2015-2016

NASA's Space Grant Midwest High-Power Rocket Competition Handbook

Informational telecons: Tues. Sept. 22, 2015 (then repeated Thurs. Jan. 21, 2016) from 7 to 8 p.m. CST

(Contact James Flaten, MN Space Grant, for call-in information)

Notice of Intent to Compete: Oct. 1, 2015

Registration Deadline: January 29, 2016

Launch Competition in Minnesota: Sun. & Mon., May 15-16, 2016 (Rain date: Tues., May 17, 2016)

Main contacts:

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

Web site:

http://www.aem.umn.edu/mnsgc/Space_Grant_Midwest_Rocketry_Competition_2015_2016

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Competition Objective

The Space Grant Midwest High-Power Rocket Competition is intended to supply student teams of affiliated universities with the opportunity to demonstrate engineering and design skills through practical application. Teams conceive, design, document, fabricate and compete with high-power rockets. 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 students that would not otherwise be available in the region.

Rocket Design Objectives

The objective of this year's competition is as follows:

> *Student teams will design and construct a high-power rocket with an active drag system that will reach an apogee of at least 3000 ft above ground level and be recovered safely and in flyable condition, predict its flight performance (both with and without the drag system engaged), and construct a non-commercial on-board data collection package for the rocket that will characterize its coefficient of drag over time and use an on-board video camera to document the state of the drag system (e.g. engaged/deployed, disengaged/retracted etc.). Note that 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 drag system for a high-power rocket. Such a system employs a mechanism to increase atmospheric drag on command, engaged after motor burnout then fully disengaged (i.e. retract any parts that are deployed to return the rocket to its burnout geometry) prior to apogee, without the use of any parts that detach from the rocket. The rocket must be fin-stabilized with a static margin of one or greater but less than or equal to five during the entire flight (i.e. it must fly stably with the drag system both engaged and stowed) and designed to land safely. The rocket must use electronic deployment of a parachute recovery system ejected at or after apogee using a commercial rocketry altimeter that will safely land the vehicle. The motor ejection charge must remain in place as a back-up to the electronic deployment system. All structural components and materials must be obtained from reputable high powered 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:

1. The same unmodified commercial motor is used in all flights
2. The mass of the rocket is identical in all flights
3. One flight does not activate the drag system and reaches an apogee of at least 3000 ft AGL
4. One flight activates the drag system after motor burnout and fully deactivates (i.e. fully retracts any deployed parts) it prior to the first recovery deployment event (i.e. prior to apogee)

and whose rocket comes closest to achieving the target apogee percentage: drag-activated apogee exactly 75% of drag-deactivated apogee, as recorded by a competition-provided flight recorder. Please note that teams may make multiple attempts at each type of flight (activated and/or deactivated drag system) and may select which two flights are to be judged. However rockets must fly deactivated first, to establish an apogee target to aim for on the drag-activated flight(s). Bear in mind that rocket motors may vary ±10% from the manufacturer, so the most responsive drag system will be one that can actually compensate for variation in motor impulse.

Teams must also construct a non-commercial data collection package for the rocket to characterize the rocket's coefficient of drag throughout each of the flights and a video system (may be an external or an internal view) to document the status (i.e. engaged/deployment, disengaged/retracted, etc.) of the drag system.

Figure 1. Events during rocket flight.

