

NAR Level 3 Certification Rocket Package

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Vehicle Design

The Level 3 High Power Rocket (HPR) is a custom constructed rocket. The rocket is a 5" diameter fiberglass, dual-deploy HPR flying on an AeroTech M1780NT-PS. The rocket was designed to be 9.25' tall with an estimated apogee of 8107 ft and maximum speed of 1051 ft/s using OpenRocket simulations. The rocket will be flown on flight-verified custom electronics and have a 75 mm motor mount. The mass of the rocket is 500 oz, including the assembled rocket, rocket motor, and recovery system.

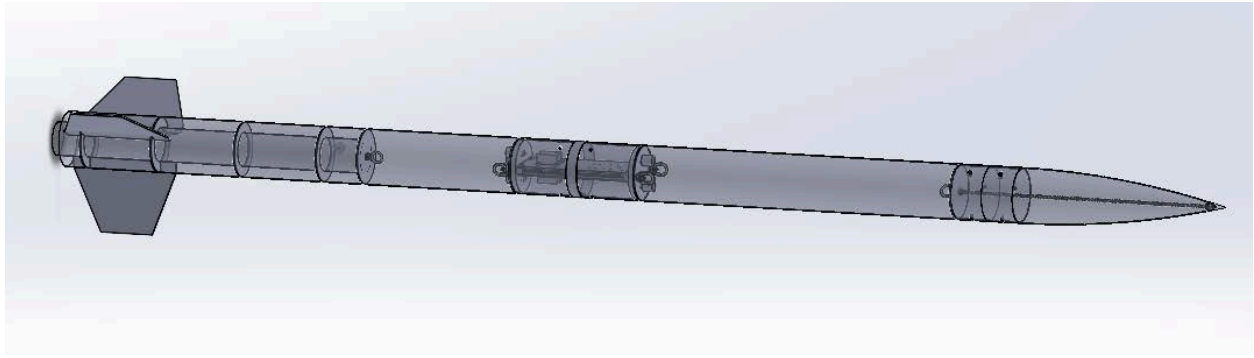


Figure 1. Solidworks CAD of L3 rocket

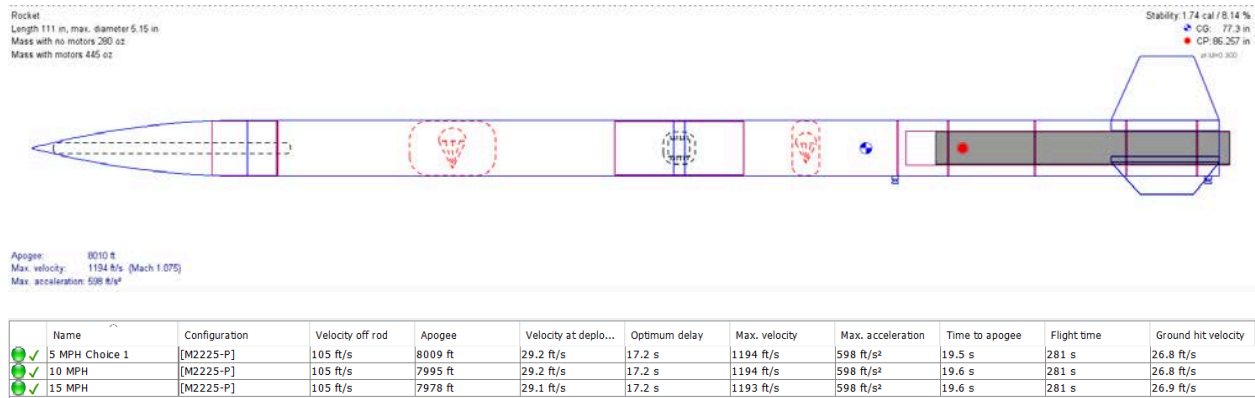


Figure 2. OpenRocket simulations

Vehicle stability during flight will be 2.36 calibers, and liftoff stability will be 1.61 calibers. 28.6 oz of ballast will be added to the nosecone section to offset the distance between the center of gravity and pressure in the rocket. Table 1 below highlights the flight characteristics

calculated by OpenRocket for a flight on an AeroTech M1780NT-PS. The OpenRocket file can be downloaded in Appendix A.

Table 1. OpenRocket predicted flight characteristics.

Motor	AeroTech M1780NT-PS
Rocket diameter	5.15 in
Rocket length	111 in
Weight (With motor)	500 oz
Weight (Without motor)	337 oz
Drag coefficient, CD	0.8
Rail exit velocity, 12ft <u>1515</u> rail	97.2 ft/s
Maximum altitude	8107 ft AGL
Maximum velocity	1051 ft/s
Launch acceleration	481 ft/s/s
Launch stability	2.36 Calibers
Loaded CG location	74.50 in from tip
CP location	86.63 in from tip
Velocity under drogue	33 ft/s
Velocity under main	26 ft/s



