2018-2019 NASA Space Grant Midwest High-Power Rocket Competition
"Efficient Supersonic" Challenge
Summary of Rules (also see kick-off slides, handbook, and website Q & A for additional details)

First flight – Direct Comparison Flight

- Must fly on a Cesaroni 491-I-218-14A "White Thunder" 1-grain 54 mm diameter motor. Unlikely to go supersonic, but this will allow for direct comparison of peak acceleration, peak velocity, and peak altitude (see Figure of Merit relation below). Be sure to design the rocket so it can accommodate a (presumably-longer-than-1-grain) motor which will take it supersonic (second flight). SM at launch must be between 1 and 3 for both flights.
- Rockets should also carry a (competition-provided) Jolly Logic Altimeter Two data logger or else a (team-provided) Jolly Logic Altimeter Three data logger, mounted diagonally if the peak acceleration is expected to exceed 24 g's.
- Figure of Merit for Flight 1 (FM1) (ranges from 0 to 1) (only applied to rockets with a (fully-or-partially) successful Flight 1) (based on Altimeter Two/Three data logger):

FM1 = (your peak altitude / highest peak altitude for Flight 1)
**** (your peak velocity / highest peak velocity for Flight 1)***
**** (your peak acceleration / highest peak acceleration for Flight 1)***

Second flight – Efficient Supersonic Flight

- Must fly on an I class or J class motor by Cesaroni or AeroTech (need not be 54 mm dia).
- If you design a minimum diameter rocket, be particularly careful about motor retention (and fin retention!). Explicitly design to avoid fin flutter and divergence. (If you are not sure how to do that calculation, ask!) The rocket must look the same (externally) for both flights but internal components, such as the avionics bay (or parts there-of) and/or ballast, can be changed between the two flights.
- It may be difficult for pressure-only commercial altimeters to determine the actual top speed so the post-competition-flight-report will ask for "evidence of going supersonic from more than one source." In particular, you should discuss such evidence based on your commercial altimeter(s) and, separately, discuss such evidence based on your non-commercial sensor suite (described below).
- Rockets should also carry a (competition-provided) Jolly Logic Altimeter Two data logger or else a (team-provided) Jolly Logic Altimeter Three data logger. These devices can technically sense going supersonic but they can also be fooled, so their result should be reported for judge consideration (along with evidence mentioned above) but it won't be taken as the final word by the judges. *{We are exploring having a competition-provided acceleration-based altimeter such as a Raven3 instead of an Altimeter Two and will let you know no later than Dec. 31, 2018 if you need to design for one – that would need to include external power and a switch.}*
- "Efficiency" Figure of Merit for Flight 2 (FM2) (ranges from 0 to 1) (only applied to rockets with a (fully-or-partially) successful Flight 2 <u>that actually go supersonic</u>):

FM2 = minimum among the rockets (impulse * max thrust * max altitude)
divided by your rocket's (impulse * max thrust * max altitude)

- Rockets that have a (fully-or-partially) successful Flight 2 but don't go supersonic will receive a flat score of 0.5 * the lowest value FM2 for any supersonic rocket.

"Successful Flight" criteria

- A flight is deemed "fully successful" if it flies vertically and stably all the way to apogee, deploys its drogue parachute at (or just past) apogee, descends under drogue no slower than 50 ft/sec, inflates its main parachute between 800 and 500 ft above ground level, lands no faster than 24 ft/sec, and is recovered in re-flyable condition.
- Rockets that don't fly vertically, stably, land traveling significantly faster than 24 ft/sec, or are deemed unsafe for any other reason are subject to disqualification by the judges, even if they are recovered in re-flyable condition. Flight disqualification decisions will be announced on the spot. (i.e. they will not be based on data analysis, just observation)
- Rockets that are recovered in re-flyable condition without satisfying all items listed above will be deemed "partially successful" with deductions at the judges' discretion – typically -15% off for each item not satisfied (like -15% for wrong drogue descent rate; -15% for wrong main deployment altitude; etc.). "Partially successful" decisions will NOT be announced on the spot because they will depend on data records that show descent rates, deployment altitudes, etc., but will be announced shortly after the competition date (i.e. prior to the post-competition-flight-report due date) based on flight data downloaded from the rockets following each flight.
- Disqualified flights may be re-tried if the rocket is deemed safe enough to re-fly (assuming motors are available). But be prepared to answer the following question from the RSO – "What have you changed to make this flight safer?"
- Partially successful (and indeed, even fully successful) flights may also be re-flown (possibly using a different motor, in the case of Flight 2), in hopes of improving results. The post-competition-flight-report should talk about your best Flight 1 and your best Flight 2 if you fly either type more than once.

