary Design Report Judging forms. There is a maximum of 100 points from the Preliminary Design Report Judging form that will be scaled for the final competition weighting.

Flight Readiness (Written) Report

Flight Performance

The team will report on the success of the test flight(s) including, but not limited to, sensor logging, video recording, and recovery system operation. Comparison of the fight performance to the predicted performance shall also be included, to demonstrate the team's knowledge and understanding of the physics involved. This will be presented in the form of a brief report which shall include a discussion of the results, especially any differences between the actual performance and predicted values.

Test Flight Format

The test flight document should follow the same formatting guidelines as the Preliminary Design Report, no more than twenty five (25) pages in length, and must be submitted electronically in *.pdf* format.

Material that must be included, as a minimum:

- Separate Cover Page with information requested for PDR (updated, if need be) (counts toward page limit)
- Separate Table of Contents page (counts toward page limit)
- Summary of Design, especially the AV-bay, the two-camera system, and the non-commercial sensor suite system (keep this to 5 pages or less)
- Budget (actual; with comments about changes since planned budget)
  - For two-camera system, must include actual cost of new equipment even if your team didn't need to spend that much - $200 max
- Construction of Rocket (include photos as well as a discussion of the AV-bay)
- Explicit discussion of any special construction issues like surface finishes, lay-ups to strengthen fins, etc.
- Photographs of Completed Rocket and video, if any, from Test Flight(s)
- Test Flight(s) Sub-report
  - Actual flight Performance (as compared to simulated performance)
  - Recovery System Performance
  - Table of Flight Characteristics (mass, motor, max altitude, max velocity, …)
- Discussion of Results
  - Compare predicted and actual apogees, predicted and actual peak velocities, and predicted and actual peak accelerations. Describe differences and defend possible reasons for differences (if any)
  - Discuss effectiveness of roll mitigation, whether passive or active
  - Compare predicted and actual descent speeds, describe and defend possible reasons for differences (if any)
  - Discuss the performance of the video camera system, if flown
  - Discuss the performance of the non-commercial sensor suite system, if flown
- Planned changes/improvements (if any) prior to the competition flights
- Required Mentor Report Form (see Appendix A-5)
- NEW (outside of 25 page limit): Appendix with text listing of all microcontroller flight code for non-commercial sensor suite, real-time text overlay onto video file (no post-flight addition of text to video files), panoramic camera mechanism operation (if controlled by a microcontroller), etc.

Evaluation Criteria

Reports will be evaluated on how closely the predicted results compare to the actual results, how well the team explains any differences, plus clarity, completeness, and professionalism of the material. The criteria are detailed in Appendix A-2 “Flight Readiness Written Report Judging.”

Scoring Formula

The scoring of the Flight Readiness Written Report is based on the average of the Flight Readiness Written Report Judging forms. There is a maximum of 100 points from the Flight Readiness Written Report Judging form that will be scaled for the final competition weighting.

Educational Outreach

Educational Outreach Performance (EPO)

An “Educational Outreach” event is expected in which each team presents information related to their work on this competition with at least 10 people, typically in a group format, who are not involved in the competition. For purposes of this competition, outreach will be scored as "completed" or "not completed." Outreach possibilities could include, but are not limited to:

- Meet with a K-12 class or student organization to explain how rockets work (including discussing your rocket design and/or your actual rocket and/or your test flight results).
- Make a presentation in the community or to a group on campus to describe this rocket competition and your team’s design, rocket, results, etc.

Evaluation Criteria

At the completion of the outreach event the team will need to have a representative at the event fill out and return to them an EPO (Education/Public Outreach) form (located on the last page of this handbook) that the team must then submit to their state’s Space Grant and to the competition organizers by e-mail.

Scoring Formula

Teams that do not complete the Educational Outreach and submit their EPO form by the due date will receive a 10% decrease in their team’s overall score.

Flight Readiness (Oral) Presentation

Presentation Format

In the late afternoon or evening of the first day of the competition, one or more team members will deliver an oral presentation to a panel of judges. All team members who will deliver any part of the presentation, or who will respond to the judges' questions, must stand in the podium area when the presentation starts and must be introduced to the judges. All team members who are part of this "presentation group" may answer the judge's questions, even if they did not present material during the presentation itself.