Figure 3. OpenRocket flight simulations

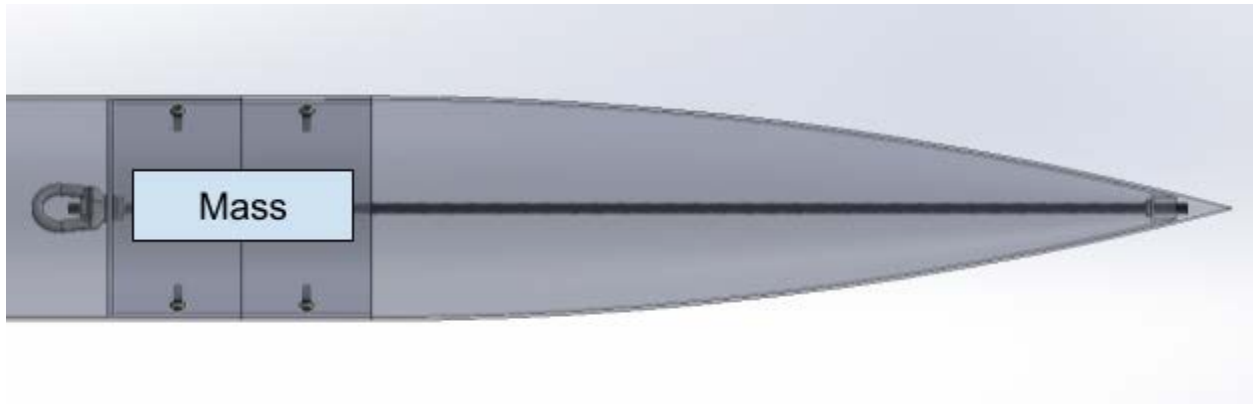


Figure 4. Nosecone tip weight

The rocket is a dual-deployment setup, with a drogue parachute in the motor section and a main parachute connected to the nosecone. The rocket will separate at the top and bottom of the electronics bay. The nosecone will remain permanently connected. The drogue parachute is 30 in, and the main parachute is 72 in. The parachutes are both connected to the electronics bay, which connects the two body tubes with a 12 in long coupler. This provides sufficient space for the dual-deployment recovery electronics as well as a GPS tracker to aid in recovery. Deployment will be controlled by two commercial dual-deploy altimeters with stepped lids and 2 threaded rods.

Recovery

A 3/8" diameter, 3600 lb rated tubular kevlar shock cord from Wildman Rocketry was selected for both parachutes. In the motor section, the shock cord is attached to the motor forward closure using an eye bolt and nut. On the nosecone side, the shock cord is attached by an eye nut and threaded rod stretching from the metal tip of the nose cone. A 30" Elliptical parachute and 72" Iris Ultra parachute were selected for the main and drogue parachutes. The drogue parachute will deploy once apogee is reached, and the main parachute will deploy at an altitude of 600 ft. The backup altimeter will deploy 1 second after each event. By using dissimilar systems, the failure of one altimeter will not cause both altimeters to fail.

