2022-2023

NASA's Space Grant (in-the-) Midwest High-Power Rocketry Competition Handbook

(v2; posted 9/27/2022 – fixed Table of Contents)
(v3; posted 10/18/2022 – fixed one minor typo)
(v4: posted 11/14/2022 – highlighted clarifications on page 4)
(v5; posted 2/13/2023 – minor corrections to point totals)

Precision Landing Challenge

Informational telecons: Mon. Sept. 19, 2022 (then repeated Thurs. Jan. 12, 2023) 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, 2022

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

Registration Deadline: January 31, 2023

Launch Competition in Minnesota: Sat. & Sun., May 13-14, 2023** (Rain date: Mon., May 15, 2023)

** **If Minnesota has a particularly wet spring, the competition dates might need to shift. This will be announced in as far in advance as is practical. See details in handbook.**

Main contacts:

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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_2022_2023/

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Competition Objective

The Space Grant (in-the-) Midwest High-Power Rocketry 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 rocket(s) to accomplish specific goals which vary from year to year. Restrictions are placed on rocket motors and dimensions so that knowledge, creativity, and imagination of the students are challenged. The end result is an engaging aerospace experience for college/university students that might not be available to them during their normal course of studies.

Rocket Design Objectives

Here is a summary description of this year's "Precision Landing Challenge."

College/university student teams will design and construct a single motor, single stage, high-power rocket that will fly twice during the competition. The challenge is ***(A) to use a steerable parachute during a totally-unpowered descent to guide the rocket booster to land as close as possible to a specified ground target****, probably about 1000 ft from the launch pad, and* ***(B) to land the booster so that it remains upright****. For the purposes of this competition, the "booster" is defined to be the section of a rocket that fully contains the motor and also has the main stabilization fins and an up/down camera system on it. (Aside: The booster is allowed to separate from, and descend independently from, the upper section of the rocket, as long as all parts of the rocket land at safe speeds and are recovered in re-flyable condition.) If the booster is separated from other sections of the rocket in flight, all independent sections must contain tracking devices unless the separation occurs at or just prior to landing so that all the sections of the rocket land within 100 ft of one another.) Rockets will fly first on a Cesaroni 273H225-14A "White Thunder" (2-grain, 38 mm diameter) motor, and must exceed 1000 ft AGL (Above Ground Level). The second flight will have a target apogee as close as possible to, but not exceeding, 3000 ft AGL, and can be on any Cesaroni or AeroTech I-class or J-class 54 mm diameter motor. The rocket must carry a "non-commercial" (i.e. not sold for rocketry) data-logging sensor suite to characterize flight performance, including logging (at least once a second) GPS, av-bay pressure, 3-axis acceleration, and 3-axis rotation. The intent of the gps part of sensor suite is to track the booster. Thus, the sensor suite must be within the booster, or at least in a part of the rocket that is tied to (i.e. descends with) the booster, at least until landing (or very near landing). Do not separate the gps (at least) from the booster section at apogee, and have them descend separately (possibly landing far apart). The booster must also contain a look-up and look-down camera system, to collect video of the rocket motor boosting, the rocket separating, the steerable parachute in action, and the rocket landing. Bonus points will be given to teams whose members increase their certification level using individually-built rockets (which will be unrelated to the (team-built) competition rocket described above). Additional details about the competition will be included in a handbook. Note that all fabrication work on the rocket(s), except for possibly machining of plastic and/or metal parts, must be performed by students.*

Here are additional details.

All rocket flights need to carry an "Altimeter Two" (organizers will lend those out) or an "Altimeter Three" (if you own one) from JollyLogic. This is just a data logger – it cannot fire ejection charges – but will give a second opinion about flight performance. On the other hand, all team-installed ejection charges need to be fired by a commercial altimeter, with motor-eject as back-up for a (required) apogee parachute deployment.

In this context, "remains upright (after landing" will be interpreted as "does not tip after touch-down for at least 30 seconds." The up/down camera system should provide evidence of this, in case the booster has tipped by the time the team arrives to recover it. The booster must land upright (and stay upright), not right itself after landing (although the ability to do that would be impressive).

The competition rocket must have externally-mounted indicator LED(s) in view of the camera system which indicate the status/intent of the electronics such as (a) data being logged, (b) gps is locked, (c) status of steering – idle (not turning) / turning right / turning left / other?, (d) status of landing mechanism – stowed / deployed / other? This can help distinguish between what the mechanisms were told to do, as seen from the indicator LEDs (and the data log), and what the mechanisms actually did, as seen in the up/down video.

The competition rocket should be test-flown on a high-power motor (perhaps the 273H225-14A Cesaroni motor required for Flight 1 at the competition) <u>at least once</u> prior to the competition. If the competition rocket will use a steerable parachute, that parachute should be onboard for a deployment test on this flight (whether it is actually steered or not). Implementing the vertical-landing mechanism on the test flight is encouraged, but not required, as are flying the "non-commercial" sensor suite and/or the up/down camera system. The rocket should carry dummy mass (appropriately located) of any items not actually flown, to mimic the expected performance as closely as possible.

The location of the target (with respect to the launch pads) will be announced the day before the competition, in time for inclusion of your plan for reaching the target to be added to your oral presentations to the judges. The target will be no more than 1000 ft from the launch pads and will be the same location for both the first and second flights. The target will probably be "in a direction rockets would not naturally tend to drift (and hence dependent on predicted winds)."

Dual deploy is allowed, though not required. Implementing dual deploy might be useful, to keep the rocket from drifting laterally too far on descent. On the other hand, a steearable parachute system (no "wings" that attach to the rocket body, please – this is a <u>parachute</u> challenge) should be able to accomplish that as well. Notice that getting the steerable parachute out as high as possible, to give it the most time to do its thing, might be best. The steering mechanism, if attempted, may be autonomous (possibly using gps data from the "non-commercial sensor suite"), or it may be radio-controlled from the ground. If attempting the latter, note that personnel are limited to certain places on the ground (typically "behind the flight line"), so the range of the radio system needs to be chosen carefully.