Oral presentations are limited to a maximum of ten (10) minutes. The judges will stop any presentation exceeding eleven (11) minutes. The presentation itself will not be interrupted by questions. Immediately following the presentation there will be a question and answer session of up to three (3) minutes. Only judges may ask questions (at first). Only team members who are part of the "presentation group" may answer the judges' questions. If time allows, there may be opportunity to take additional questions from the audience. If questions are asked by the audience, a designated competition official will determine if the question is appropriate and, if so, will allow the team to answer.

In addition to the 10-minute presentation described above, each team will also do an oral safety check with a representative of Tripoli MN (which does not count toward the FRR score) and show one or more judges their full-opened AV-bay (which does count toward their FRR score). These will not be timed events but the AV-bay examination will need to be fairly quick – perhaps about another two or three (2-3) minutes to show off your AV-bay and answer any questions from the judge(s).

Evaluation Criteria

Presentations will be evaluated on content, organization, visual aids, delivery, and the team's response to the judges' questions. The scoring criteria are detailed in Appendix A-3 "Flight Readiness Oral Presentation Judging." The criteria are applied only to the team's presentation itself. The team that delivers the best oral presentation, regardless of the quality of their actual rocket, will score highest for the oral presentations.

Scoring Formula

The scoring of the Oral Presentation is based on the average of the Oral Presentation Judging forms. There is a maximum of 100 points from the Oral Presentation Judging form that will be scaled to meet the final competition weighting.

Competition Flight

Launch and Flight Format

The launch will take place at a site determined by Tripoli Minnesota (near North Branch, MN, which is about a one-hour drive north of Minneapolis and St. Paul). Each rocket must pass a safety inspection before each flight and any additional equipment must be cleared by the Range Safety Officer (RSO) before entering the launch area. The official flight data recorder, an Altimeter Two, will be placed in the rocket by a competition official or designee or, minimally, proper placement and arming will be verified by such an official prior to each flight. Note: Altimeter Two data loggers can time out if they don't detect a launch soon enough after they are armed so be sure to design your rocket so the Altimeter Two can be armed and inserted easily just before launch (and is accessible enough to be re-armed easily, if need be). No more than five team members per Tripoli member may tend to the rocket once it is in the launch area. Each team must also field a recovery team/subteam that will follow the directions of the RSO or designee.

All rockets must be designed so that they can be prepared for flight within one hour. Therefore, the following additional requirements are in effect:

- All teams must present their rockets in ready-to-fly condition to the RSO within one hour of the end of the on-site launch briefing at the start of the day. The specific time will be announced on site, but this will be approximately 10:15 a.m. on flight day (assuming the briefing runs from about 9:00 to 9:15 a.m.).
- Upon completion of providing flight data to the flight operations recorder after each flight, the time will be recorded and the team must again present their rocket in ready-to-fly condition to the RSO within one hour of that time.
- Teams that do not meet these pre-flight time requirements will be allowed to fly, but will be subjected to (modest) late-flight penalties. Again, safety is more important than timeliness. Achieve the 1-hour goal by practice, not by rushing.
- Wait time in the RSO line does not count against the 60-minute clock.

To be considered a safe and (nominally) successful flight, the rocket must:

- Launch
- Rocket flies vertically (the launch rail will be vertical itself)
- Rocket is stable throughout the ascent
- Recovery system (apogee parachute only or drogue + main parachutes, if dual deploy) is successfully deployed
- Landing speed is deemed reasonable (≤ 24 ft/sec)
- All rocket components remain attached throughout the flight (e.g., no disassembly or shedding of components) (exception – allowed to disconnect parachute(s) after landing, as long as they are also recovered)
- Rocket must be recovered in flyable condition
- Note: Failure to log sensor data and/or to collect video will not, in and of itself, constitute a failed flight if the conditions above are met. For example, there will not be an explicit deduction or disqualification if part of the recovery system is ejected successfully by the back-up charge rather than by the primary charge. A dual-deploy rocket that lands at a safe velocity and is undamaged, even if both parachutes didn't deploy exactly as planned, will not be subject to disqualification

but might sustain a point deduction. However in dual-deploy rockets failure to deploy a main parachute may well, depending on the size of drogue, result in a too-fast landing and result in disqualification, even if the rocket is undamaged (judges' discretion).

