NASA STUDENT LAUNCH 2019

FLIGHT READINESS REVIEW

1/4/2019

SOCIETY OF AERONAUTICS AND ROCKETRY

4202 East Fowler Avenue, MSC Box #197

Tampa, Florida 33620

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1. SUMMARY OF FRR REPORT

1.1 TEAM SUMMARY

1.1.1.1 NAME AND ADDRESS

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1.2 LAUNCH VEHICLE SUMMARY

SOAR has designed and built a fiberglass high-powered rocket with two untethered sections, a fully redundant recovery subsystem, a payload descent leveling subsystem, a dynamic apogee adjustment subsystem, and an adjustable ballast subsystem. This vehicle will be designed to carry the payload to exactly 5,000 ft above ground level.

1.2.1 SIZE AND MASS

Note items in the table are recommend not required so add more if you wish or take away any that are not important.

Table 1: Launch Vehicle size and mass.

Measurement	Value
Diameter (in)	6.1
Length (in)	138
Unloaded Weight (lb)	38.2
Loaded Weight (lb) - includes payloads & motor	56.3
Ballast Allocation (lb)	0
Launch Motor Weight (lb)	10.5
Airframe Material	Fiberglass

Fin Material	Carbon Fiber Sheet

1.2.2 LAUNCH DAY MOTOR

After a short analysis, Aerotech L2200 75mm motor has been selected as the full scale launch vehicle's motor. According to simulations by OpenRocket and RockSIm, the thrust available from Aerotech L2200 makes it easier for the launch vehicle to reach its target altitude at 5000 ft. Most of these motors, under most configurations, exceed the target altitude predicted by the simulation softwares, but the Adjustable Ballast System (ABS) will assist in controlling the target apogee.

Table 2: Motor selection details

Motor Choice	Aerotech L2200
Average Thrust (N)	2200.0
Total Impulse (N·s)	5104.0
Burn Time (s)	2.3
Propellant Weight (lbs)	5.54

1.2.3 TARGET ALTITUDE (FT.)

The target altitude of the launch vehicle is 5000 feet.

1.2.4 RECOVERY SYSTEM

A completely redundant and reliable dual deployment system has been designed for the full scale launch vehicle. The dual deployment system consists of three parachutes and two seperate avionics sections. The first parachute deployment will be a drogue at the apogee, initiated by a deployment charge, where the lower airframe will separate from the lower section avionics bay. At 700 ft, the main deployment charges will fire, deploying the lower section and upper section main parachutes respectively. All the deployment charges will be controlled by two MissileWorks RRC3 Altimeters. A MissileWorks RTx Telematics System (GPS Unit) will also be installed in the launch vehicle to ensure safe retrieval of all the sections of the rocket.

1.2.5 RAIL SIZE

The launch vehicle will use a 12 ft 15x15 launch rail.

1.2.6 MILESTONE REVIEW FLYSHEET

1.3 PALOAD SUMMARY

The competition rover design is inspired by the Recon Scout XT, a military camera robot with drive wheels on either side of a central body. The rover will contain an Arduino, batteries, soil recovery module, and advanced guidance sensors. The projected diameter is 5.92"; the internal diameter of the rocket body. The rover will be seated inside the vehicle payload bay during flight and held in place with high-strength solenoids. The rover will be deployed via a winch deployment system and will complete the mission objective after a remote initiation signal has been received.

Table 3: Payload Summary

Component	Value
Max Weight	8lb
Diameter	6 inches
Motor	Greartisan DC 12V 300RPM Gear Motors
Projected Motor Run Time	4 hours

2 CHANGES MADE SINCE CDR

2.1 CHANGES MADE TO VEHICLE CRITERIA

Table 4: Changes to Vehicle Criteria since CDR.

Change Summary	Reason for Change	Section Reference
Changed Motor to Aer-oTech L2200	Significant safety concerns were raised with regards to Cesaroni motors due to recent organization CATO events.	REFERENCE: Motor Change
Removed Dynamic Apo-gee Adjustment Subsys-tem	The added mass of the system resulted in an insuffi-cient apogee surplus for the brakes to engage.	N/A

Lower Airframe Shortened by 5 Inches	Removed unnecessary extra space for the drogue parachute to save mass and improve ejection performance.	REFERENCE: Shortened Lower Airframe
Added Terminal Blocks to Avionics	Screw-terminal blocks for e-matches located at easy-to-access locations in the avionics bays will enable rapid launch setup.	REFERENCE: Terminal Blocks

2.2 CHANGES MADE TO PAYLOAD CRITERIA

Table 5: Changes made to Payload Criteria since CDR.

Change Summary	Reason for Change	Section Reference
Updated Vacuum System	To increase internal volume.	REFERENCE Payload Criteria
New housing for electronics	Protection and easy access	REFERENCE Payload Criteria
New Structural Wall	Increase support	REFERENCE Payload Criteria

2.3 CHANGES MADE TO PROJECT PLAN

Table 6: Changes made to Project Plan since CDR.