Rocket internals need not be identical for both flights, though the rocket needs to look the same from the outside (so the CP does not change). For example, you might elect to use different size parachutes on the two flights, or ballast on one and not the other.

Be prepared to document the gps location of both the launch pad and the landing site (the gps location of the target will be provided) so that you can calculate the distance between the two. The gps in the rocket should measure both, but be sure you have a back-up in case that fails.

See description later in the handbook for fairly-stiff deductions associated with flying to less than 1000 ft AGL on the first flight or more than 3000 AGL on the second flight.

Radio tracking (or at least audio devices) and encouraged, but not required. If you decide to let the rocket land in parts – boost to target; nosecone elsewhere, for example – consider putting tracking on at least the smallest part(s), especially on the second flight which will probably go much higher (possibly out of sight), to ensure that you are able to locate all parts after landing.

The competition rocket must be team-built by the current team – no flying previously-built rockets. (Aside: Team members seeking certification may do so using previously-built (individually-built, or course) rockets.) All rocket(s) that a team plans to fly at the competition must be included in a Draft-of-Design report, to be submitted before building any rockets (or at least any scratch-built rockets), so that competition organizers can steer teams away from potentially-unsafe options, including those listed below.

The following extra rules apply to the team-built competition rocket (mostly for safety reasons, in a competition that may include inexperienced fliers): (1) no multi-stage rockets, (2) no multi-motor (AKA cluster) rockets, (3) no air-starts, (4) no canards (fin-type objects forward of the CP) or piggy-back devices (like the space shuttle configuration), (5) no gimballed nozzles, (6) descent must be <u>genuinely unpowered</u> – no rocket nor propeller nor compressed gas thrusters nor other active propulsion allowed, (7) all rockets must have a fully-operational motor-eject recovery system, at least for their apogee parachute (8) all rockets must use 10-10 rail buttons or guides and have a reasonable thrust-to-weight ratio upon launch and leave the rail at a reasonable speed (see Design and Safety Review Section), (9) all rocket parts (which are allowed to be detached from one another for descent for this particular competition – this is unusual) must land at a reasonable speed (see Competition Engineering Section) under parachute – no streamer-only recovery systems or drogueless descent allowed, (10) deployment <u>and full unfurling</u> of a safe-landing-speed parachute must occur at least 500 feet above ground level – if using a chute release, be sure you open a safe-landing-speed parachute at least by 500 feet AGL, after which you may attempt to open even-larger supplementary parachutes at lower altitudes if you wish (though keep in mind that parachutes take a while to unfurl), (11) the parachute(s) for the booster section may be released upon landing, to try to keep the parachute from tipping the booster over, as long as all parts are recovered, (12) no ground-penetration landing mechanisms (i.e. no javelin/harpoon *landers), (13) all rockets must fly on Cesaroni or AeroTech H-class, I-class, or J-class motors – see motor specification details for two competition flights elsewhere, (14) the main competition rocket must be able to adapt to fly both 38 mm and 54 mm diameter motors. Metal fins, nose cones, and airframes are not permitted except (A) nose cones may have aluminum tips and (B) in the case of a minimum-diameter rocket, the portion of the airframe that serves as the motor case may be made of metal.*

To encourage team members to get certified, or increase their certification level, teams will be offered up to a 10% bonus as follows:
2% for every successful new Level 1 certification
4% for every successful new Level 2 certification
6% for every successful new Level 3 certification
No single student may claim more than one of the above, so a student going for Level 2 certification does not merit 2% for the Level 1 certification they need on their way. Such certifications flights must occur after the team signs up for the competition but no later than the competition flight date in May 2023. Uncertified students seeking Level 2 certification at the competition should get their Level 1 certification flight done before the competition date. Do not attempt to earn Level 1 and Level 2 certification flights on the same date (though such flights may be done with the same rocket, if the rocket is up to it).

Note – since the main competition rocket must be team-built, it cannot serve as a certification rocket for any team member.

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: A Draft of Designs (described later) is expected and there will be a 20% overall deduction if it is not submitted by its due date. Some community 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 team-build a rocket capable carrying out the challenge goals. Rockets may fly on different motors, though all motors must be Cesaroni or AeroTech H-class, I-class, or J-class commercial motors. Both disposable motors and reloads, are allowed.

All rockets must be fin-stabilized, with a static margin between 1 and 5 at launch, and designed to land safely. Each 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 for this competition, 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 and fully unfurled at least 500 feet above the ground. No streamer or drogueless descent is allowed, though achieving dual-deploy using a chute release is allowed.

The recovery system must safely land the vehicle (or each separate part of the vehicle, if it is not all connected together at landing – allowed, for this challenge) at a descent speed not to exceed 35 ft/sec (the current value in the Tripoli Safety Code). The motor ejection charge must remain in place, to serve as a back-up to the electronic 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.

Top scores for the flight portion of the competition will be awarded to team(s) whose rockets all complete safe and successful flights – see details below about how "Successful Flights" are defined.

On the competition date, teams may make multiple attempts at each type of flight (within reason – the launch waiver closes at 4 p.m.) and teams may select which flights are to be judged after the fact. However, bear in mind that rocket motors can vary ±10% from the manufacturer, so if aiming for specific performance perhaps consider rocket designs that can deal with variation in motor impulse from nominal values (or at least concede uncertainties in performance in your predictions).