The stability condition (i.e. "static margin between 1 and 5 on launch (max weight)") is a safety consideration. Safety decisions (associated with stability, among others) will be made by the launch-site judges. If need be, the judges may use "instant replay" (i.e. ground video footage of the launch and/or on-board footage from the rocket itself) to assist them in making their decision. Rockets (or parts thereof) that go unstable during ascent, even unintentionally, will be subject to disqualification on safety grounds, even if they aren't actually damaged upon landing.

Flyable condition is defined to be that if the flyer were handed another motor, the rocket would pass RSO inspection and could be put on the pad and flow again safely. Rockets that sustain only minor damage sometimes can still qualify as flyable.

The entire rocket must be returned to a designated location for post-flight inspection by the RSO or designee.

A flight performance report sheet will be filled out by a designated flight operations recorder. The flight operations recorder will record the Altimeter Two data following each flight and make a copy of the on-board video footage and the on-board sensor log(s). Upon completion of this data download, a team member must sign their initials of acceptance before the rocket will be released to the team for additional flight(s).

Evaluation Criteria

Finishing order for of the competition flights will based on:

- Having timely launches and safe flights
- Having successful flights and recoveries, as defined above
- Meeting the mission requirements, which are different for the two flights

Scoring Formula (Figures of Merit)

Teams competition flight score will be based on the following formulas:

Figure of Merit 1 (FM1) (a point value between 0 and 35) (only applies to rockets with a fully-successful or-partially successful Flight 1 (i.e. not disqualified):

Altitude Ranking 1 (AR1) (a point value between 0 and 15)
AR1 = 15*(1- $\left|$ *(2345 feet – actual apogee)/500 feet* $\right|$) *or zero, whichever is greater*

Video sensor-text overlay V1 (a fraction between 1 and 0.75)
V1 = 1 for complete/live sensor-text overlay on at least one video saved during flight
V1 between 1 and 0.75 (judges' discretion); some text overlay, but not complete/live
V1 = 0.75 for no text overlay on any flight video

Photography Ranking 1 (PR1) (a point value between 0 and 20 + 5 bonus points possible)

{quality of view (up to 2.5 points)
+ quality of ascent footage (minimizing roll*) (up to 5 points)
+ quality of descent footage ("other part" in view**) (up to 5 points)
+ quality of post-landing footage (panorama & height) (up to 2.5 + 5 points***
+ possible 5 bonus points)}

FM1 = AR1 + V1*PR1

Figure of Merit 2 (FM2) (a point value between 0 and 35) (only applies to rockets with a fully-successful or-partially successful Flight 1 (i.e. not disqualified):

Altitude Ranking 2 (AR2) (a point value between 0 and 15)

AR2 = 15*(1- │*(3456 feet – actual apogee)/750 feet*│) *or zero, whichever is greater*

Video sensor-text overlay V2 (a fraction between 1 and 0.75)

V2 = 1 for complete/live sensor-text overlay on at least one video saved during flight
V2 between 1 and 0.75 (judges' discretion); some text overlay, but not complete/live
V2 = 0.75 for no text overlay on any flight video

Photography Ranking 2 (PR2) (a point value between 0 and 20 + 5 bonus points possible)

{quality of view (up to 2.5 points)
+ quality of ascent footage (minimizing roll*) (up to 5 points)
+ quality of descent footage ("other part" in view**) (up to 5 points)
+ quality of post-landing footage (panorama & height) (up to 2.5 + 5 points***
+ possible 5 bonus points)}

FM2 = AR2 + V2*PR2

* 5 points for "essentially no roll" (achieved actively or passively) down to 2.5 points for "average roll" down to ~0.5 points for "collected ascent video, but spinning wildly" – judges' discretion (note: these points may be awarded based on just a single camera)
** 1 point for seeing "other part" (from two different parts of the rocket that separate) during separation plus up to 2 points for fraction of time "other part" is in view during descent plus up to 2 points for seeing "other part" during landing (points based on all camera views)
*** 2.5 points for quality of 360º panorama and, if successful in capturing a 360° view, up to 5 height points, awarded as follows (note: these points may be awarded based on just a single camera)

1 point: panorama taken from less than 1 foot off the ground
3 points: panorama taken from 1 to 2.5 feet off the ground
5 points (full credit): panorama taken from more than 2.5 feet off the ground
5 bonus points: panorama taken from more than 5 feet off the ground

The team must document, possibly by using photos showing a tape measure in view (or something similar/appropriate), the height above the ground the panoramic photo/video was taken from before touching the rocket during recovery. This "evidence of height"

must be submitted along with raw flight footage (see note below) immediately after each competition flight.