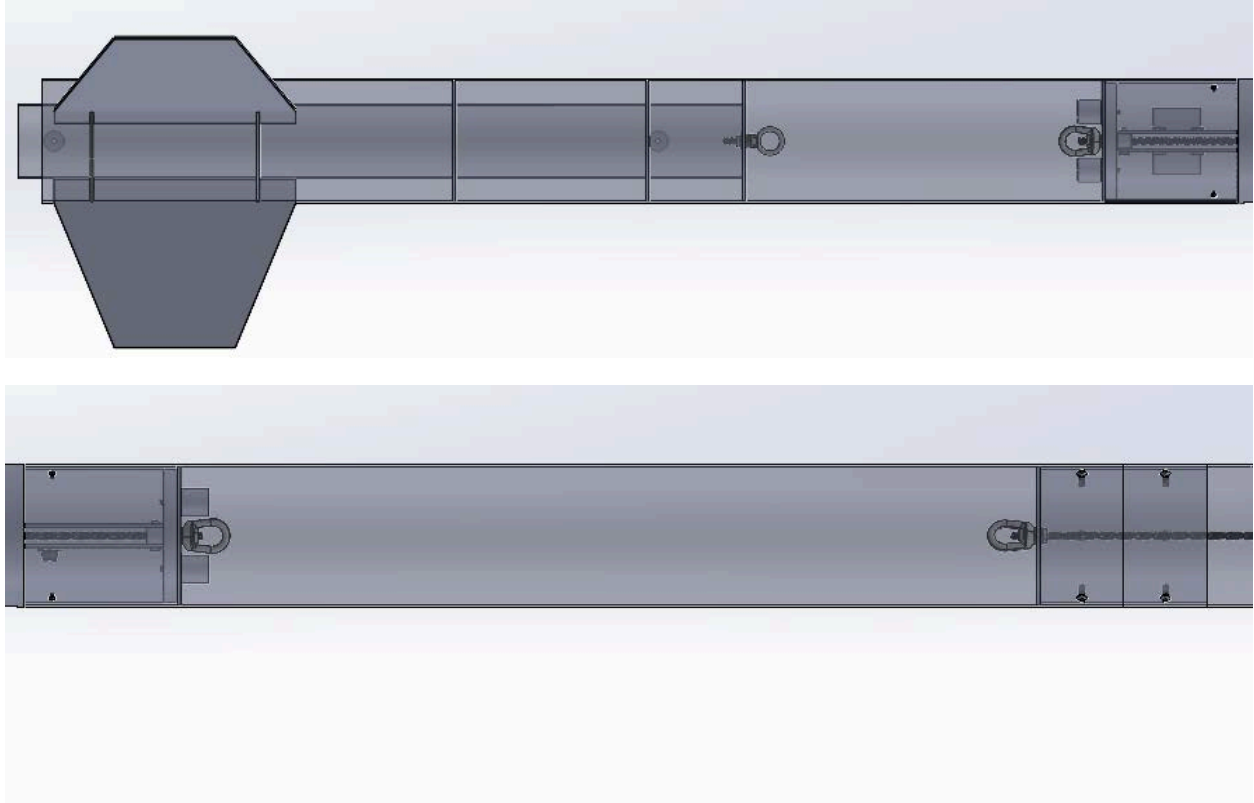


Figure 5. Shock cord attachment locations

Each section is retained by three 4-40 shear pins for drogue and main bays, based on potential differential pressure calculations from [this shear pin calculator](#) and napkin math. The smokeless black powder charges will be ignited by standard MJG Fireworks Initiator matches and are contained in 3D printed blast caps. Ground ejection testing was performed to determine the exact charge sizes.

Electronics

Dual deployment is controlled by an EasyMini altimeter and Stratologger powered by two 9V batteries. These are mach-safe, barometric pressure sensing, dual-deploy altimeters. Additional ride-along electronics for data collection and GPS telemetry are included and electrically isolated from deployment electronics. The electronics bay will be turned on while on the launch pad using the opening in the switch band to activate the screw switch. The wiring diagram for the electronics bay is shown below.

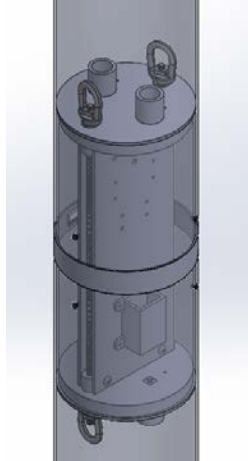


Figure 6. Rocket electronics bay

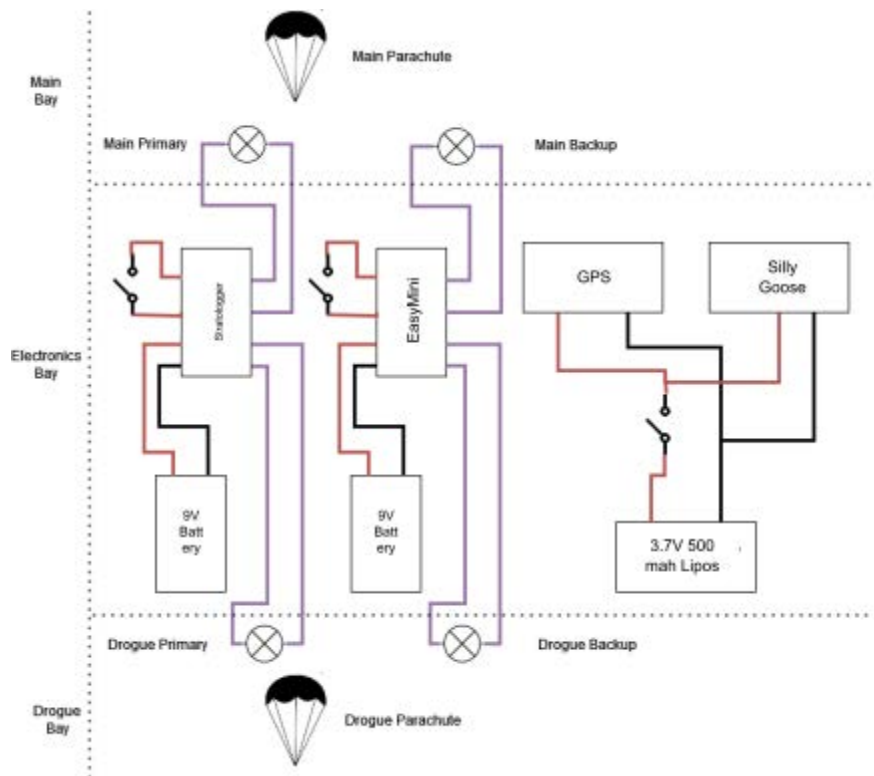


Figure 7. Electronics wiring diagram

Altimeter power and pyro charge disconnects are provided by the flight proven screw switch design shown in Figure 8 below. This design has three electrically independent channels, and will be used to switch power to electronics.

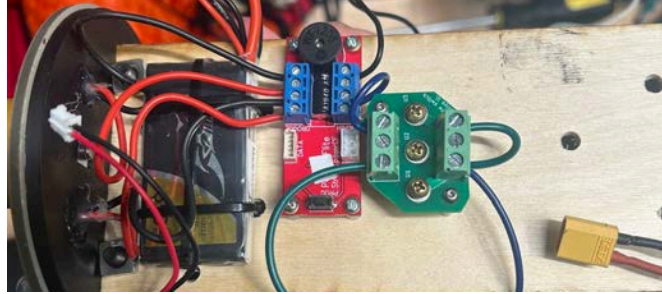


Figure 8. PCB screw switch

Electronics are mounted to one of two plywood electronics bay sleds, manufactured of $\frac{1}{8}$ " laser cut plywood. The altimeters are secured using 4-40 bolts and nylon standoffs.