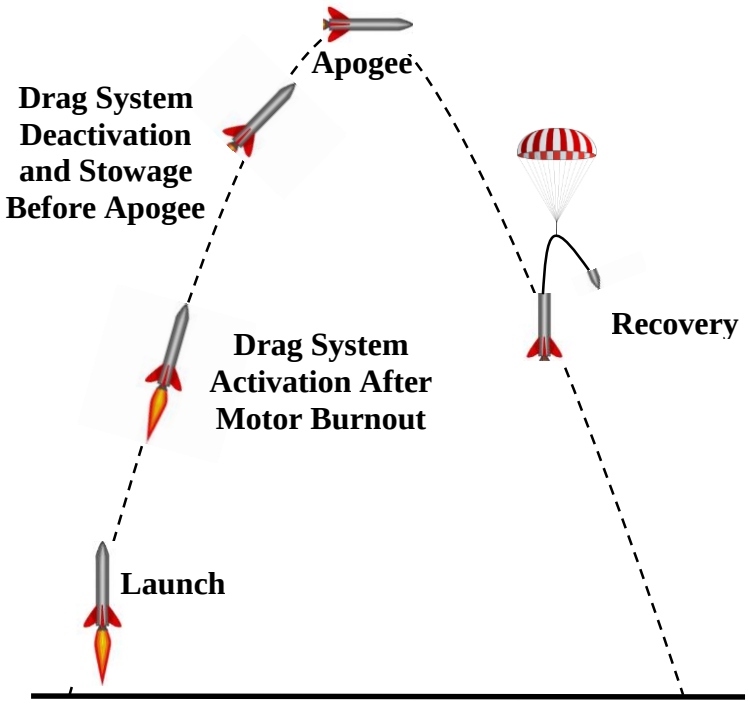


Table 1. Competition Parameters

Flight Mission	⇤ Use an active drag system to attain an altitude of exactly 75% of the not-deployed apogee (of at least 3000 ft AGL) with the same rocket flown on the same motor. Document the state of the drag system with on-board video and collect sensor data to characterize the effectiveness of the drag system as a function of time. Fully disengage/retract the drag system prior to apogee.
Rocket Recovery	⇤ Electronic ejection of a recovery system no earlier than apogee using a commercial rocketry altimeter required ⇤ Dual deployment optional (but this may help minimize recovery time between flights) ⇤ Motor ejection backup (post-apogee) is required ⇤ Apogee/Main Parachute required ⇤ Ejection of recovery parachute during ascent prohibited ⇤ Ejection of recovery system while drag system is still activated/deployed is prohibited ⇤ Landing speed $\leq$ 24 ft/sec.
Rocket Constraints	⇤ Each team must prepare a mounting location for a competition Altimeter Two data recorder – make it accessible! ⇤ 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 5 p.m. Wait-time in the RSO line will not count against the 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 competition flight data extracted. Modest point deductions will be made for taking longer than one hour to prep a rocket but DO NOT JEOPARDIZE 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 4 p.m. ⇤ The static margin of the rocket must be greater than or equal to 1 and less than or equal to 5 during the entire ascent, with drag system both engaged and stowed.
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 rocket experience may request a waiver of this requirement from the competition Technical

	Advisor. Teams may satisfy this requirement by building and flying a (non-competition) high-power rocket rather than a model rocket if they wish.
Required Pre-Competition Test Flight	⇤ Each team must assemble, fly, and successfully recover their fully-functional competition rocket at least once 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 oral presentation.) Here "fully-functional" means that the rocket at least has the drag system and the recovery system fully operational and utilized in flight. (i.e. A single test flight with the drag system turned off is insufficient to satisfy this requirement.) If you elect not to fly all of your other electronics (e.g., drag system monitoring electronics), replace them with dummy weights so the vehicle performance is as accurate as possible. It is recommended, although not required, that the rocket be flown on the planned competition motor (see below). The test flight must be performed using at least a high-power (H-class) motor. Note: Teams considering test-launches with smaller-diameter motors than the competition motor might consider using a motor mount adapter in their design. Teams are strongly encouraged to fly an Altimeter Two (the competition organizers will lend you one if you want) on the test flight(s), to become familiar with how they work.
Rocket Design and Safety Reviews	⇤ Each team, with their rocket, must participate in the Safety Review the day before the competition launch. In addition to a faculty adviser every team is required to have a mentor with extensive high power rocket experience (a Tripoli or NAR member with a Level 2 or higher certification) evaluate the safety of your design both prior to and during the build process, preferably more than once. The faculty adviser and rocketry mentor (potentially could be the same person) are strongly encouraged, though not required, to attend the competition itself in Minnesota in May of 2016. o Analysis of non-"pre-qualified" components must accompany the rocket at the Design Safety Review. ⇤ Each rocket must pass the Range Safety Officer's Inspection the day of the launch, 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 one non-rocketry group. 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 requisite documentation by the scheduled due date, as verified by their state's Space Grant, will receive a 10% deduction from their final score.
Successful Flights	⇤ Launch (at least two flights – first with drag system deactivated (to establish the base apogee of at least 3000 ft AGL) then with drag system activated (to achieve the reduced-apogee goal)) ⇤ Rocket flies vertically ⇤ Rocket is stable throughout the flight ⇤ Drag system (on second flight) is successfully activated after motor burnout and deactivated/fully retracted prior to apogee, as documented by on-board video and/or monitoring system ⇤ Landing descent rate is deemed reasonable (≤ 24 ft/sec) ⇤ All rocket components remain attached together throughout the flight (e.g. no disassembly of components) ⇤ Rocket must be recovered in flyable condition