Only photos and/or video taken within 5 minutes of landing may be used for panoramic photography. The team must document, possibly by using duration of continuously-running video and/or by putting time stamps on video/photos, the relative time elapsed between landing and taking the panoramic photo/video. If you aren't using continuously-running video, at least take some photos/video immediately upon landing to establish the time of landing in the time stamps.

Post-flight processing of post-landing photos/video is allowed (for the Post-Competition Final Report) but teams will be required to submit a copy of their raw flight footage immediately after each flight and that will be used to assign a "quality of post-landing footage" (see note *** above) score for use in the Figure of Merit calculations above. Raw flight footage will also be used to assign "quality of view" (somewhat subjective, but will consider things like non-obstructed view, in focus footage, etc.) and "quality of ascent footage" (see note * above) and "quality of descent footage" (see note ** above) scores for use in the Figure of Merit calculations.

Note: Be prepared to download flight footage between flights (before the 60 minute timer starts) and to provide it to the judges in a standard-enough video format that they can view it. Collecting audio along with in-flight video is optional.

Flight Score = 0 (AKA disqualification) if rocket is not recovered in flyable condition or if the flight is deemed "unsafe" or in violation of competition rules, even if the rocket is undamaged or if the apogee is not within 500 feet (either higher or lower) of the intended apogee altitude. Rockets may be disqualified for events like unstable ascent, too-fast descent, not deploying recovery systems, etc. Rockets that are disqualified may be launched again later in the day if the disqualification issue(s) can be resolved to the RSO's satisfaction.

Flight Score (if not disqualified) = 10 points for two timely flights (loss of 2 points per 15 minutes over 60 minutes of prep time for either flight)
PLUS
20 points (10 points each) for completing two safe (fully or partially-successful) flights
PLUS
FM1
PLUS
FM2

Notice that up to 30 points will be awarded to rockets that are prepped in a timely manner and safely complete two flights and are recovered in flyable condition, even if they don't perform perfectly. There is a maximum of 100 points for the Competition Flight Score that will be scaled for the final competition weighting. If a rocket is flown more than twice during the competition, the best two flights (one of each type) will count (even if one or more other flights are disqualified). However there is a finite launch window and the Tripoli MN members running the launch might not allow you to launch a rocket that

appears to them (in advance) to be fundamentally unsafe, so don't expect to bend the safety limits nor bet too heavily on the prospect of flying more than twice.

If weather conditions – particularly low cloud cover – allow for Flight #1 but not Flight #2 for some rockets on the primary flight day, additional flights will be allowed on the weather-delay date. If weather prevents flights (of either type) altogether on both dates, teams will be given options to complete their flights at their home field at a later date and submit their flight results to the judges remotely.

Post-Flight Performance Report

Performance Comparison

The comparison of the fight performance to the predicted performance will help to demonstrate the team's knowledge and understanding of the physics involved. It will be presented in the form of a brief report that will include a "Flight Performance Comparison Sheet" and discussion of the results, especially any differences between the actual and the predicted values.

Performance Comparison Format

The performance comparison document should follow the same guidelines as the Preliminary Design Report, no more than fifteen (15) pages in length, and must be submitted electronically in *.pdf* format.

Material that must be included, as a minimum:

- Separate Cover Page with information requested for PDR (updated, if need be) (counts toward page limit)
- Flight Performance Comparison Sheet
  - Table of Flight Characteristics (mass, motor, max altitude, max velocity, max acceleration, etc.)
  - Plots of raw Acceleration, Roll Rate, and Pressure (from both sensors) vs Time from non-commercial sensor suite (at least) as well as Velocity vs Time (determined from pressure values)
  - Screenshots (at least a few) from the video system, if any, and link to where full flight videos can be viewed on-line (e.g. posted to YouTube)
- Discussion of Results
  - Compare predicted results with actual results as measured by you're your commercial and non-commercial sensor suites: discuss (at least) apogee, peak velocity, peak acceleration, success in quashing roll (active or passive), success in hitting target altitudes (active or passive), main deployment altitude (if dual-deploy), and landing speed – describe and defend possible reasons for differences. The competition-provided Altimeter Two data logger will give apogee, peak acceleration, peak velocity, and some other performance details, but nothing about roll.
  - Discuss photography data, including post-landing camera handling
  - Discuss any other optional-sensor data collected during the flight
- Code Appendix (outside of 15 page limit) (only if code changed since FRR)
  - Update the code appendix, if any flight code changed after the FRR.