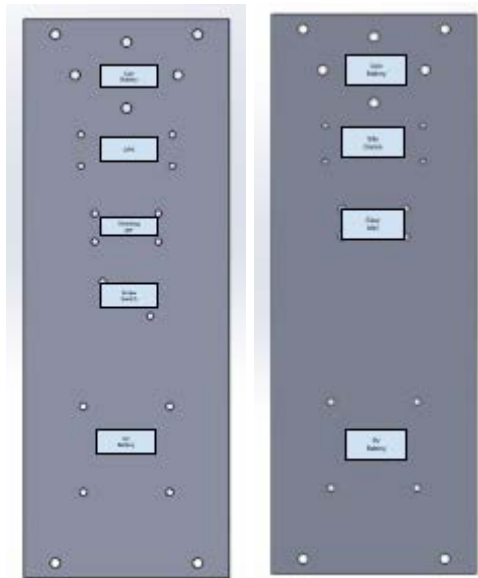


Figure 9. Altimeter and screw switch mounting

Fins

OpenRocket was used to evaluate the fin design for the flight. To ensure the rocket remained under the 10,000 ft height limit of the Champlain Region Model Rocket Club, the fins were designed as trapezoidal. The design choice moved the center of pressure further from the center of gravity, and the rocket wouldn't exceed the height limit at supersonic speeds. The three fins are $\frac{1}{4}$ " G10 fiberglass with a tab to insert into the centering rings of the motor section for ease of construction. Using through-the-wall mounting, the fins will remain secure to the motor tube during supersonic flight.

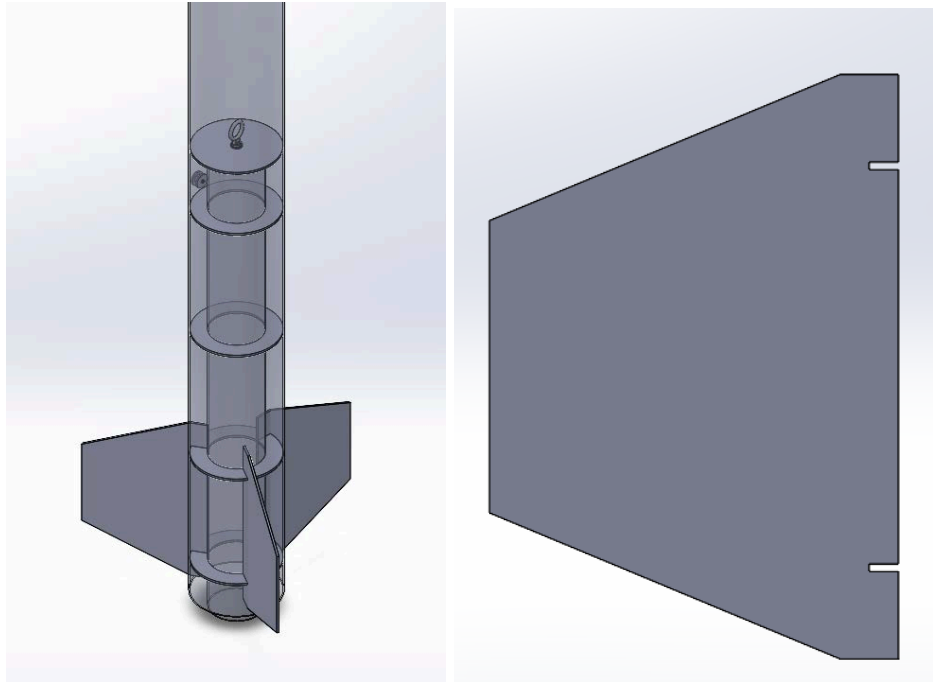


Figure 10. Motor section assembly with fins

The FinSim Software was used to evaluate the fin design for the flight. Since the rocket would attain transonic speeds for a brief period of time, the software determined that the rocket will need $\frac{1}{4}$ " G10 fiberglass fins to prevent a failure mode. FinSim predicted that fin divergence would occur at 1313 ft/s and fin flutter to occur at 2063 ft/s. The fins have a root cord of 10 in, tip cord of 5 in, and height of 6 in.