Equipment provided by Competition:

Competition Rocket Motors (two provided; pay more if total cost exceeds $100)	⇤ Teams may select a Cesaroni H through K motor for competition use. Thrust curve data can be found at: http://www.thrustcurve.org/searchpage.jsp
Radio Tracking	⇤ Optional (but strongly recommended) Communication Specialties R-300 (ground) Tracking Receivers will be available to lend out, but teams will need to provide their own on-board radio transmitters. See http://www.com-spec.com/rocket/index.html
Competition Flight Data Recorder	⇤ Jolly Logic "Altimeter Two" (just a 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) These recorders are separate from the team's electronic deployment system(s) and will be inserted prior to each launch to record 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 can be accessed at http://www.tripolimn.org and comparable websites.

Competition Schedule

Teams will be required to adhere to the following schedule:

- Late August, 2015 – Announcement of rules
- September 22, 2015, 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)
- October 1, 2015 – (Non-binding) Notice of Intent to Compete and "sponsorship" by a Space Grant required of all teams, including those starting later in the year
- January 21, 2016, 7 to 8 p.m. CST – Repeat of informational telecon (for teams starting in the spring)
- January 29, 2016 – 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 – changes, if any, announced no later than Dec. 31, 2015)
- February 12, 2016 – Declaration of Competition Attendance due
    - Specify Number of Team Members Attending Launch
    - Specify Number of Hotel Rooms Required and Dates Required
- March 18, 2016 – Preliminary Design (Written) Report due (see rubric below)
    - Must include the type and number of motors desired – 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) for test flights and/or to try to 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. Include Model Rocket Demonstration Flight documentation
- April 2016 – Test flight(s), at least one "fully-functional" rocket. Be sure to conduct test flight(s) 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 6, 2016 – Flight Readiness (Written) Report and Educational Outreach form due
- May 15-16, 2016 – Competition

    - Sunday, May 15 – Mid-afternoon into the evening: Flight Readiness (Oral) Presentations and Safety Checks
    - Monday, May 16 – Competition launch all day (North Branch, MN) and evening social event with announcement of partial results[1]
    - Tuesday, May 17 – Alternative competition launch (Rain Date)
- May 27, 2016 – Post-Flight Performance Evaluation and Data Collection Report due
- Final competition results will be reported on or before June 10, 2016.

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.

[1] At this event we expect to announce, and celebrate, the top team in select categories which may include closest-to-goal apogee separation percentage along with (peer-judged) milestones like "Best Design". All teams should plan to stay through the evening of May 16 so you can attend this event and in case we need to launch on the alternate/rain date.

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 2. 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 3. 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 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. The reviewer must not be associated with the team whose design is being reviewed in order to avoid a possible conflict of interest. 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.

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
- A diagram of the rocket indicating the configuration of its main components
- Flight simulation showing max altitude and launch rail departure velocity (speed at 6 ft – should exceed 45 ft/s)
- Deployment altimeter user manual
- Preflight Checklist
- Launch Pad and Flight Arming Checklist

    - Must include the altimeter's ready/standby tones
- Recovery/Postflight Checklist
    - Must include procedure to "safe" unexploded deployment charges (if any) and turn off payload (if needed for safety reasons)

Preflight 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) and Center of Pressure (CP) must be clearly marked on the rocket's exterior
- Preflight 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/Postflight Checklist
    - Must include procedure to "safe" unexploded deployment charges (if any) and turn off payload (if needed for safety reasons)

Postflight Check-in

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

- The team's rocket
- Recovery/Postflight 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 the competition flight data 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 this 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!