Evaluation Criteria

Reports will be evaluated on how closely the predicted results compare to the actual results and how well actual values from various sources agree with one another, how well the team explains any differences, as well as clarity, completeness, and professionalism of the material. The criteria are detailed in Appendix A-4 "Post-Flight Performance Report Judging."

Scoring Formula

The scoring of the Post-Flight Performance Report is based on the average of the Post-Flight Performance Report Judging forms. There is a maximum of 100 points from the Post-Flight Performance Report Judging form that will be scaled for the final competition weighting.

APPENDIX A-1

PRELIMINARY DESIGN REPORT JUDGING

Score the following categories according to the following scale (any number or fraction along this scale may be used).

0 = inadequate or no attempt
¼ Max Value = attempted but below expectation
½ Max Value = average or expected
¾ Max Value = above average but still lacking
Max Value = excellent, perfectly meets intent

_____ **OVERALL TEXT RELEVANCE (15 pts)**

- Executive Summary (5 pts)
- Overall description of rocket functions (5 pts)
- Design fit to competition objectives (5 pts)

_____ **ROCKET MECHANICAL & ELECTRICAL DESIGN (25 pts)**

- Airframe and Propulsion System Specifications (with dimensions) (5 pts)
- Recovery System Design Specifications (3 pts)
- Avionics/Payload System Design Specifications (5 pts)
- Camera System Design, including text overlay plans (5 pts)
- Planned Construction Solutions & Techniques (4 pts)
- Structural Analysis of Scratch-Built Parts and Overall Risk Mitigation Analysis (3 pts)

_____ **PREDICTED PERFORMANCE FOR BOTH FLIGHTS (25 pts)**

- Launch Analysis (5 pts)
- Flight Analysis (peak altitude, peak velocity, peak acceleration, etc.) (5 pts)
- Recovery Analysis (5 pts)
- Stability Analysis (5 pts)
- Environmental Conditions Analysis (5 pts)

_____ **SAFETY (20 pts)**

- Designed for Safe Flight & Recovery (5 pts)
- Documented Material-Handling Procedures (5 pts)
- Planned Assembly Procedures (5 pts)
- Planned Pre- & Post-Launch Procedures (5 pts)

_____ **REPORT AESTHETICS (15 pts)**

- Followed Specifications (3 pts)
- Consistent Formatting (3 pts)
- Correct Spelling and Grammar (3 pts)
- Documented Figures and Graphs (3 pts)
- References and Labeling (3 pts)

_____ **TOTAL PRELIMINARY DESIGN REPORT POINTS (100 points maximum)**

COMMENTS:

APPENDIX A-2

FLIGHT READINESS WRITTEN REPORT JUDGING

Score the following categories according to the following scale (any number or fraction along this scale may be used).

0 = inadequate or no attempt
¼ Max Value = attempted but below expectation
½ Max Value = average or expected
¾ Max Value = above average but still lacking
Max Value = excellent, perfectly meets intent

_____ **RECAP OF ROCKET DESIGN (25 pts)**

- Design and Dimensions (3 pts)
- Construction Techniques (3 pts)
- Stability Analysis (3 pts)
- Constructed for Safe Flight & Recovery (4 pts)
- AV-bay Design - tough but user-friendly (4 pts)
- Video camera design (4 pts)
- Discussion of Changes Since Preliminary Design Report (4 pts)

_____ **ROCKET OPERATION ASSESSMENT (25 pts)**

- Launch, Boost, and Coast Phase Analysis (10 pts)
- Recovery System and Descent Phase Analysis (10 pts)
- Pre- & Post-Launch Procedure Assessment (5 pts)