All rocket flights must carry a commercial Jolly Logic AltimeterTwo (will be lent out) or AltimeterThree (if you own one) data logger – even rockets which are not using electronics to fire charge(s) for recovery purposes. This will provide a minimum amount of performance data on every flight, such as maximum altitude, maximum velocity, maximum acceleration, etc. Commercial "genuine altimeters" (as opposed to the

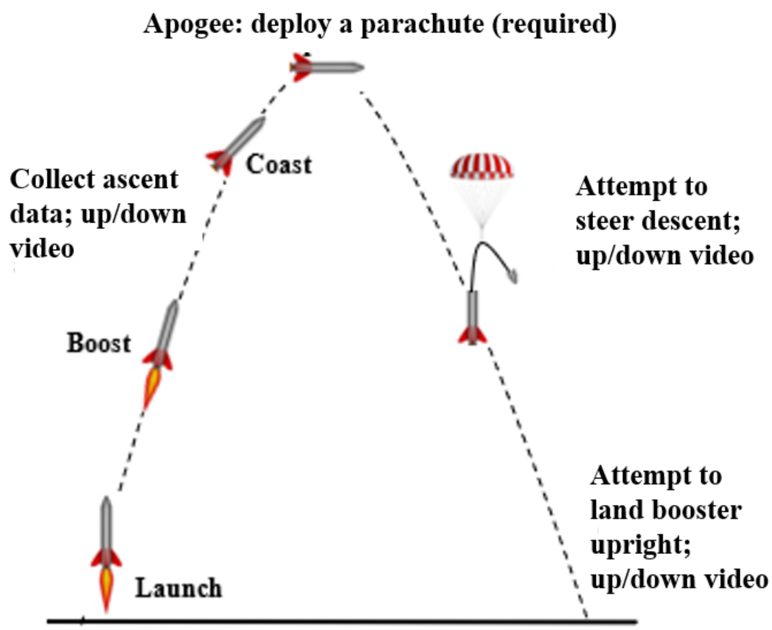
AltimeterTwo and AltimeterThree, which are just data loggers) must be used to fire team-installed ejection charges. Teams must also build and fly a "non-commercial" data-logging sensor suite – details of what to log stated above. In this context, "non-commercial" means "not intended/sold for use in rocketry."

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

AeroTech "single use" motors (AKA "the AeroTech DMS (disposable motor system)") do not require an external metal motor case – 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 disposable motors are easier to use, the selection is much more limited than reloadable motors which go into metal cases.

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 the $100 covered by your registration fee) no later than mid-February 2023, several weeks before submitting your PDR. Motors for test flights should be ordered even earlier – like in January – from a high-power rocketry vendor such as one who serves high-power launches in your part of the country.

Figure of flight profile for the "Precision Landing Challenge."



Flight Mission	- Build (as a team) a rocket that attempts one or both of the "Precision Landing" challenges. - The rocket also needs to carry an up/down (view) camera system as well as a "non-commercial" sensor suite that logs, at least once a second, GPS, av-bay pressure, 3-axis acceleration, and 3-axis rotation
Recovery System	- Leave the motor eject in place to eject a parachute at (or just beyond) apogee on all flights (see caveat below). - If a flight has electronic motor eject at apogee – ejecting a parachute prior to apogee is not allowed – a back-up for the apogee parachute is required. This may be either the motor eject or else use a second, independent commercial altimeter / ejection charge system. - A dual deployment recovery system is optional, but may assist in ensuring the rocket lands on sod (at North Branch). For dual deploy rockets, the main parachute must be deployed, at fully unfurled, at least 500 feet above ground level.
Rocket Constraints	- Each rocket must include a mounting location for a competition-provided "AltimeterTwo" 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 your team owns either an AltimeterTwo or an AltimeterThree (from Jolly Logic), you may consult with the competition organizers about potentially using your own device(s) for competition flights. • The launch window, which will run from 9 a.m. (plus about 15 minutes for an on-site launch briefing at the start of the day) until 4 p.m. All Level 1 certification rockets must be ready to fly within **<u>one hour</u>** of the opening of the launch window. All Level 2 certification rockets must be ready to fly by 11 a.m. (about two hours in). All remaining rockets ("core" rockets and other non-certification rockets) must be ready to fly by noon (about three hours in). Wait-time in the Range Safety Officer (RSO) line will <u>not</u> count against these time limits. - Any rocket intended to fly more than once must be prepped for RSO inspection within one hour of being released from the post-flight check-in table (after the rocket has been recovered, passes a post-flight inspection, and any requested flight data has been extracted). - Modest point deductions will be made for taking longer than the times stated above 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 3 p.m., so as to be launched by the time the launch window closes at 4 p.m.
- The static margin of the rocket must be between 1 and 5 at launch (i.e. at maximum rocket weight).
- The thrust-to-weight ratio for each flight must be no less than 3 to 1 at launch (i.e. at maximum rocket weight).
- Specific points will be awarded for avionics bay design – make it "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.

Draft of Designs

- Before you begin to build any rockets (or at least before you begin to build any scratch rocket(s)) you must generate a "Draft of Designs" which includes an OpenRocket or RockSim simulation of the design basics plus details about airframe materials and planned commercial altimeter(s) for each rocket. 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 at least one "model" rocket. Pictures of the team at the launch site with the rocket before and after the launch must be included with the Preliminary Design Report. Teams whose members all have previous high-power rocketry experience may request a waiver (by e-mail) 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(s)

- Each team must assemble, fly, and successfully recover the team-built main competition rocket on a high-power motor (i.e., H-class or above) prior to the competition. We recommend flying the main rocket on planned H-class motor for the competition itself. (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.)