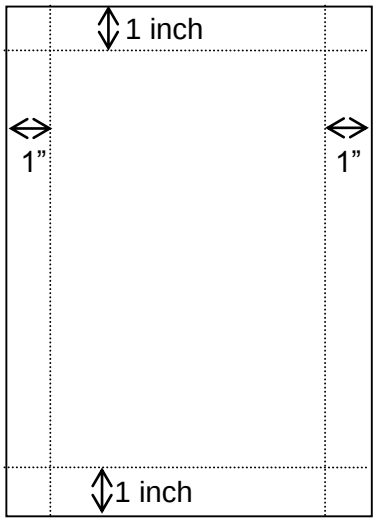
Preliminary Design (Written) Report

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), Student Team Lead (with contact information), 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
- Design Features of Electronics/Payload (i.e. Drag System and monitors)
- Diagram of Rocket Identifying the dimensioned locations for the:
  - CP (center of pressure)
  - CG (center of mass with the fully loaded rocket motor)
- Analysis of the Anticipated Performance (for both drag system engaged and disengaged/stowed) – including how each were estimated

    - Estimated Maximum Altitude
    - Estimated Peak Velocity
    - Plot of Estimated Velocity vs. Time
    - Plot of Estimated Coefficient of Drag vs Velocity
    - Plot of Estimated Coefficient of Drag vs Time
- Budget (planned, including (value of) Registration fee and Competition Travel)

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 score.

Flight Readiness (Written) Report

Flight Performance

The team will report on the success of the test flight(s) including, but not limited to, the drag system activation and deactivation/stowing plus the 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 and the 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 (counts toward page limit)
- Team Name, School Name, Team Mentor, Team Faculty Adviser (with contact information), Student Team Lead (with contact information), 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)
- Summary of Design (keep this to 5 pages or less)
- Budget (actual; with comments about changes since planned budget)
- Construction of Rocket (include photos)
- Explicit discussion of the drag system. Explain how it works, show photos of it "in action" (in lab), describe the logic used to decide when to engage it and when to disengage it during a flight. (Aside – You may elect to <u>not</u> discuss/divulge your drag system logic during your oral (public) Flight Readiness presentation at the competition, but you will still need to talk about your drag system hardware.)
- Photographs of Completed Rocket and Test Flight(s)
- Test Flight(s) Report
  - Flight Performance
  - Dray System Performance
  - Recovery System Performance
  - Table of Flight Characteristics (mass, motor, max altitude, max velocity, …)
  - Plot of Altitude, Velocity, and Acceleration vs. Time – both estimated and actual, if possible (these may come from your commercial altimeter, if desired)
  - Plot of Coefficient of Drag vs Velocity – both estimated and actual, if possible (this should be based on your non-commercial data-logging package, if flown on your test flight(s))
  - Plot of Coefficient of Drag vs Time – both estimated and actual, if possible (this should be based on your non-commercial data-logging package, if flown on your test flight(s))
- Discussion of Results
  - Compare predicted and actual apogees, describe and defend possible reasons for differences

    - Compare predicted and actual peak velocities and peak accelerations, describe and defend possible reasons for differences
    - Performance of the on-board drag system video monitoring and data-logging system (optional, but encouraged –test flight(s) without logging are allowed, as long as the drag system and recovery system are fully operational)
- Planned changes/improvements (if any) prior to the competition flights

Evaluation Criteria

Reports will be evaluated on how closely the predicted results compare to the actual results, how well the team explains any differences, 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 score.

Educational Outreach

Educational Outreach Performance

An “Educational Outreach” element, in which each team shares information related to their work on this competition with a non-rocketry group of at least 10 people, is expected. 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 your rocket design).
- Make a presentation in the community or to a group on campus to describe this rocket competition and your team’s design.

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 document) that the team must then submit to their state’s Space Grant and to the competition organizers.

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

One or more team members will deliver the oral presentation to the judges. All team members who will deliver any part of the presentation, or who will respond to the judges' questions, must be 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 speak during the presentation itself.

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 taken from the audience, a designated presentation official will determine if the question is appropriate and, if so, allow the team to answer.

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 makes the best oral presentation, regardless of the quality of their 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 score.