_____ **TEST LAUNCH ACTUAL VS PRED. PERFORMANCE (35 pts)**

- Peak Altitude Comparison to Expectations (10 pts)
- Peak Velocity and Peak Acceleration Comparison to Expectations (10 pts)
- Discussion of roll mitigation (active or passive) (5 pts)
- Recovery System Performance Comparison to Expectations (10 pts)
- Video Results, non-Commercial Sensor Suite Results, and/or panoramic photography mechanism, if any – test flying these is optional, but recommended – if you did fly them, by all means discuss your results (0 pts)

_____ **FINDINGS AND FUTURE WORK (8 pts)**

- Key Findings (4 pts)
- Potential Design Improvements (4 pts)

_____ **CODE APPENDIX (2 pts)**

_____ **REPORT AESTHETICS (5 pts)**

_____ **TOTAL POST-FLIGHT PERFORMANCE REPORT POINTS (100 points maximum)**

COMMENTS:

APPENDIX A-3

FLIGHT READINESS ORAL PRESENTATION JUDGING

Score the following categories according to the following scale (any number or fraction along this scale may be used).

0 = inadequate or no attempt
¼ Max Value = attempted but below expectation
½ Max Value = average or expected
¾ Max Value = above average but still lacking
Max Value = excellent, perfectly meets intent

_____ **ENGINEERING & DESIGN CONTENT (28 pts)**

- Discussion of Engineering Methodology (4 pts)
- Use of Design Tools (4 pts)
- Thorough Presentation of Custom Rocket Design and How It Addresses Competition Objectives/Requirements (12 pts)
- Use of Analytical Data – Comparison of Test Flight(s) Performance to Expectations (4 pts)
- Description of Construction Techniques (4 pts)

_____ **ORGANIZATION (20 pts)**

- Logical Organization & Structure (5 pts)
- Presentation Clarity (5 pts)
- Use of Visual Aids as Support Material (5 pts)
- Balance & Transitions Among Presenters (5 pts)

_____ **VISUAL AIDS (10 pts)**

- Appropriate Use of Text (2 pts)
- Informational Charts & Illustrations (2 pts)
- Appropriate Design and Use of Graphics (2 pts)
- Use of Supporting Physical Materials (2 pts)
- Appropriate Use and Formatting of Slides (2 pts)

_____ **ROCKET EXPERNAL/OVERALL APPEARANCE (6 pts)**

- Visual Appearance (3 pts)
- Quality of Construction (3 pts)

_____ **AV-BAY (INTERNAL APPEARANCE (UNTIMED)) (8 pts)**

- Appropriateness of Design (tough, yet user friendly) (4 pts)
- Quality of Construction (4 pts)

_____ **COMMUNICATION SKILLS (20 pts)**

- Articulation (4 pts)
- Eye Contact (4 pts)
- Verbal Projection (4 pts)
- Body Language/Poise/Presence (4 pts)
- Adherence to Time Constraints (4 pts)

_____ **QUESTION & ANSWER (8 pts)**

- Active Listening Skills (2 pts)
- Answer Relevance/Correctness (4 pts)
- Response Confidence/Persuasiveness (2 pts)

_____ **TOTAL ORAL PRESENTATION POINTS (100 points maximum)**

COMMENTS:

APPENDIX A-4

POST-FLIGHT PERFORMANCE REPORT JUDGING

Score the following categories according to the following scale (any number or fraction along this scale may be used).

0 = inadequate or no attempt
¼ Max Value = attempted but below expectation
½ Max Value = average or expected
¾ Max Value = above average but still lacking
Max Value = excellent, perfectly meets intent

_____ **ROCKET OPERATION ASSESSMENT (30 pts)**

- Flight Anomalies Analysis (10 or 0 pts)
  {If no anomalies, then points are distributed to remaining subsections}
- Propulsion System Assessment (4 or 6 pts)
- Flight Trajectory Assessment (4 or 6 pts)
- (In-flight) Recovery System Assessment (4 or 6 pts)
- Ground Recovery Assessment (4 or 6 pts)
- Pre- & Post-Launch Procedure Assessment (4 or 6 pts)

_____ **ACTUAL VS PREDICTED PERFORMANCE (55 pts)**

- Peak Altitude Comparison to Expectations (10 pts)
- Peak Velocity and Peak Acceleration Comparison to Expectations (5 pts)
- Discussion of roll mitigation (active or passive) (10 pts)
- Recovery System Performance Comparison to Expectations (5 pts)
- Discussion of Video Results: ascent, descent, post-landing (including panoramic photography mechanism, if any) (15 pts)
- Discussion of Non-Commercial Sensor Suite Results, as compared to commercial altimeter results (10 pts)

_____ **UPDATED CODE APPENDIX (if any changes since FRR) (2 pts)**

- If no changes, state that explicitly.

