2021-2022

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

(v2; posted 9/20/2021)

Return to Flight: Fleet Challenge

Informational telecons: Mon. Sept. 20, 2021 (then repeated Thurs. Jan. 13, 2022) 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, 2021

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

Registration Deadline: January 31, 2022

Launch Competition in Minnesota: Sat. & Sun., May 21-22, 2022** (Rain date: Mon., May 23, 2022)

** **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_2021_2022/

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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 rockets 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

The general objectives of this year's "Return to Flight: Fleet Challenge," especially for teams that are new to high-power rocketry or have had to limit their activities in the past year due to COVID-19 restrictions, are as follows:

> *In this competition, college-student teams will design and construct a set of (fairly-low-cost) high-power rockets (either five rockets (a "fleet") or else three rockets (a "flotilla") or else eight rockets (an "armada")). These rockets are to differ from one another in as many ways as possible, to illustrate the ability of the team to successfully demonstrate a wide variety of rocketry styles and build techniques. Every fleet (or flotilla) (or armada) must include one "core" team-built kit-rocket flown on a specific motor (see details in handbook) for "head-to-head" competition. This "core" rocket will be accompanied by four (or two) (or seven) additional rockets, some team-built and some individual-built (for certification – see expectations below).*
>
> *Possible differences between rockets include, but are not limited to, (A) kit rocket vs scratch built, (B) single vs dual deploy, (C) two-parachute dual deploy vs chute-release dual deploy, (D) team-built vs individual-built (see certification expectations below), (E) commercial airframe (or nose-cone) vs hand-wrapped airframe (or 3-D printed nose-cone), (F) using a variety of materials (wood vs fiberglass for fins; using different airframe materials; etc.), (G) demonstrate a variety of geometries in airframe, fins, nose-cones, etc., (H) have recovery triggered by different commercial altimeters, (I) rockets carrying video (or not), (J) rockets collecting performance data from a non-commercial sensor suite vs using commercial altimeters only – note: all rockets should at least collect basic performance data using a Jolly Logic "AltimeterTwo" or "AltimeterThree" (each team may borrow one AltimeterTwo from competition organizers, if need be), (K) rockets sending down performance data by radio telemetry (or not), (L) have all rockets fly on different motors – probably a given – but also selecting different motor diameters and/or cases/closures and/or manufacturers, (M) have rockets fly on different classes of motors (H class vs I class vs J class), (N) using reloads vs disposable motors, etc.*

Judges (working as a group) will be given some latitude in deciding how to weight various differences. Some differences, like paint job, size of rail buttons, and/or different shapes of commercial nose cones, might be considered "trivial" and not given much/any weight. Other differences, like varying airframe diameter, airframe and/or fin material, number and/or shape of fins, type of commercial altimeter, motor diameter, and/or type of recovery might be considered "modest" and given more weight. Some differences, like building at least some (well-simulated) scratch-built rockets, exploring different motor classes and/or motor manufacturers, using fly-away rail guides, or doing something "special" (like making your own nosecone(s), adding camera(s), non-commercial data logging, data telemetry, air brakes, roll control, minimum diameter, etc.) might be considered "significant" and given even more weight. But the highest possible weight category will not exceed the middle category by more than 50%, meaning that teams can do well even if their set of rockets does not exhibit any "significant" differences. Teams will be awarded full points for showing up to 3 differences in a given area, like number of fins, class of motor, or airframe diameter. This means that a very diverse flotilla (3 rockets) can technically keep up with an armada (8 rockets), at least on diversity scoring. Thus, each team should select how many rockets to build based on personnel (and budget), not because they expect to get more points.