Competition Flight

Launch and Flight Format

The launch will take place at a site determined by Tripoli Minnesota (probably 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 will be placed in the rocket by the altitude tracking official or designee or, minimally, proper placement and arming will be verified by such officials. Since Altimeter Twos can time out if they don't detect a launch soon enough after they are armed, 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 attend to the rocket once it is in the launch area. Each team must assemble a recovery team 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 for their "clean" (no drag system engaged) flight to the RSO within one hour of the end of the on-site launch briefing. The specific time will be announced on site but this will be approximately 10:15 a.m. on flight day.
- Upon completion of providing flight data with the flight operations recorder, the time will be recorded and the team must again present their rocket in ready to fly condition for their next flight to the RSO within one hour of that time.
- Teams that do not meet these pre-time requirements will be allowed to fly but will be subjected to late-flight penalties (see scoring formula below).
- Wait time in the RSO line does not count against the 60 minutes.

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

- Launch
- Rocket flies vertically
- Rocket is stable throughout the ascent
- Recovery system is successfully deployed
- Descent rate is deemed reasonable (≤ 24 ft/sec)
- All rocket components remain attached throughout the flight (e.g., no disassembly of components)
- Rocket must be recovered in flyable condition
- Note: Failure to log data, collect video, engage or fully disengage the drag system, or even exercise the full recovery system, will <u>not</u> 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 the recovery system is ejected successfully by the motor back-up rather than by the electronic system. Similarly, a dual-deploy rocket that lands safely, even if the dual parachutes didn't deploy exactly as planned, will not be subject to disqualification merely for that issue.

The stability condition (i.e. "static margin of one or greater but less than or equal to five") is a safety rule and applies from launch to apogee. 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.

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.

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 data on the sheet during and following the flight. Upon completion, a team member must sign their initials of acceptance before a copy will be released to the team.

Evaluation Criteria

Finishing order for of the competition flights will based on:

- Having safe flights
- Having successful flights and recoveries, as defined above
- The apogee separation between your non-activated and activated drag system flights, on a percentage basis

Scoring Formula

Teams will score points based on the formula:

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. This is at the judges' discretion. 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 can be resolved to the RSO's satisfaction.

Flight Score (if not disqualified) = 10 points for 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 flights)

PLUS

$$70 - 280 * \left\| \frac{Drag\ System\ Engaged\ Peak\ Altitude}{Drag\ System\ Not\ Engaged\ Peak\ Altitude} - .75 \right\| where\ Result\ \geq 0$$

POTENTIAL PLUS

Bonus points (up to 10) for apogees over 3000 ft (see below)

POTENTIAL MINUS

Deducted points (up to 100, so this can even carve into points awarded for safe and timely flights) for apogees below 3000 ft (see below)

Notice that 30 points will be awarded to rockets that are prepped in a timely manner and safely complete at least two flights and are recovered in flyable condition. There is a maximum of 100 points (plus potential bonus points and minus potential deductions – see below) from the Competition Flight that will be scaled for the final score. If a rocket is flown more than twice during the competition, the best flights will count (even if one or more flights are disqualified). However there is a finite launch window and the Tripoli MN members running the launch might not allow launching 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.

Apogee goal: Aim for an apogee of at least 3000 ft on your "clean" (drag system never engaged) flight. You may earn 1 bonus point for every 200 ft higher than 3000 ft your rocket goes (max 10 points) but will lose 1 point for every 10 ft under 3000 ft (max 100 points). Thus an apogee of 5000 ft (or higher) could potentially merit 10 bonus points but an apogee of 2000 ft (or lower) will lose 100 points (i.e. essentially a disqualification).