_____ **REPORT AESTHETICS (13 pts)**

- Followed Specifications (3 pts)
- Professionally Written (5 pts)
- Accurate Representation of Events (5 pts)

_____ **TOTAL POST-FLIGHT PERFORMANCE REPORT POINTS (100 points maximum)**

COMMENTS:

APPENDIX A-5

MENTOR REPORT FORM

Mentors are to use this form to report their interaction with their teams. Mentors must submit this form to the Technical Advisor by the date and time specified for each report. We anticipate that mentors need to spend at least a few hours with each team for each report – and possibly more than a few for less experienced teams. We thank you in advance for your time!

Mentor Name: _____ TRA/NAR #: _____

Team Name: _____ School Name: _____

Current phase of the competition: ☐ Preliminary Design ☐ Flight Readiness

For the current phase of the competition indicate:

In person:
Number of Interactions: _____ Number of Interaction Hours: _____

Remote (Phone, Skype, e-mail, …):
Number of Interactions: _____ Number of Interaction Hours: _____

List of Topics Discussed: _____

General Comments about Team Interactions & Mentoring Discussions:

General Comments about Difficulties/Obstacles with Team Interactions & Mentoring:

APPENDIX A-6

DRAFT OF DESIGN FORM

Submit this to your mentor and to the competition Technical Adviser BEFORE YOU START TO BUILD – definitely no later than February 15, 2020 and possibly much earlier than that if you start working on this competition in the fall of 2019. Expect feedback from Gary Stroick within one week. Pay attention to it!

- Simulation file (OpenRocket or RockSim) including the basic airframe with the supersonic motor selected – (be sure to fully describe extra items you include – don't just call them "mass objects")
- List basic specs (especially material and dimensions (including thickness)) of fins, airframe, coupler tube (if any), centering rings and bulkplates, nose cone, retention harness, eyebolts (forged or not) (plus other attachment types such as shear pins, rivets, epoxy joints, etc.)
- Brief discussion of how motor will be retained (in both directions), how retention harness will be attached, and how fins will be attached (and possibly reinforced)
- Brief discussion of what commercial altimeter(s) you will use for the supersonic flight and what they will be called up to do (log what sort of data, make what sort of decisions (about when to fire ejection charges), etc.)

2019-2020 NASA's Space Grant Midwest High-Power Rocket Competition Education/Public Outreach Documentation Form

The Minnesota Space Grant Consortium (MnSGC), on behalf of NASA, would like to thank you for giving our Midwest High-Power Rocket Competition participants a chance to provide educational outreach to your organization. Please take a moment to fill in some information below to verify the students' participation. A portion of their competition score is based on their outreach activities, so your willingness to let them present to you is appreciated.

One main goal of Space Grant activities nationwide is to "raise awareness of, or interest in, NASA, its goals, missions and/or programs, and to develop an appreciation for and exposure to science, technology, research, and exploration."[1] Space Grant Consortia in every state promote science, technology, engineering, and math (STEM) fields through educational opportunities for college/university students, such as this rocket competition. We are also grateful for your involvement in this mission. If you have any questions about the Midwest High-Power Rocket Competition or about NASA's Space Grant program, please contact the MN Space Grant Consortium (MnSGC), which is running this competition, by writing to mnsgc@umn.edu, or else contact your state's Space Grant Consortium directly. Web sites can be found at:

http://www.nasa.gov/offices/education/programs/national/spacegrant/home/Space_Grant_Consortium_Websites.html

Activity 1 (required)

Name of Organization	Supervisor Name	Phone or e-mail
Duration of Activity (hrs)	Signature	Date
Approx. # of Attendees	Brief descrip. of attendees	Brief decrip. of activity

Activity 2 (optional)

Name of Organization	Supervisor Name	Phone or e-mail
Duration of Activity (hrs)	Signature	Date
Approx. # of Attendees	Brief descrip. of attendees	Brief decrip. of activity

1 – Source: *Explanatory Guide to the NASA Science Mission Directorate Education & Public Outreach Evaluation Factors*, Version 3.0, April 2008