- Individuals seeking Level 2 certification at the competition will need to earn their Level 1 certification in advance, potentially on the same rocket. That said, those rockets may also need to fly (on Level 1 motors) in advance of the competition date as well.
- If you elect to do any test flight(s) without all of the electronics in place – especially custom electronics that are not flight-critical and would be hard to replace if things don't go well), be sure to replace them with dummy weights so the rocket's performance is as realistic as possible.
- If you plan to use a steerable parachute for the competition, you need to have that onboard during the test flight (even if you do not attempt to steer it).
- 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 2023.
- 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 evening before the competition launch date – which is 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	➢	Only "successful" flights can count toward flight day points. Flights will be deemed "successful" based on the criteria listed below:
	➢	Rocket ascends vertically (except for acceptable amounts of weather cocking – judge's discretion)
	➢	Rocket flies stably throughout ascent
	➢	"Apogee parachute" is deployed at (or just past) apogee, either by electronics or by the motor eject back-up backup
	➢	The main parachute, if rocket is dual-deploy, must be deployed and fully unfurled no lower than 500 feet above ground level.
	➢	Landing descent rate for all rocket parts is deemed reasonable (≤ 35 ft/sec) – based on judge's observation, not sensor values.
	➢	All parts of the rocket are recovered in re-flyable condition, which means that if given another motor, the rocket could be re-flown without <u>requiring</u> repairs – non-critical (AKA minor) (AKA cosmetic) damage allowed.
	➢	Notice that failure of non-flight-critical on-board electronics (e.g., a video camera or non-commercial sensor suite) to collect data will not automatically result in an "unsuccessful" flight rating.
	➢	However, note that "landing without damage" is NOT the same thing as having a "successful flight" – judges may disqualify a rocket based on safety reasons, like failure to satisfy one or more of the criteria listed above, even if it is recovered in re-flyable condition. Rockets that are disqualified may be proposed for re-flight, if undamaged, as long as the RSO is convinced that the safety issue(s) is(are) resolved.
Required equipment:		
Competition Rocket Motors (team pays overage cost beyond $100)	➢	Teams must fly their first flight on a <u>38 mm diameter</u> 273H225-14A Cesaroni motor and must reach at least 1000 ft AGL.

	➢ For the second flight, teams may select any <u>54 mm diameter</u> Cesaroni or AeroTech I-class or J-class motor. Thrust curve data can be found at: http://www.thrustcurve.org/searchpage.jsp ➢ Note: As of September 2022, a Cesaroni 38 mm diameter 2-grain H225 White Thunder motor costs $39.00 (not including a case) from Off We Go Rocketry, and I and J motors start at $60 and go up from there, so competition motors will almost certainly cost over $100, to say nothing of cases and closures.
Radio Tracking	➢ The Tripoli MN club requires on-board radio tracking electronics (not just an audio beeper) on all flights that will go higher than 3000 feet above ground level (AGL). We recommend radio tracking on ALL competition flights, even those not expected to reach 3000 feet AGL – especially on parts that are to land separately from the booster (which you will presumably be watching most closely). 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, though not too high yet) 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 every flight)	➢ Jolly Logic “AltimeterTwo” (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 own 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 performance data).
- Teams may borrow one AltimeterTwo from the competition organizers and/or use their own.
- AltimeterThree units, also from Jolly Logic, are allowed instead (but are not available to be borrowed). Though more expensive, they have the advantage that their data can be accessed remotely (by Blue Tooth).

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 the Tripoli Minnesota Association (a high-power rocketry association); or a high-power rocketry association nearer them. Students interested in gaining information or experience by observing high-power rocket launches are encouraged to contact Gary and/or to attend one of the regular high-power rocket launches held in North Branch, MN, by Tripoli MN, or a comparable launch nearer them. Additional information, launch site maps, and launch schedules are posted at http://www.tripolimn.org (and comparable websites for other clubs).

Competition Schedule

- August 31, 2022 – Announcement of the 2022-2023 academic year competition
- September 19, 2022, 7 to 8 p.m. Central Time – Informational telecon (for teams starting in the fall and also for faculty advisers (at least) who expect to form teams after the fall) and posting of handbook
- October 1, 2022 – (Non-binding) Notice of Intent to Compete and "sponsorship" by a Space Grant required of all teams, including those starting after the fall
- BEFORE YOU START TO BUILD (or at least before you start to build scratch rocket(s)) – Submit Draft of Designs (specs & sim)
- ORDER MOTORS 3 MONTHS IN ADVANCE: Test flight motors should be ordered in January 2023, if not before, and competition flight motors should be ordered by mid-February 2023. The registration fee covers up to $100 toward the cost of competition motors. Teams whose 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) must include payment with their order. Generally speaking, purchasing additional motors are the responsibility of the team. Motors must be purchased from a high-power rocketry vendor and paid for in advance.
- January 12, 2023, 7 to 8 p.m. Central Time – Repeat of informational telecon (especially for teams starting in the spring)
- January 31, 2023 – 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) (†schools that entered teams in the COVID-aborted 2019-2020 Space Grant Midwest High-Power Rocketry Competition and did not compete in 2021-2022 may elect to have their previous registration fee applied to this new competition, but may not extend registration credit beyond this year
- February 10, 2023 – Declaration of Competition Attendance due
    - Specify Number of Team Members Attending Launch
    - Specify Number of Hotel Rooms and Dates Required
- February 10, 2023 – Last possible date to get credit for Draft of Designs
- Mid-February – Suggested last date to order motors for April test flight(s)
- March 10, 2023 – Preliminary Design (Written) Report due (see rubric below)
    - Must include the type and number of motors desired for the competition date.
    - This report must also include the Model Rocket Demonstration Flight documentation (or waiver)
- March and April 2023 – likely times for test flight(s), at least one of which should be of the main competition rocket with steerable parachute (if any) installed, and also Level 1 certification flights for team members who will seek Level 2 certification on the competition date. 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 potentially have time to repair and re-fly the rocket(s) prior to the FRR due date (see below), if things don't go as planned.
- May 1, 2023 – Flight Readiness (Written) Report and Educational Outreach form due
- May 13-14, 2023 – Competition**

- Saturday, May 13 – Mid-afternoon into the evening: Flight Readiness (Oral) Presentations and Safety Checks
- Sunday, May 14 – Competition launch all day (North Branch, MN) and evening social event, with announcement of partial results[1]
- Monday, May 15 – Alternative competition launch (Rain Date) (so don't make travel plans that prevent you from staying through May 15 if conditions require – if the launch date is delayed by one day, that will be announced no later than the evening of May 13)

- May 26, 2022 – Post-Flight Performance Evaluation and Data Collection Report due
- Final competition results will be reported on or before June 9, 2022.