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 (counts toward page limit)
- Team Name, School Name, Team Mentor, Team Faculty Adviser (with contact information), Student Team Lead (with contact information), and a listing of all Student Team Members – this information can all go on the Cover Page
- Flight Performance Comparison Sheet
  - Table of Flight Characteristics (mass, motor, max altitude, velocity, …)
  - Plot of Estimated vs Actual Coefficient of Drag vs Velocity (this must be based on your non-commercial data-logging package)
  - Plot of Estimated vs Actual Coefficient of Drag vs Time (same as above)
  - Plot (or video still frame evidence) of Drag System State vs Time (engaged, disengaged/stowed, etc)
- Discussion of Results
  - Compare predicted and actual apogees, describe and defend possible reasons for differences
  - Compare predicted and actual peak accelerations and peak velocities. (Note: the Altimeter Twos will give peak acceleration and peak velocity, and other performance characteristics, so you don't necessarily have to log acceleration and velocity separately to accomplish this), describe and defend possible reasons for differences
  - Compare predicted and actual drag coefficients over time and discuss differences
  - Compare drag system deployment record with drag coefficient record
  - Optional – discuss other (optional) sensor data that was collected during the flight

Evaluation Criteria

Reports will be evaluated on how closely the predicted results compare to the actual results, how well the team explains any differences, 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 score.

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

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

- Dimensional Specifications (2 pts)
- Recovery System Design Specifications (5 pts)
- Propulsion System Specifications (2 pts)
- Avionics/Payload System Design Specifications (5 pts)
- Planned Construction Solutions & Techniques (5 pts)
- Structural Analysis of Scratch-Built Parts (3 pts)
- Risk Mitigation Analysis (3 pts)

_____ **PREDICTED PERFORMANCE (25 pts)**

- Launch Analysis (5 pts)
- Flight Analysis (5 pts)
- Recovery Analysis (5 pts)
- Stability Analysis (5 pts)
- Environmental Conditions Analysis (5 pts)

_____ **INNOVATION (15 pts)**

- Uniqueness of Components/Systems (5 pts)
- Functional Relevance of Components (5 pts)
- Relevance to Competition Objectives (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 (5 pts)
- Construction Techniques (5 pts)
- Stability Analysis (5 pts)
- Constructed for Safe Flight & Recovery (5 pts)
- Discussion of Changes Since Preliminary Design Report (5 pts)

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

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

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

- Peak Altitude Comparison (10 pts)
- Coefficient of Drag Comparison (10 pts)
- Peak Velocity Comparison (10 pts)
- Video and Data Logging Performance/Comparison (5 pts) (if intentionally not flown, discuss ground testing instead)

_____ **FINDINGS AND FUTURE WORK (10 pts)**

- Key Findings (5 pts)
- Potential Design Improvements (5 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 (25 pts)**

- Discussion of Engineering Methodology (5 pts)
- Use of Design Tools (5 pts)
- Addressed Competition Objectives/Requirements (5 pts)
  Note – team must discuss drag system hardware but is allowed not to divulge their engage/disengage logic orally – that is covered in their written FRR
- Use of Analytical Data (5 pts)
- Description of Construction Techniques (5 pts)

_____ **ORGANIZATION (25 pts)**

- Logical Organization & Structure (10 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 APPERANCE (5 pts)**

- Visual Appearance (2 pts)
- Quality of Construction (3 pts)

_____ **COMMUNICATION SKILLS (25 pts)**

- Articulation (5 pts)
- Eye Contact (5 pts)
- Verbal Projection (5 pts)
- Body Language (3 pts)
- Poise/Presence (3 pts)
- Adherence to Time Constraints (4 pts)

_____ **QUESTION & ANSWER (10 pts)**

- Active Listening Skills (4 pts)
- Answer Relevance (3 pts)
- Response Correctness/Confidence/Persuasiveness (3 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 Path Assessment (4 or 6 pts)
- (In-flight) Recovery System Analysis (4 or 6 pts)
- Rocket Location & (Ground) Recovery Analysis (4 or 6 pts)
- Pre- & Post-Launch Procedure Assessment (4 or 6 pts)

_____ **ACTUAL VS PREDICTED PERFORMANCE (30 pts)**

- Peak Altitude Comparison (10 pts)
- Coefficient of Drag Comparison (10 pts)
- Peak Velocity Comparison (10 pts)

_____ **DATA COLLECTION (20 pts)**

- Drag System Report (5 pts) (other sensors too, optional)
- Coefficient of Drag Data Analysis (5 pts)
- Data Interpretation/Comparison (10 pts)

_____ **REPORT AESTHETICS (20 pts)**

- Followed Specifications (3 pts)
- Professionally Written (10 pts)
- Accurate Representation of Events (7 pts)

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

COMMENTS:

2015-2016 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