All rockets must be built for this competition by the current team – no flying previously-built rockets. The following are "off limits" (for safety considerations, with a competition that will include many first-time fliers): (1) no multi-stage rockets, (2) no multi-motor (AKA cluster) rockets, (3) no air-starts, (4) no canards, (5) all rockets must have a fully-operational motor-eject recovery system, at least for their drogue/apogee parachute, (6) all rockets must leave the rail at a reasonable speed (see Design and Safety Review Section), (7) all rockets must land at a reasonable speed (see Competition Engineering Section) under parachute – no streamer-only recovery systems, (8) all rockets must fly on Cesaroni or AeroTech H-class, I-class, or J-class motors, (9) all rockets must come down with all parts tied together – no fly-away parts, such as releasable gliders or other payloads (exception – fly-away rails guides are allowed). Also (9) no points for the widest possible differences in performance like apogee or acceleration or top speed (for example, no explicit points for supersonic vs subsonic, but strengthening a rocket to allow it to go supersonic would be considered valuable), (10) no points for the most expensive vs least expensive rocket – indeed, to keep costs down, we encourage <u>all rockets to be relatively low cost – perhaps in the $50 to $250 range (aside from motor, motor case and closure, and electronics)</u>, etc. 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, every "flotilla" must include one individual-built rocket for a Level 1 certification attempt and every "fleet" must include one individual-built rocket for a Level 1 certification attempt and also one individual-built rocket by a different team member for a Level 2 certification attempt and every "armada" must include two individual-built rockets by different team members for Level 2 certification attempts. The certification level of each team member must be declared before and after the competition. Certification attempts do not have to be 100% successful for a rocket to be included in the judging. For example, if a student fails their Level 2 certification test their rocket may still be flown, under supervision – just not for certification. All team-built rockets need to be flown under supervision, by the team's mentor or another certified individual.

All proposed differences a team intends to demonstrate must be included in a Draft-of-Design report, to be submitted before building any rockets (or at least any scratch-built rockets), so competition organizers can steer teams away from potentially-unsafe options. On the other hand, points will be awarded for "most effective use of (fleet) theme." That said, rocket names, paint jobs, etc. should be coordinated.

On the day of the competition flights, which we plan to hold in person at North Branch, MN, teams are allowed to, though not required to, request simultaneous launches of their team-built rockets (though this might be more expensive, because it will preclude sharing electronics and/or motor cases between rockets). (Aside: Rockets flying for certification will need to be launched individually, for observation purposes, and probably will be flown early in the day (before team-built rockets)). We encourage, but will not require, teams to test-fly all team-built rockets in advance of the competition date – especially the "core" kit rocket. Certification rockets, on the other hand, by definition should not fly in advance, or at least not on their certification-level motor. However, a Level 1 certification rocket may be pre-flown on a G-class motor (or lower) and a Level 2 certification rocket may be pre-flown on an I-class motor (or lower). Every rocket is expected to fly just once at the competition. This means that anyone trying for a Level 2 certification needs to gain their Level 1 certification, possibly using the same rocket flying on a Level 1 motor, at a launch prior to the competition date.

Only rockets that are recovered in re-flyable condition will be eligible for judging, so a "fleet" might need to be downgraded to a "flotilla" if not all rockets fly successfully. To save on costs, consider sharing electronics and/or motor cases between rockets (assuming they won't be on the rail at the same time). Competition organizers will be able to lend each team one Jolly Logic AltimeterTwo data logger unit, either at the competition or in advance. The Tripoli-Minnesota club requires active radio tracking on all flights expected to go higher than 3000 ft above ground level. Audio beepers are not a substitute for genuine radio tracking, but might also be useful to include – especially true for

summer/fall launches (at North Branch) but less-needed at our competition in May.

The "Core" Kit Rocket

Every fleet (or flotilla or armada) is required to include the following team-built "core" kit rocket. Note that the judging of this "head-to-head" part of the competition will be based on (A) the quality of the rocket build plus documentation of improvements made to the given instructions and (B) "Did the team correctly predict how the rocket would perform and did the rocket perform as expected?", **not** "Which rocket went highest?"

Binder Design Excel Dual Deploy kit rocket: 3" diameter, 38 mm motor mount, phenolic airframe, plastic nosecone, you choose parachute size(s) – the kit comes with a 12" drogue parachute (use that, if desired)
http://binderdesign.com/store/3-inch-kits.html

Build the kit with a 38 mm motor mount according to the instructions provided, unless you can do better. This is a challenge, not to fundamentally modify the kit but rather to improve on it. For example, it is probably not necessary to strengthen the fins or airframe with fiberglass or carbon fiber considering the motor you will fly it on (listed below). Verify, using software, whether or not the rocket is likely to suffer fin flutter and/or divergence issues before deciding to unilaterally add fiberglass. (If you want to demonstrate your ability to add fiberglass to a rocket, consider doing that on a different rocket.) On the other hand, switching from the provided (bent) eye-bolts to forged eye-bolts would be one possible improvement. Document all changes made to the kit build, defending each decision in your reporting.