** If Minnesota has a particularly wet/snowy winter and it becomes apparent that rocket flights won't be possible at North Branch 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 2023). Such a "drastic" decision will be made no later than the end of April, 2023. If teams assemble in May and do oral presentations but are unable to launch due to wet conditions on both May 14 and 15, 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 orders, forms, etc. are due to the Technical Advisor by e-mail by 5:00 p.m. Central Time on the dates specified above. Scores for late reports will be reduced by 20% for each portion of each day that they are late, so DON'T BE LATE!

[1] At this event we expect to announce, and celebrate, the top teams in selected categories. This may include peer-judged awards like "Best Landing Mechanism" and/or "Best Rocket Build" and/or "Coolest-Looking Rocket". All teams are strongly encouraged to stay into the evening following the primary launch day so they can attend this event and also 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 by which to complete their competition flights at their home field and instructions on how to submit their results for judging from a distance.

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 Launch Director 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/Launch Control Officer (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 Level-2-Certified (Tripoli or NAR) non-student mentor that reviews the design and construction of their rocket in advance of the competition flight. If you need assistance in finding a certified high-power 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 your certified 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 your mentor has something to say (and make sure it is positive)!

At the safety review the team must be prepared to discuss the design of their rocket(s) and systems. In addition, the teams must be able to demonstrate/exhibit:

- Their rocket(s) in various state of assembly, including full exposure of the Av-bay(s) – internal structure – and other custom mechanisms (if any)
- Diagram(s) of the rocket(s), indicating the configuration of main components
- Flight simulation(s) showing max altitude and launch rail departure velocity(ies) (speed at the end of an 8 ft launch rail – this speed should exceed 45 ft/s) – build rocket to fit on a 10-10 rails
- Familiarity with all commercial rocketry altimeter(s) used for data logging and, even more importantly, for ejection charge deployment (study the user manuals!)
- A Pre-flight Checklist
- A Launch Pad and Flight Arming Checklist
    - Must include notes about all altimeter ready/standby tones
- A Recovery/Post-flight Checklist
    - Must include procedure to "safe" unexploded deployment charge(s) (if any) and instructions about how to turn off payload(s), 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 designs and deployment systems. In addition, the teams must display:

- Each 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 all altimeter ready/standby tones
- Recovery/Post-flight Checklist
    - Must include procedure to "safe" unexploded deployment charge(s) (if any) and instructions about how to turn off payload(s), 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. After each flight the team will then proceed to the recovery check-in station 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 (potentially to be prepped for additional flight(s)). For rocket(s) that are to be re-flown, the one-hour prep timer (for successful flights only) will start when the rocket is released from the post-flight check-in station. 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!

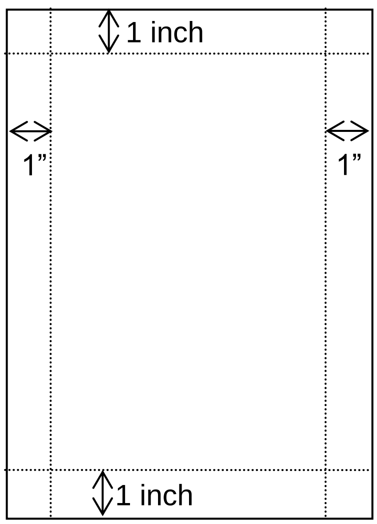
Preliminary Design (Written) Report

Design Report Objectives

The purpose of this design report is to evaluate the engineering effort that went into the design and construction of the rockets, with their diverse features, and how that effort 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. This, and all written reports, 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 each edge of the page. All pages (except for the cover page) must be numbered in the upper righthand 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) which includes (at least) Team Name, School Name, Certified Non-student 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
- Separate Table of Contents page (1 page max, counts toward page limit)
- Separate Executive Summary page (1 page max, counts toward page limit)
- Labeled figures showing features of rocket airframe and custom mechanism(s)
- Design features of on-board electronics/payloads (i.e., commercial altimeter, data logger, video camera(s) and/or custom/non-commercial electronics (if any), etc.)
  - Usability and reliability design features of avionics bay(s) (i.e., ease of assembly/use, sled layout, power layout, wiring layout, switch positions, etc.)

- Diagram of each 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 value was estimated (typically using simulation software)
    - Estimated maximum altitude (remember that radio tracking is encouraged for all flights and required for flights predicted to go higher than 3000 feet AGL)
    - Estimated peak velocity
    - Estimated peak acceleration
    - Estimated (landing) descent speed
    - Estimated performance of steerable parachute system
    - Estimate performance of vertical-landing mechanism
- Budget (planned) including kit rockets (if any), scratch components, build materials, motors, cases/closures, electronics, as well as registration fee (even if paid during an earlier year) and estimated cost of competition travel
- 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 Readiness Report Objectives

The team will report on flight readiness for all rockets and on test flight(s) for all rockets flown in advance. This includes, but is not limited to, sensor logging, video recording (if any), and recovery system operation, landing system operation. Comparison of actual fight performance to 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.