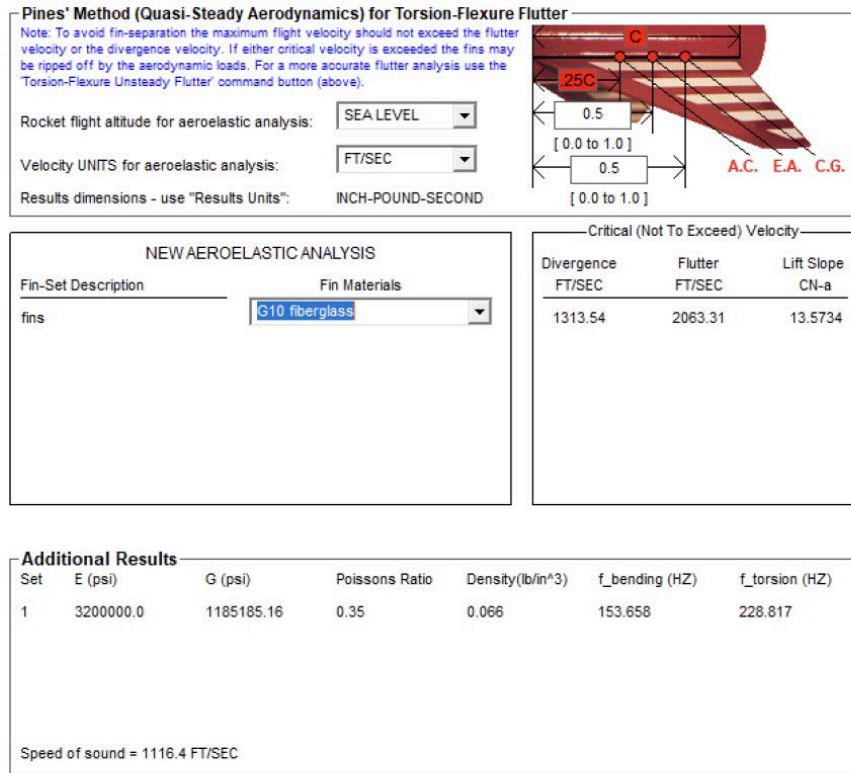


Figure 11. 1/4" fiberglass FinSim results

Airframe Section Construction

Motor Section

The motor section contains four 1/8" centering rings, two that are used to mount the fins and two as support further into the body tube. The centering rings and fins were cut using a waterjet.

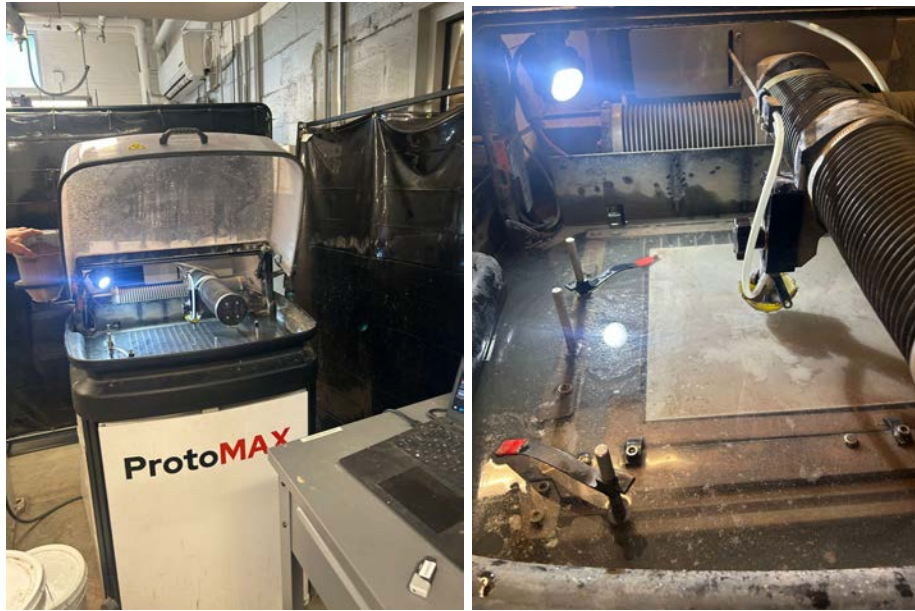


Figure 12. Construction of fiberglass fins and centering rings using waterjet

The motor was assembled by first epoxying the centering rings to the correct height on the motor tube. Then, the fins were inserted into the lower centering rings and epoxied. Using a motor jig in Figure 13 below, slots for the fins were cut into the lower body tube. The slots were marked, and the slots were cut using a dremel. Once the motor section was cured, the assembly slid directly into the body tube. The fins were then epoxied on the main body tube to ensure the fins were connected to the motor tube and body tube, ensuring they would remain intact during flight. The fillets for the fins were 0.25", in which a popsicle stick was used to create smooth and clean fillets.



Figure 13. Motor Section Construction

As shown in Figure 13, the 75mm motor retainer was also epoxied onto the top of the motor tube. By extending the motor tube beyond the main airframe, the motor retainer was placed above the fillets for the fins, and the slots cut for the fins in the airframe were reinforced by epoxy and the G10 ¼" fiberglass fins.

Finally, an eye bolt and fiberglass plate was placed at the top of the motor tube. The eye bolt allowed for the drogue parachute's shock cord to connect to the lower motor section. To ensure the eye bolt would remain in place during launch, 2 hex nuts were tightened on the other side and epoxied to the plate. After several pull tests, the section remained intact.

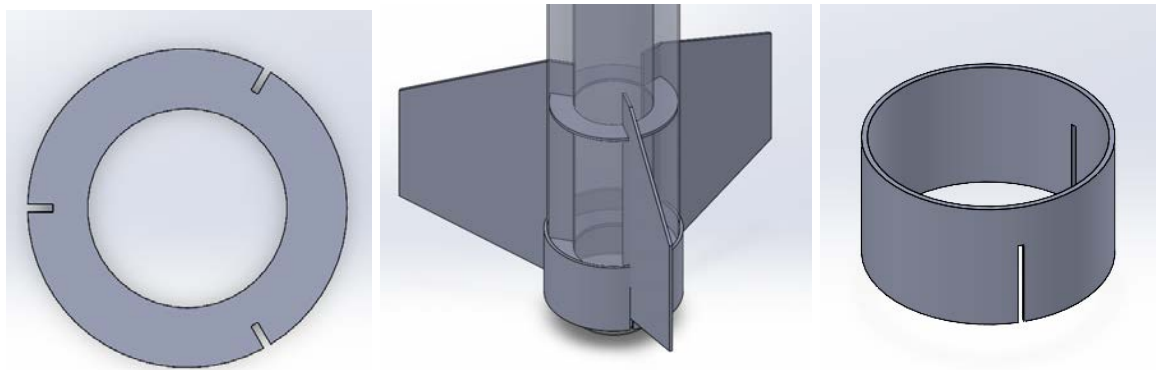


Figure 14. Motor section assembly with fins

The rail buttons were installed after the fiberglass plate dried. The rail buttons were strategically placed below the lowest centering ring and above the fiberglass plate. That way,

the rail buttons would be accessible in the case of failure. The rail buttons were lined with a straight edge, and they have been tested successfully on a 1515 rail.