Fly the rocket in dual deploy mode on a Cesaroni 38 mm 2-grain H225 White Thunder motor (which requires a case). Use a commercial altimeter to control the dual deploy, deploying the first (drogue) parachute at apogee. Provide evidence (possibly using an on-board camera – allowed) that the drogue parachute was deployed ***by the altimeter, not by the motor eject*** *(which must remain in place, as a back-up for drogue deployment). Deploy the main parachute between 600 and 700 feet above ground level, on descent. In addition to the commercial altimeter controlling the ejection charges, fly a Jolly Logic AltimeterTwo or AltimeterThree data logger to give an independent record of the performance.*

Note: The decoration of this "core" rocket is expected to tie in with the other rockets the team builds, so we do not expect teams to necessarily use the decals provided, nor follow the paint scheme suggested.

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, *and, for this*

particular competition, "effective use of (fleet) theme," 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 fabricate rockets 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 – teams are encouraged to try both (to illustrate diversity).

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, but possibly advantageous to minimize drift on descent to help ensure the rocket lands on the sod), the second (AKA main) parachute must be deployed at least 500 feet above the ground. No drogue-less descent allowed, though achieving dual-deploy using a chute release is allowed.

The recovery system must safely land the vehicle at a descent speed not to exceed 24 ft/sec. 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 rockets must carry a commercial data-logger such as a Jolly Logic AltimeterTwo or AltimeterThree – even rockets which aren't 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 may elect to build and fly a non-commercial data-logging sensor suite (as evidence that they are able to build one that works). 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 disposable motor system") don't 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 a portion of your registration fee) no later than March 11, 2022, in conjunction with submitting your PDR. Motors for test flights should be ordered even earlier – from a high-power rocketry vendor such as one who serves high-power launches in your part of the country.

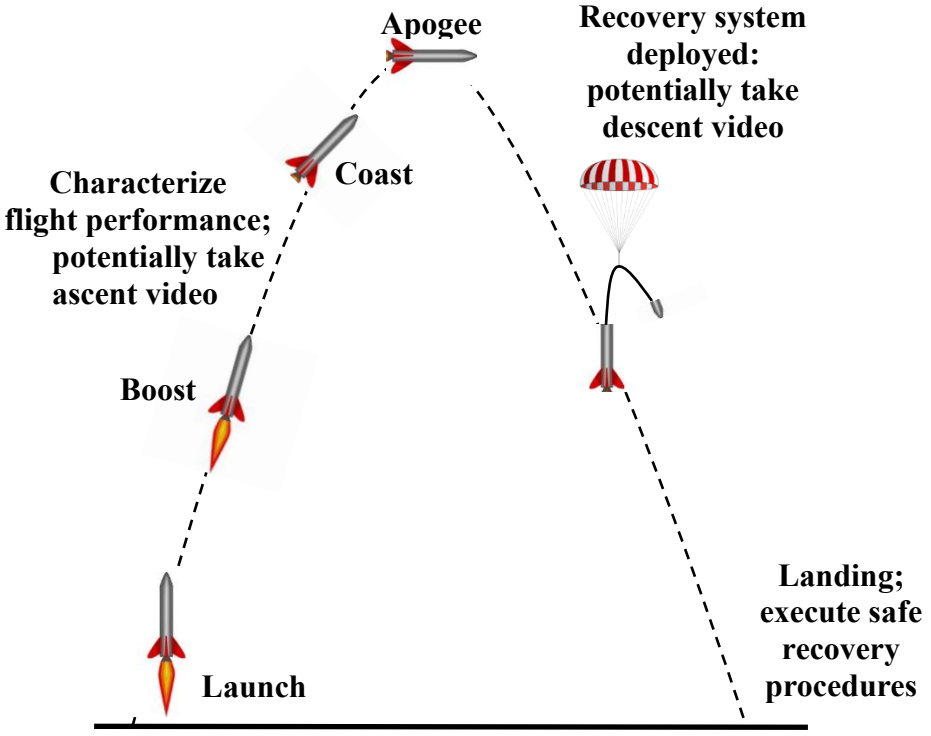


Figure 1: Generic single-deploy rocket flight profile.