Report Format

The flight readiness document should follow the same formatting guidelines as the Preliminary Design Report and be no longer than twenty-five (25) single-sided 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 rocket designs, especially the unique airframe features, av-bays, precision landing mechanisms(s), and electronics
- Budget (actual; with comments about changes since planned budget)
- Construction photos of all rockets, including photos of av-bays and custom mechanisms
- Explicit discussion of any special features/construction techniques (e.g., special surface finishes, lay-ups to strengthen fins, etc.)
- Photographs of all completed/assembled rockets (perhaps in a single image)
- Links to video clips from test flight(s), if any
- Test flight(s) sub-report
    - Actual flight performance (as compared to simulated/desired performance)
    - Recovery system performance, including steerability (if attempted)
    - 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)
    - Compare predicted and actual (landing) descent speeds. Describe and defend possible reasons for differences (if any)
    - Discuss the performance of video camera and/or non-commercial sensor suite system(s), if any
    - Discuss effectiveness of mechanisms actuated in flight, if any (e.g., steerable parachute, landing legs, roll control, air brakes, etc.)
- Planned changes/improvements (if any) prior to the competition flights
- Required Mentor Report Form (see Appendix A-5)

- (Outside of page limits given above): Appendix with text listing of microcontroller flight code (if any) for non-commercial sensor suite and/or other microcontroller-run electronics

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 designs and/or your actual rockets and/or your test flight results).
- Make a presentation in the community or to a group on campus to describe this year’s rocketry competition and your team’s designs, rockets, results, etc.

Evaluation Criteria

At the completion of the outreach event the team will need to have a representative from the invited group complete an EPO (Education/Public Outreach) form (located on the last page of this handbook). The team must then submit that form 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 (preferably) more team member(s) 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 have read the written reports in advance, so you don't need to take a long time introducing the rocket from scratch. 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(s) (which does count toward their FRR score) and the precision landing mechanism(s). These will not be timed events, but the examinations will need to be fairly quick – probably no more than 5-10 minutes to show off your rocket 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 the Tripoli MN launch site near North Branch, MN, which is about a 1-hour drive north of Minneapolis. (See maps at www.tripolimn.org). 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 competition flight data recorder, a Jolly Logic AltimeterTwo, 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: AltimeterTwo data loggers can time out if they don't detect a launch soon enough after they are armed, so be sure to design your rockets so the AltimeterTwo 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:

- The launch window, which will run from 9 a.m. (plus about 15 minutes for an on-site launch briefing at the start of the day) until 4 p.m.
- All competition rockets must be ready to fly (i.e. the team needs to be in the RSO line and ready to present their rockets in ready-to-fly condition) within <u>**one hour**</u> of the opening of the launch window.
- Upon completion of providing flight data to the flight operations recorder after each flight, the time will be recorded. If a rocket is intended to fly again, it must be in ready-to-fly condition and back in the RSO within one hour of that time.
- Teams that do not meet these prep-for-flight time requirements will be allowed to fly, but will be subjected to (modest) late-flight penalties. Remember, safety is more important than timeliness. Meet the prep time deadlines by <u>practice</u>, not by rushing.
- 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 the time the launch window closes at 4 p.m.

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

- Launch
- Rocket flies vertically (the launch rail itself will be vertical)
- Rocket is stable throughout the ascent
- Recovery system (apogee parachute only, or drogue plus main parachute if dual deploy) is successfully deployed
- Landing speed is deemed reasonable ($\leq$ 35 ft/sec) for all parts – for this challenge the rocket is allowed to land in separated pieced (this is unusual), but each one must have a parachute and all must be recovered and presented at the post-flight check-in
- Rocket must be recovered in flyable condition
- Note: Failure to log sensor data and/or to collect video 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 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 automatic disqualification (but might sustain a point deduction). However, in dual-deploy rockets failure to fully deploy a main parachute may well, depending on the size of drogue parachute, result in a too-fast landing meriting 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 AltimeterTwo data following each flight and possibly request a copy of the on-board video footage and the on-board sensor log(s), at least from rockets that plan to be re-flown. Upon completion of the post-flight data download, a team member must sign their initials of acceptance before the rocket will be released to the team.

Rockets flown for certification must be declared in advance to the RSO (and a written test taken in advance, in the case of Level 2 certification attempts), so that certification observers may be appointed. Such rockets will need to be examined post-flight by the RSO, or an appointee, in addition to the competition post-flight check in. Certification flight results will be recorded, but not used as part of the competition scoring. Team members who merit certification are expected to accept it and pay for a one-year membership at a student rate. Maintaining active membership beyond that time, which will incur an annual membership fee, is a personal decision unrelated to this competition.

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
- Accomplishing the full number of flights planned (two, minimum, for the main competition rocket, plus additional certification flights (optional))

Scoring Formula (Figures of Merit)

Competition flight scores will be based on the following formulas:

Figure of Merit 1 (FM1) (a point value between 5 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 5 and 15 points)

AR1 = 15 points if apogee is 1000 ft AGL, or greater
AR1 = 10 points if apogee is ≥ 750 ft AGL, but under 1000 ft AGL
AR1 = 5 points if apogee is ≥ 500 ft AGL, but under 750 ft AGL
Disqualification if apogee is under 500 ft AGL

Distance to Target Ranking 1 (DT1) (a point value between 0 and 10 points)

DT1 = 10 points if within 50 ft of target
DT1 = 8 points if > 50 ft but within 100 ft of target
DT1 = 6 points if > 100 ft but within 200 ft of target
DT1 = 4 points if > 200 ft but within 400 ft of target
DT1 = 2 points if > 400 ft but within 800 ft of target
DT1 = 0 points if > 800 ft of target

Vertical Landing Ranking (VL1) (a point value between 0 and 10 points)

VL1 = 10 points for "landing and staying upright" for at least 30 seconds (show onboard video evidence to judges immediately after the flight)
VL1 = 6 to 8 points (judge's discretion) if "almost succeeded in landing and staying upright" (e.g. had a promising mechanism that worked, but rocket tipped after landing)
VL1 = 2 to 4 points (judge's discretion) if "approach had promise, but it didn't work"
VL1 = 0 points (judge's discretion) if "didn't really try to land upright"

FM1 = AR1 + DT1 + VL1

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

Altitude Ranking 2 (AR2) (a point value between 1 and 15 points)