Figure 15. Location of rail buttons on rocket

Electronics Bay

The bulkheads, blast caps, battery mount, and threaded rod clamps were 3D printed of an infill greater than 75% and 4 perimeter walls, ensuring structural stability. The sleds to mount the electronics were lasercut from $\frac{1}{8}$ " plywood. The two plates that enclose the electronics bay were waterjet from $\frac{1}{8}$ " G10 fiberglass. The EasyMini, Stratologger, Silly Goose, and GPS were mounted with 4-40 screws and secured in place with nuts and loctite.

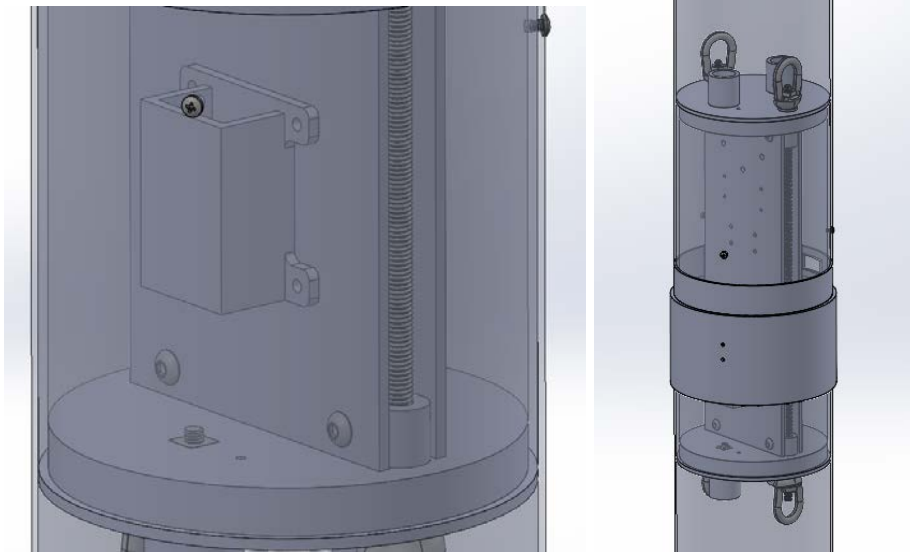


Figure 16. Electronics bay battery mount, square nut locations, clamp, and jig

The switchband was installed in the middle of the coupler using epoxy. A dremel was used to develop an opening to access the screw switch during launch. Using square nuts, rod clamps, and threaded rods, the battery mount, blast caps, and sleds were held in place in the assembly. The shear pins were installed using a hole jig, evenly spacing the screws across the rocket. The shear pins were placed above and below the switch band and threaded with a 4-40 jig. The 3D prints were sandwiched between a fiberglass plate. During ejection, the location of the fiberglass plate ensures the load of the charge will transfer to the fiberglass plate, rather than a 3D print. The 3D print on the inside of the electronics bay contained four nut pockets, which secured the blast caps and threaded rods in the assembly.