Flight Mission	▪ Build (as a team) the "core" kit rocket, documenting any improvements you make to the build instructions, then simulate its flight and fly it successfully in dual deploy mode on a Cesaroni 38 mm 2-grain H225 White Thunder motor (see details above). ▪ Build additional rockets, some as a team and some by individuals for certification, to flesh out a coordinated "fleet" of 5 rockets (or "flotilla" of 3 rockets) (or "armada" of 8 rockets) (see details above). Make use of this opportunity to illustrate your team's ability to execute the widest (but still safe, of course) range of rocket styles and build techniques.
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 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 **one hour** 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 not 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 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 at least one fully-functional, team-built competition rocket on a high-power motor (i.e., H-class or above) prior to the competition. We recommend flying the "core" rocket on planned H-class motor or, to get more practice, use Cesaroni or AeroTech motors that require cases (and closures) (and assembly). (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.

	⇤ 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 2022. ⇤ 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 rockets that fly "successfully" can count for diversity scoring. 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 no lower than 500 feet above ground level.
- Landing descent rate is deemed reasonable (≤ 24 ft/sec) – based on judge's observation, not sensor values.
- All rocket components remain attached together throughout the flight (e.g., no disassembly or shedding of components – exception: fly-away rail guides are allowed, but must be recovered from the field and presented in the post-flight check-in).
- Rocket is recovered in re-flyable condition, which means that if given another motor, the rocket could be re-flown without requiring 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 flights on either a Cesaroni or an AeroTech H-class or I-class or J-class motors. Thrust curve data can be found at: http://www.thrustcurve.org/searchpage.jsp
- Note: as of August, 2021, a Cesaroni 38 mm 2-grain H225 White Thunder motor costs $39.00 (not including a case) from Off We Go Rocketry, so motors for an entire fleet (or flotilla) (or armada) 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. 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, to share among their rockets, 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, 2021 – Announcement of the 2021-2022 academic year competition
- September 20, 2021, 7 to 8 p.m. CST – 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, 2021 – (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)
- January 13, 2022, 7 to 8 p.m. CST – Repeat of informational telecon (especially for teams starting in the spring)
- January 31, 2022 – 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 may elect to have their previous registration fee applied to this new competition (or else to next year's competition), but may not extend registration credit beyond 2022-2023)
- February 11, 2022 – Declaration of Competition Attendance due
    - Specify Number of Team Members Attending Launch
    - Specify Number of Hotel Rooms and Dates Required
- February 11, 2022 – Last possible date to get credit for Draft of Designs
- Mid-February – Suggested last date to order motors for April test flight(s)
- March 11, 2022 – Preliminary Design (Written) Report due (see rubric below)
    - Must include the type and number of motors desired for the competition date. The registration fee covers 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 submit the extra funds along with this report. Generally speaking, purchasing additional motors are the responsibility of the team and must be purchased from a high-power rocketry vendor and paid for in advance.
    - This report must also include the Model Rocket Demonstration Flight documentation (or waiver)
- March and April 2022 – likely times for test flight(s), at least a team launch of a fully-functional "core" rocket and also Level 1 certification flight(s), if need be, 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 9, 2022 – Flight Readiness (Written) Report and Educational Outreach form due
- May 21-22, 2022 – Competition**
    - Saturday, May 21 – Mid-afternoon into the evening: Flight Readiness (Oral) Presentations and Safety Checks

    - Sunday, May 22 – Competition launch all day (North Branch, MN) and evening social event, with announcement of partial results[1]
    - Monday, May 23 – Alternative competition launch (Rain Date) (so don't make travel plans that prevent you from staying through May 23 if conditions require – if the launch date is delayed by one day, that will be announced no later than the evening of May 21)
- June 3, 2022 – Post-Flight Performance Evaluation and Data Collection Report due
- Final competition results will be reported on or before June 15, 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 2022). Such a "drastic" decision will be made no later than the end of April, 2022. If teams assemble in May and do oral presentations but are unable to launch due to wet conditions on both May 22 and 23, 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 "Most Effective Use of (Fleet) Theme" and/or "Best 'Core' 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
- 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)
- 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!