AR2 = 15 points if apogee is between 2950 and 3000 ft AGL
AR2 = 12 points if apogee is between 2850 and 2950 ft AGL
AR2 = 9 points if apogee is between 2650 and 2850 ft AGL
AR2 = 6 points if apogee is between 2250 and 2650 ft AGL
AR2 = 3 points if apogee is less than 2250 ft AGL
AR2 = 12 points if apogee is between 3000 and 3100 ft AGL
AR2 = 9 points if apogee is between 3100 and 3200 ft AGL
AR2 = 6 points if apogee is between 3200 and 3300 ft AGL
AR2 = 3 points if apogee is between 3300 and 3400 ft AGL
AR2 = 1 point if apogee is between 3400 and 3500 ft AGL
Disqualification if apogee is over 3500 ft AGL

Distance to Target Ranking 1 (DT2) (a point value between 0 and 10 points)

DT2 = 10 points if within 50 ft of target

DT2 = 8 points if > 50 ft but within 100 ft of target
DT2 = 6 points if > 100 ft but within 200 ft of target
DT2 = 4 points if > 200 ft but within 400 ft of target
DT2 = 2 points if > 400 ft but within 800 ft of target
DT2 = 0 points if > 800 ft ft of target

Vertical Landing Ranking (VL2) (a point value between 0 and 10 points)
VL2 = 10 points for "landing and staying upright" for at least 30 seconds (show onboard video evidence to judges immediately after the flight)
VL2 = 6 to 8 points (judge's discretion) if "almost succeeded in landing and staying upright" (e.g. had a promising mechanism that worked, but rocket tipped after landing)
VL2 = 2 to 4 points (judge's discretion) if "approach had promise, but it didn't work"
VL2 = 0 points (judge's discretion) if "didn't really try to land upright"

FM2 = AR2 + DT2 + VL2

Note: If the rocket booster landed upright, download raw flight footage between flights (before the 60-minute timer starts) (you should do this anyway, just in case the rocket crashes on the second flight) and to provide it to the judges in a standard-enough video format that they can view it.

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 (like under 500 ft AGL for first flight or over 3500 ft AGL for second flight), even if the rocket is undamaged. 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 (not to exceed a loss of 10 points))
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 and be no more than fifteen (15) single-sided 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 Results
    - Table of Flight Characteristics (mass, motor, max altitude, max velocity, max acceleration, etc.)
    - Plots vs time, if any from commercial altimeter(s) and/or non-commercial sensor suite(s), of raw data such as acceleration, velocity, altitude, voltage on lines to fire ejection charge(s), etc.
    - Screenshots (at least a few) from all on-board videos, if any, and links to where full flight videos and/or pad videos and/or spectator videos can be viewed on-line (e.g., posted to YouTube)
- Discussion of Flight Results vs Flight Predictions
    - Compare predicted results with actual results as measured by on-board electronics. Discuss (at least) apogee, peak velocity, peak acceleration, main deployment altitude for dual-deploy flight(s) (if known), and landing speed – describe and defend possible reasons for differences. The competition-provided AltimeterTwo data logger will give some, but not all, of this information.
- Discussion of Precision Landing Performance
    - Briefly discuss how the rocket fared, considering what you tried to accomplish (which might not be everything).
    - Based on your experiences, and what you observed about other teams, make at least some comments about what you might do differently/next if you were to continue to work on this challenge.
- (Outside of page limits given above): Code Appendix (but only if code changed since FRR – describe changes and include updated code listing)

Evaluation Criteria
Reports will be evaluated on how closely the predicted results compare to the actual results, how well actual values from various sources (if any) agree with one another, and how well the team explains any differences, as well as clarity, completeness, and

professionalism of the material, including the diversity discussion. 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 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

________ **OVERALL TEXT RELEVANCE (16 pts)**

- Executive Summary (4 pts)
- Thorough and organized presentation about approach to precision landing challenges (4 pts)
- General description of rocket general features / functions (4 pts)
- Discussion of how the rocket's unique features / functions will help achieve competition objectives (4 pts)

________ **ROCKET MECHANICAL & ELECTRICAL DESIGNS (32 pts)**

- Airframe and propulsion system specifications (with dimensions) (4 pts)
- Recovery system (steerable parachute) design specifications (8 pts)
- Avionics/payload system design specifications (4 pts)
- Vertical landing system design specifications (8 pts)
- Planned construction solutions and techniques (4 pts)
- Structural analysis of scratch-built parts, if any, and overall risk mitigation analysis (4 pts)

________ **PREDICTED PERFORMANCE FOR FLIGHT (20 pts)**

- Launch analysis (4 pts)
- Flight analysis (peak altitude, peak velocity, peak acceleration, etc.) (4 pts)
- Steering on descent and recovery analysis (4 pts)
- Overall stability and vertical landing analysis (4 pts)
- Environmental conditions analysis (4 pts)

________ **SAFETY (16 pts)**

- Rocket design for safe flight & recovery (4 pts)
- Documentation of materials-handling procedures (4 pts)
- Planned build and launch assembly procedures (4 pts)
- Planned pre- & post-launch procedures (4 pts)

________ **REPORT AESTHETICS (16 pts)**

- Followed specifications (4 pts)
- Consistent formatting; correct spelling and grammar (4 pts)
- Documented figures and graphs (4 pts)
- References and labeling (4 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

________ **OVERVIEW OF PRECISION LANDING APPROACH (8 pts)**

- Thorough and organized presentation of approach to challenge (8 pts)

________ **DISCUSSION OF MAIN ROCKET BUILD (8 pts)**

- Documentation of main rocket team-build, including custom mechanisms (8 pts)

________ **RECAP OF ROCKET DESIGN (24 pts)**

- Designs and dimensions (4 pts)
- Construction techniques implemented (4 pts)
- Av-bay design(s) – tough, but user-friendly (4 pts)
- Construction details regarding safe flights & recoveries, including steerable parachute (4 pts)
- Stability analysis, including vertical landing (4 pts)
- Discussion of changes made since Preliminary Design Report (4 pts)