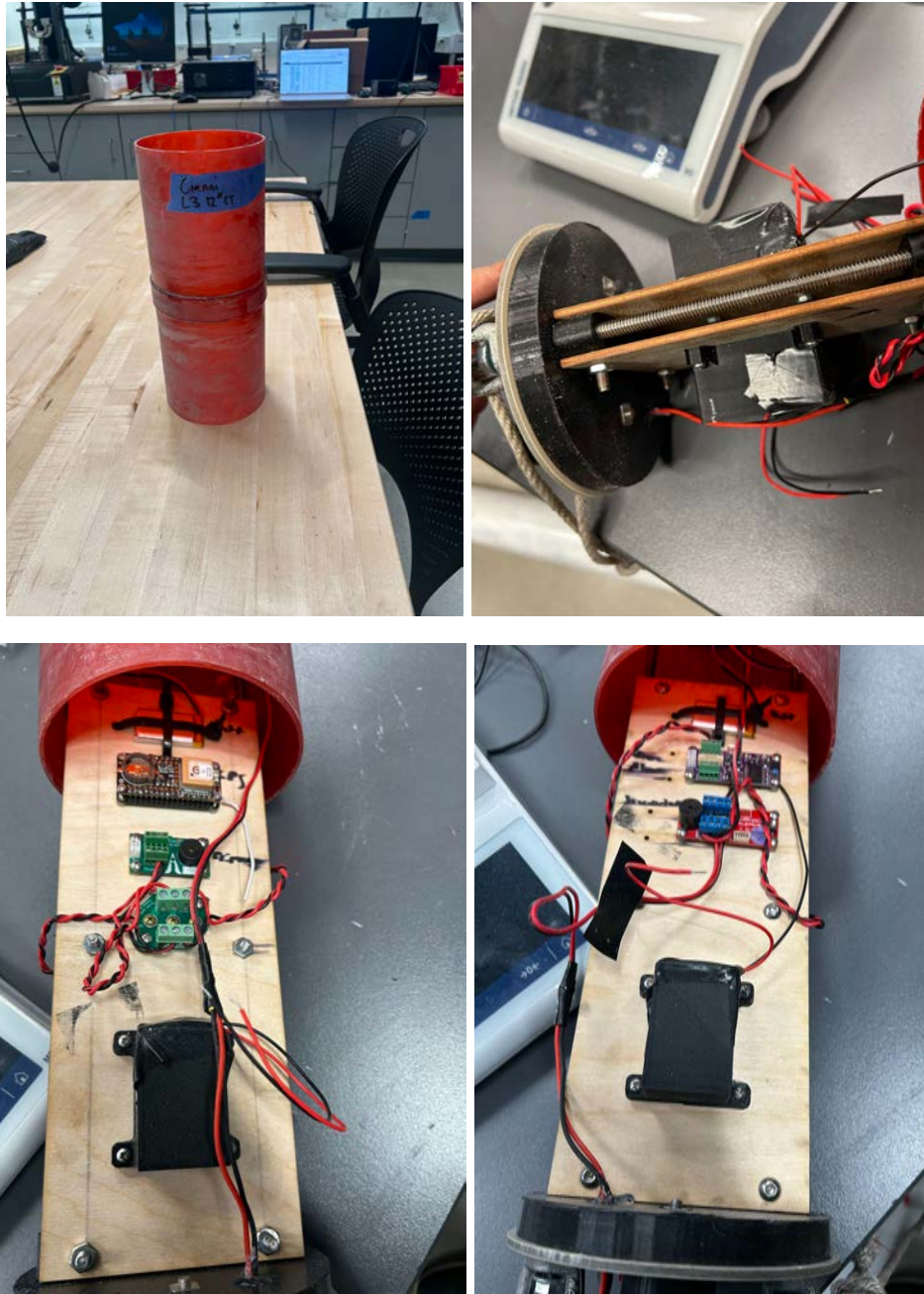


Figure 17. Wired electronics bay

Nosecone

The nosecone was attached to the upper body tube by a 7" long tube coupler fastened by six 10-32 screws threaded into the body tube. A 26" $\frac{1}{4}$ " diameter threaded rod extended from the aluminum tip of the nosecone to the bottom of the tube coupler, where an $\frac{1}{8}$ " fiberglass plate

was used to mount the eye nut. 1.79 lbs of ballast was placed around the threaded rod to compensate for the center of pressure location, and the fiberglass plate was secured by hex nuts on the other side. pressurizing the upper body tube section.



Figure 18. Nosecone assembly

On the threaded rod, washers and jam nuts were tightened with a wrench to sandwich the ballast. The reason was to secure the ballast, and washers were used to transfer the load as well. At the top of the nose cone, the metal tip was loctite to the thread, and a nut was tightened to the tip as well.

Recovery and Parachutes

Shock cord lengths were determined based on the points of ejection in the rocket. The measurements of the shock cord accounted for the deployment of the drogue and main parachute. During each point of ejection, the body tubes were aligned at different heights to ensure that the sections of the rocket would not collide and damage another in descent. The initial design was planned using rope, and the final design was replaced with $\frac{3}{8}$ " diameter 3600 lb rated kevlar shock cord.

Each section of the rocket was secured using an alpine knot and stress tested. On the electronics bay, the eye nuts have a quick link attached to each end. Not only did this allow for ease of electronics bay assembly, but the quick links and alpine knot ensured that the axial force of tension on the electronics bay during flight would not shear the threaded rods.



Figure 19. Layout of shock cord and rocket sections

Ejection Testing and Design Safety Critique

After the construction of the rocket, The rocket was spray painted and colored with markings to identify screw locations. The spray paint was the final step in the rocket assembly before the rocket was ejection tested.



Figure 20. Paint scheme of "Omni-rocket"

Both deployment sections of the rocket were tested with the calculated grams of smokeless black powder. The charges contained an e-match, blackpowder, dog barf, and tap to secure the charge. Both the main and drogue parachute section required 5 grams of FFG smokeless black powder for a successful separation. Please refer to Appendix A for a video of the ejection test. The ejection finalized the rocket design, and no more changes or holes were added to the rocket.

Prior to launch, the rocket was reviewed by a committee of three members at AerospaceNU at Northeastern University. The committee contained club members and alumni with over 4+ years of experience and L2 HPR certifications. Please refer to Appendix B for the DSC checklist. The committee reviewed all sections of the rocket to ensure the rocket didn't have safety issues prior to launch. The DSC revealed that the rocket needed to loctite the nose cone and electronics bay and verify continuity in the electronics bay. The actions were tended to immediately in preparation for a design review by the RSO at launch.