Required recovery system operation

- Dual deploy
    - Drogue parachute deployed at (or slightly after) apogee – <u>not</u> before apogee
    - Two independent drogue deployment mechanisms
        - Drogue primary ejection – must be electronic, using a mach-capable commercial altimeter
        - Drogue back-up ejection – either motor eject or electronic with a second mach-capable commercial altimeter (which must be independently powered and independently wired and fire an independent charge from the primary drogue electronic ejection charge)
    - The average descent speed under drogue must at least 50 ft/sec (about 100 ft/sec recommended, to minimize wind drift)
    - Main parachute fully inflated between 800 and 500 ft above ground level (AGL)
        - Main primary ejection – must be electronic, using a mach-capable commercial altimeter
        - A back-up ejection mechanism for the main parachute is encouraged, though not required. The back-up ejection for the main, if any, should be set to activate 1 second after, or 100 ft lower, than the main primary mechanism.
    - The average descent speed under main + drogue (i.e. the landing speed) must be no more than 24 ft/sec

Required data-logging sensor suite

- Must be "non-commercial" which means constructed from items NOT sold specifically for use in rocketry
- Must log rocket performance data at 10 Hz (even faster would be better) including at least axial acceleration, rotation about rocket axis (AKA "roll"), and ambient pressure in the av-bay (to see what happens when rocket goes supersonic). Also log velocity and altitude, though these might be calculated using acceleration and/or pressure data rather than measured "directly." Time-stamp all data, at least in a relative (since-launch) sense.

3 ways to get extra points – encouraged, but technically optional

- Up to 10% extra (5% for each flight on which this is flown and it works): Fly a "thorough video camera system" (one or more cameras, possibly pointed in different directions) that captures (a) flames and ground receding during boost, (b) deployment/inflation of drogue parachute, (c) deployment/inflation of main parachute, and (d) impact with the ground.
- Up to 10% extra (5% for each flight on which this is flown and it works): Add a radio telemetry system to the non-commercial sensor suite and send to the ground and report them to the judges BEFORE the rocket lands all of the following from on-board sensor measurements: max acceleration, duration of boost, max velocity, duration of coast, max altitude, and descent velocity under drogue (calculated during just early part of descent).
- Up to 5% more (2.5% for each flight on which this is flown and it works) (additional radio telemetry – this will require adding gps to your non-commercial sensor suite): report to the judges within 5 minutes of landing all of the following from on-board sensor measurements: altitude of main parachute full inflation, descent velocity under main + drogue (i.e. landing velocity), and landing gps location (latitude, longitude, altitude (above sea level)).

Note 1 – You should test launch your rocket at least once on a high-power motor (H-class or above) before coming to the competition, with all electronics on board and functioning. You do NOT need to do test launch(es) on the motor(s) you have selected for competition use, though doing so is strongly encouraged if your test flight launch site can accommodate the altitude(s) you will reach. Rockets that have not been test-flown in advance may still come to and fly at the competition but will be hampered (score-wise) on both the FRR written report and the oral report, which assign points for presentation of test-flight results.

Note 2 – Remember to purchase all required case(s) and closure(s) for every motor that you plan to fly. Note that Cesaroni and AeroTech both sell "1-grain spacer" units that allow you to fly a shorter motor in a longer case, but no more than two spacers may be used at one time in a case. Cesaroni and AeroTech motor cases and spacers are NOT interchangeable. AeroTech's limited DMS "disposable motor system" motors do not require cases. If desired, a 54 mm diameter motor mount tube can accommodate 38 mm diameter motors, or even 29 mm diameter motors, if an appropriate adapter is incorporated into the design.

Note 3 – If using motor eject, be sure to run simulations to help select a motor whose delay grain is long enough. Don't let the motor eject fire before the rocket reaches apogee! There are tools to grind motor delay grains shorter, but they cannot be made longer than the original

manufacturer value. In Cesaroni and AeroTech motors, "-%%A" in a motor designation means "delay grain timing is **A**djustable, from %% seconds downwards" and "-P" in a motor designation means "**P**lugged – no motor eject." Cesaroni 54 mm diameter motor delays range from 11 to 19 seconds. In AeroTech motors, most delay grains are for 14 seconds. Note that it is possible to remove the motor eject altogether from any motor, if you elect to go with the 2-independent-commercial-altimeter option in your design.