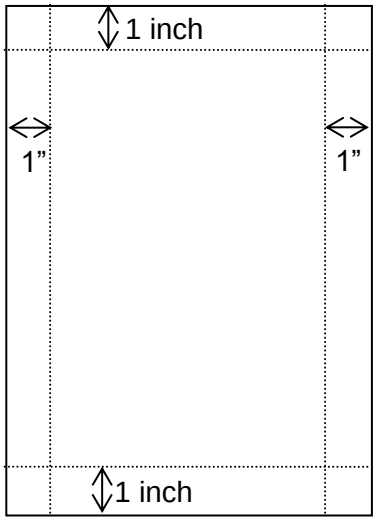
Preliminary Design (Written) Report

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 for a fleet (or twenty (20) pages for a flotilla) (or thirty (30) pages for an armada). 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 each 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) 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)
- Diversity of rocketry styles and build techniques to be implemented – perhaps in table format (~1 page)
- Labeled figures showing features of each rocket airframe

- 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
- Budget (planned) including kit rockets, 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. 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 for a fleet (or twenty (20) pages for a flotilla) (or thirty (30) pages for an armada), 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)
- Diversity of rocketry styles and build techniques implemented – perhaps in table format (~1 page)
- Discussion of "core" rocket build, including changes made from build instructions (with defense of each)
- Summary of rocket designs, especially the unique airframe features, av-bays, and electronics (keep this to about 1 page per rocket, or so)
- Budget (actual; with comments about changes since planned budget)
- Construction photos of all rockets, including photos of the interiors of at least some of the av-bays
- 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 performance)
    - Recovery system performance
    - Table of flight characteristics (mass, motor, max altitude, max velocity, …)
- Discussion of results
    - Compare predicted and actual apogees, predicted and actual peak velocities, and predicted and actual peak accelerations. Describe differences and defend possible reasons for differences (if any)
    - 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., 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, whether you build a fleet, a flotilla, or an armada. (Note – the judges will have read the written reports in advance, so you don't need to take a long time introducing each rocket from scratch. Instead, maybe just point out unique features of each rocket.) 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). These will not be timed events, but the av-bay examinations will need to be fairly quick – probably no more than 5 minutes to show off all your av-bays 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 Level 1 certification rockets must be ready to fly within **one hour** 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).
- All teams must be in the RSO line and ready to present their rockets in ready-to-fly condition by the times listed above. Certification rockets will be given priority over non-certification rockets for pad assignments up until noon.
- 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 practice, 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 and main parachute, if dual deploy) is successfully deployed
- Landing speed is deemed reasonable (≤ 24 ft/sec)

- All rocket components remain attached throughout the flight (e.g., no disassembly or shedding of components) (exception – exception: fly-away rail guides are allowed, but must be recovered from the field and presented in the post-flight check-in)
- Rocket must be recovered in flyable condition
- Note: Failure to log sensor data and/or to collect video will not, in and of itself, constitute a failed flight if the conditions above are met. For example, there will not be an explicit deduction or disqualification if part of the recovery system is ejected successfully by the back-up charge rather than by the primary charge. A dual-deploy rocket that lands at a safe velocity and is undamaged, even if both parachutes didn't deploy exactly as planned, will not be subject to 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 for a fleet, flotilla, or armada

Scoring Formula

Competition flight scores will be based on the following formulas:

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 and is re-flyable. Rockets may be disqualified for events like unstable ascent, too-fast landing, 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 for each rocket** (if not disqualified) = 10 points for a timely flight (loss of 2 points per 15 minutes beyond the expected presentation time)*
PLUS
20 points for completing a safe flight (whether fully or partially successful)

***Overall flight score** will be the total flight scores for all rockets, scaled to 100 points total.*
For a fleet, that will be total flight score (potentially up to 150 points) times 2/3.
For a flotilla, that will be total flight score (potentially up to 90 points) times 10/9.
For an armada, that will be total flight score (potentially up to 240 points) times 5/12.

In all cases, up to 1/3 of the points are awarded to rockets that are prepped in a timely manner and the remaining points are for safe flights in which rockets are recovered in re-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 once during the competition, the best flight (team choice) 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 very many rockets more than once.