________ **ROCKET OPERATION ASSESSMENT (20 pts)**

- Launch, boost, and coast phase analysis (4 pts)
- Recovery system and descent phase analysis (6 pts)
- Landing system analysis (6 pts)
- Pre- & post-launch procedure assessment (4 pts)

________ **ALL TEST LAUNCH(ES) (INCLUDING LEVEL 1 CERT. FLIGHTS FOR TEAM MEMBERS SEEKING LEVEL 2 CERT. AT COMPETITION, IF ANY): ACTUAL VS PREDICTED PERFORMANCE (12 pts)**

- Peak altitude, peak velocity, and peak acceleration comparison(s) to expectations (4 pts)
- Recovery system performance comparison(s) to expectations (4 pts)
- Other in-flight data collected (if none, spread points out over two bullet points above): video (if any), other logged sensor data (if any), performance of in-flight mechanisms besides recovery system (if any), etc. (4 pts)

_________ **FINDINGS AND FUTURE WORK (12 pts)**

- Key findings (4 pts)
- Potential design changes / improvements (4 pts)
- "If we were to do it again" – things you are <u>not</u> able to change / improve, but wish you could (and explain why) (4 pts)

_________ **REPORT AESTHETICS (14 pts)**

- Followed specifications (4 pts)
- Consistent formatting; correct spelling and grammar (4 pts)
- Documented figures and graphs (4 pts)
- References and labeling (2 pts)

_________ **CODE APPENDIX (2 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 (30 pts)**

- Discussion of engineering methodology (5 pts)
- Use of design tools (5 pts)
- Thorough presentation of how rocket design addresses the competition objectives (15 pts)
- Use of analytical data – comparison of test flight(s) performance to expectations (5 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)

________ **SET OF ROCKETS EXPERNAL/OVERALL APPEARANCE (12 pts)**

- Visual appearance (6 pts)
- Quality of construction (everything except the av-bay) (6 pts)

________ **AV-BAY(S) (UNTIMED SAFETY CHECK) (8 pts)**

- Appropriateness of design (tough, yet user friendly) (4 pts)
- Quality of av-bay construction (4 pts)

________ **COMMUNICATION SKILLS (12 pts)**

- Verbal projection / articulation (4 pts)
- Eye contact / 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 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

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

- Flight anomalies analysis (10 or 0 pts)
  {If no anomalies, then points are distributed to remaining subsections below}
- Propulsion system assessments (4 or 6 pts)
- Flight trajectory assessments (4 or 6 pts)
- Steerable parachute system assessments (4 or 6 pts)
- Vertical landing assessments (4 or 6 pts)
- Pre- & post-launch procedure assessments (4 or 6 pts)

_________ **ACTUAL VS PREDICTED PERFORMANCE (40 pts)**

- Peak altitude, peak velocity, and peak acceleration comparison to expectations for all rockets (10 pts)
- Steerable parachute performance (10 pts)
- Vertical landing performance (10 pts)
- Discussion of other in-flight results (data available will vary from team to team, but should definitely include peak altitude, peak velocity, and peak acceleration); comparison of video to indicator LEDs; other logged sensor data; performance of other in-flight mechanisms besides recovery system and vertical landing mechanism (if any), etc. (10 pts)

_________ **FUTURISTIC DISCUSSION (10 pts)**

- Discussion of the way forward, were team to keep working on these challenges (10 pts)

_________ **REPORT AESTHETICS (18 pts)**

- Followed specifications (6 pts)
- Professionally written (6 pts)
- Accurate representation of events (6 pts)

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

- If no changes, state that explicitly to earn full points.

________ **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 will spend at least a few hours with each team prior to each report – and possibly more than a few hours 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, Zoom, 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(S) FORM

Submit this to your mentor and to the competition Technical Adviser BEFORE YOU START TO BUILD (or at least before you start to build any scratch rockets) – no later than February 10, 2023, and possibly well before that if you start working on this competition in the fall of 2022. Expect feedback from Gary Stroick within one week. Pay attention to it!

- Discuss your main competition rocket, including your tentative plans for controlling a steerable parachute and/or a vertical-landing mechanism.
- Include simulation files (OpenRocket or RockSim) for the main competition rocket (and all certification rockets). Include details about the basic airframe and the intended competition motors. Be sure to fully describe the extra items you plan to include – don't just call them "mass objects."
- List basic specs for each rocket (especially material and dimensions (including thickness)) of fins, airframe, coupler tube (if any), centering rings and bulk plates, nose cone, retention harness, eyebolts (forged or not), parachute(s), landing legs, plus attachment materials such as shear pins, rivets, epoxy joints, etc.
- Briefly discuss how the motor will be retained (in both directions), how retention harness will be attached, how fins will be attached (and possibly reinforced), how the landing mechanism will be stowed (and deployed), and how the steerable parachute will be stowed (and deployed) (and controlled).
- Briefly discuss what commercial altimeter(s) you will use 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.).
- Briefly discuss what other (custom) electronics will be onboard and what it will go – log other sensors, try to steer the parachute, deploy the landing mechanism, etc.
- State explicitly which team members are building which rockets (individually) to attempt to certify at what level. Also mention which team members, if any, already are Level 1 certified. Remember that earning a Level 1 certification is a pre-requisite for attempting a Level 2 certification, and Level 1 should be done in advance – not on the same day as the Level 2 certification. We plan to offer the Level 2 certification test the evening before the competition flights, and you need to have passed your Level 1 certification before being allowed to take that test (and you must pass the test before trying the certification flight, so be sure to study for it).

2022-2023 NASA's Space Grant
Midwest High-Power Rocketry 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 Rocketry 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 rocketry competition. We are also grateful for your involvement in this mission. If you have any questions about the Midwest High-Power Rocketry 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