Appendix A – Simulations and Videos

📺 Gianni Drab - L3 Cert

Appendix B – Related Documentation

📄 Gianni Drab - L3 HPR Certification PDR

📋 Gianni Drab L3 - DSC Checklist

📋 Gianni Drab - L3 HPR Rocketry Proposal

Appendix C – Flight Operations Checklist

Packing List

Rocket

- ☐ Nosecone
- ☐ Motor section with motor tube & retainer
- ☐ Body sections
- ☐ Complete E-Bay
- ☐ Parachutes & shock cord

Equipment

- ☐ (Folding) Tables
- ☐ Large AC output battery
- ☐ Dremel & attachments
- ☐ Drill & drill bits & battery (2)
- ☐ Tarp
- ☐ Hot glue gun & hot glue
- ☐ Pliers
- ☐ Needle nose pliers
- ☐ Multimeter
- ☐ Tweezers
- ☐ Phillips head screwdrivers
- ☐ Flat head screwdrivers
- ☐ Soldering iron & solder
- ☐ Socket drivers

- ☐ Stratologger Data Programming Cord
- ☐ Wire strippers
- ☐ Mallet
- ☐ Clamps
- ☐ Saw
- ☐ Small scale
- ☐ Flashlight
- ☐ Extra Stratologger
- ☐ Face mask
- ☐ Gloves
- ☐ Goggles

Consumables

- ☐ BP
- ☐ Dog Barf
- ☐ E-Matches
- ☐ Centrifuge caps
- ☐ Shear screws
- ☐ Washers
- ☐ Nuts
- ☐ Epoxy
- ☐ Brown paper
- ☐ Masking Tape
- ☐ Duct tape
- ☐ Sandpaper
- ☐ Heat shrink
- ☐ Spare shock cord
- ☐ Spare parachutes
- ☐ Popsicle sticks
- ☐ Wire
- ☐ Quick links
- ☐ Swivels
- ☐ Rail buttons (different sizes)
- ☐ Blast caps
- ☐ Terminal blocks
- ☐ Extra nosecone weights
- ☐ Motor w/ ignitor
- ☐ Motor casing & retainer
- ☐ Food (bagels, doughnuts, cookies, bars)
- ☐ ~\$40 Cash

Night Before

General

- ☐ Verify all flight batteries are fully charged and disconnected
- ☐ Inspect all recovery hardware for abrasions or knots
- ☐ Verify loctite blue applied to all recovery critical eye bolts
- ☐ Inspect and tug-test all electrical connections (including screw switches)
 - ☐ Leave in state: all batteries and other connections made, all switches **open**
- ☐ Install electric matches through avionics bay bulkheads and seal hole with hot glue
 - ☐ Verify continuity
- ☐ Program altimeters
 - ☐ Primary: 0s apogee delay, 800ft main
 - ☐ Backup: 1s apogee delay, 700ft main
- ☐ Test all tracking electronics get GPS fix and output power is nominal
- ☐ Verify rail buttons (size 1515) are installed and aligned
- ☐ Fully assemble motor reload
- ☐ Measure all charges

Motor

- ☐ Perform grain-to-liner bonding per [AeroTech instructions](#)
- ☐ Collect supplies per [AeroTech assembly instructions](#) (note that M2050x instructions are not online)
 - ☐ 75/5120 case
 - ☐ Forward and aft closures
 - ☐ 75mm FSD SS
 - ☐ Reload
 - ☐ SuperLube
 - ☐ Wildman big 'uns

Assembly

- ☐ Lay out rocket airframe with recovery hardware
- ☐ Verify all knots are present
- ☐ Inspect all recovery devices
- ☐ Remove any tape holding nomex closed
- ☐ Verify deployment interfaces are properly greased with white lithium
 - ☐ All joints should slide freely
- ☐ Verify continuity on all recovery electronics by **closing** screw switch
 - ☐ **Open** screw switch to disarm electronics after test
- ☐ Assemble pyrotechnic charges
 - ☐ At least 2 complete wraps of electrical tape around entire glove tip
- ☐ Nicely re-fold parachutes
- ☐ Burrito parachutes and assemble rocket
- ☐ Trim shear pins if required for electronics bay insertion depth and install
 - ☐ Retain shear pins with one wrap of electrical tape around rocket body OD
- ☐ Install motor reload and retain with Aeropack
- ☐ MEASURE rocket wet weight
- ☐ MEASURE rocket wet CG location and compare

At the pad

- ☐ Bring launch rail horizontal
- ☐ Ensure the rocket slides smoothly on the launch rail
- ☐ Bring rail vertical and secure well (rocket will cook off the pad)
- ☐ **Take photos here** – after this point rocket is no longer safe
- ☐ Screw in both screw switches
- ☐ Wait for altimeter to beep out staccato for continuity
- ☐ Install igniter in motor with plastic motor nozzle cap, making sure the igniter is *all the way* into the motor (~24 inches above end of nozzle)
- ☐ Feed igniter wire another 1-2in into plastic thingy to make sure it cannot fall back out
- ☐ Touch alligators together to ensure they don't spark -- **do not continue if they do**
- ☐ Strip back 1in at end of igniter and connect to alligators
 - ☐ Wrap around the alligators to ensure they can't get blown off by wind
- ☐ Hang igniters somewhere they won't short against the launch rail
- ☐ Retreat and verify we still have Eggfinder/other tracking equipment telemetry -- **if not, recycle**

Post-launch

- ☐ DO NOT TOUCH the rocket until video/pictures have been taken
- ☐ RECORD stratollogger beep codes
- ☐ REMOVE screws from screw switches to disarm avionics as soon as possible after landing
- ☐ VERIFY all pyrotechnic charges have fired
 - ☐ CONTINGENCY: charges not fired. RECORD which charge did not fire, and DISASSEMBLE the charge.