If weather conditions – particularly low cloud cover – only allow for certain flights on the primary flight day, additional flights will be allowed on the weather-delay date. If weather prevents flights 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) pages for a fleet (thirteen (13) pages for a flotilla) (eighteen (18) pages for an armada), 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 Fleet Diversity
  - Briefly discuss how you feel about the diverse rocketry styles and build techniques you tried. In particular, if you favor (or now don't care for) specific items (like fin can assembly steps, av-bay organization, etc.), explain why.
- (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 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 of diversity in style and build techniques to be implemented (4 pts)
- General description of all rockets with their unique features / functions (4 pts)
- Discussion of how the set of rockets achieves competition objectives (4 pts)

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

- Airframe and propulsion systems: specifications (with dimensions) (8 pts)
- Recovery system designs: specifications (8 pts)
- Avionics/payload system designs: specifications (4 pts)
- Planned construction solutions and techniques (8 pts)
- Structural analysis of scratch-built parts, if any, and overall risk mitigation analysis (for all teams) (4 pts)

_____ **PREDICTED PERFORMANCE FOR ALL FLIGHTS (20 pts)**

- Launch analysis (4 pts)
- Flight analysis (peak altitude, peak velocity, peak acceleration, etc.) (4 pts)
- Recovery analysis (4 pts)
- Stability analysis (4 pts)
- Environmental conditions analysis (4 pts)

_____ **SAFETY (16 pts)**

- Rockets all designed 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 ROCKETRY STYLES AND BUILD TECHNIQUES IMPLEMENTED (8 pts)**

- Thorough and organized presentation of diversity included in set of rockets (8 pts)

_____ **DISCUSSION OF "CORE" ROCKET BUILD (8 pts)**

- Documentation of team-build of "core" kit rocket (4 pts)
- Discussion of changes / improvements made to build instructions, with defense (4 pts)

_____ **RECAP OF ALL ROCKET DESIGNS (24 pts)**

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

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

- Launch, boost, and coast phase analysis (8 pts)
- Recovery system and descent phase analysis (8 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 (OR STATE IT IS NOT NEEDED) (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 rocket designs and diversity in build techniques and how set of rockets addresses the competition objectives / requirements (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 and coordination (following "fleet" theme) (6 pts)
- Quality of construction (external) (6 pts)

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

- Appropriateness of design (tough, yet user friendly) (4 pts)
- Quality of construction (internal) (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 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)
- (In-flight) recovery system assessments (4 or 6 pts)
- Ground recovery assessments (4 or 6 pts)
- Pre- & post-launch procedure assessments (4 or 6 pts)

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

- Peak altitude, peak velocity, and peak acceleration comparison to expectations for all rockets (10 pts)
- Recovery system performance comparison to expectations for all rockets (10 pts)
- Discussion of other in-flight results (data available will vary from team to team, but data collected across a set of rockets should definitely exceed peak altitude, peak velocity, and peak acceleration): video (if any), other logged sensor data (if any), performance of in-flight mechanisms besides recovery system (if any), etc. (10 pts)

_____ **DIVERSITY DISCUSSION (20 pts)**

- Discussion of performance of diversity of rocketry styles and build techniques (10 pts)
- Discussion of preferences, with defense (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 DESIGNS 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 11, 2022, and possibly well before that if you start working on this competition in the fall of 2021. Expect feedback from Gary Stroick within one week. Pay attention to it!

- Include a full list – a table probably is best – of all the diversity you intend to implement and which rocket(s) from your fleet (or flotilla) (or armada) will exhibit which feature(s). The second paragraph of the Rocket Design Objectives section gives a non-exhaustive list of styles and build techniques you might consider trying to include.
- 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. This is, in part, because 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.
- Include simulation files (OpenRocket or RockSim) for each rocket, including all kit rocket(s). Include the basic airframe and the intended competition motors. Be sure to fully describe extra items you 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) (plus other attachment types such as shear pins, rivets, epoxy joints, etc.).
- For each rocket, briefly discuss how the motor will be retained (in both directions), how retention harness will be attached, and how fins will be attached (and possibly reinforced).
- For each rocket, 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.).

2021-2022 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