Change Summary	Reason for Change	Section Reference
No Second Subscale Test	A second test was unable to be completed due to time constraints needed to fabricate the full scale launch vehicle	N/A
Additional Launch before the submission of the FRR	A second test launch was able to be completed in order to test the vehicle for a second time before the submission of the FRR	N/A
February 9th, 2019 Launch was Rescheduled for February 16th, 2019	This launch had to be postponed 1 week due to flooding at the launch site	N/A

3 VEHICLE CRITERIA

3.1 VEHICLE SUMMARY

For the 2019 NASA Student Launch competition, SOAR has designed and constructed a 12′ tall, 6″ diameter fiberglass rocket that will propel itself and a payload to 5,000 feet AGL on an AeroTech L2200 solid motor. The rocket features several innovative subsystems, including an adjustable ballast subsystem and a payload descent leveling subsystem. The rocket has been flown twice, and will be flown once more prior to the competition launch date. The rocket has been named *Apis III*.

As the CAD models from the CDR were used throughout the build process as build instructions, very few changes have been made to the original design. These changes are noted below.

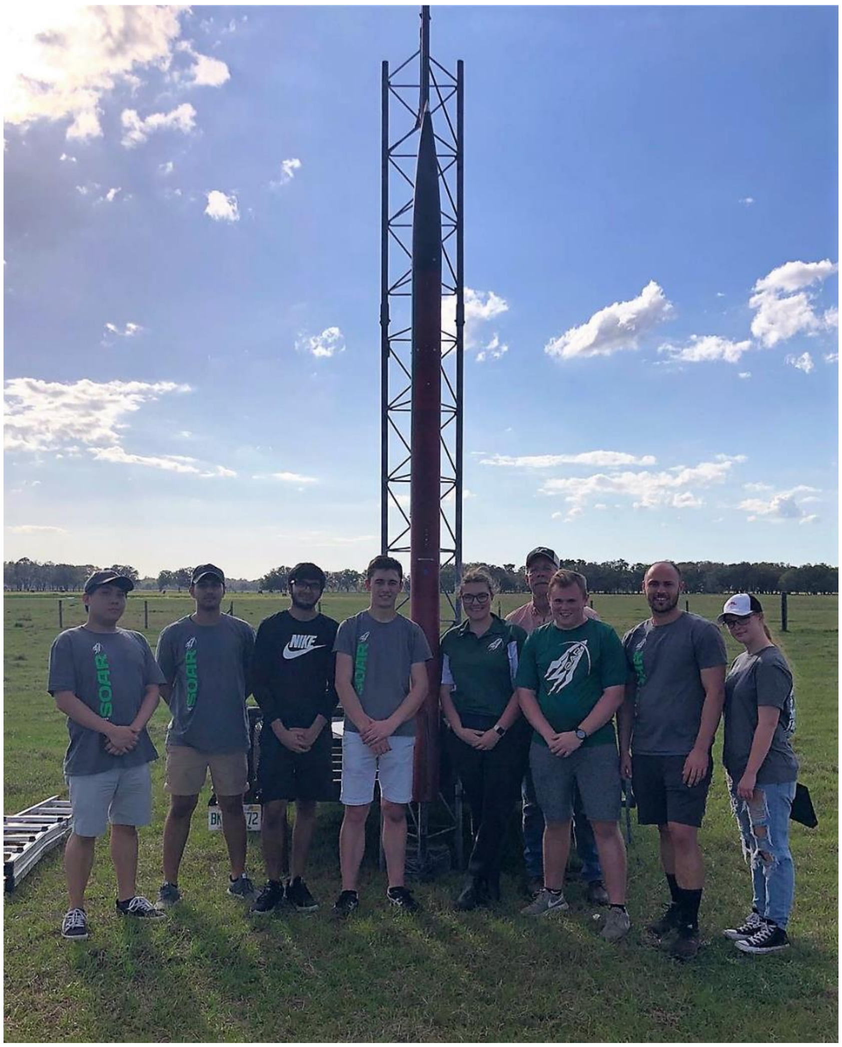


Figure 1: Fully-assembled (unpainted) Apis III and the SOAR NSL team at the test launch rail

3.2 DESIGN AND CONSTRUCTION OF VEHICLE

3.2.1 CHANGES SINCE CDR

3.2.1.1 MOTOR CHANGE

The motor used in the launch vehicle has been changed from a Cesaroni L2375 to an AeroTech L2200. This change was made as a result of recent within-organization experiences with Cesaroni motors, including multiple catastrophic failures at take-off (CATOs). The Aerotech L2200 was chosen because it can easily be cross loaded into the already owned Cesaroni motor casing and it has similar specifications to the Cesaroni L2375. This change was approved by the Student Launch RSO and the new motor was successfully used in both full-scale vehicle test flights.

3.2.1.2 DAAS REMOVAL

The Dynamic Apogee Ascent Subsystem (DAAS), informally known as airbrakes, was removed from the final rocket design. After testing the system in the first full-scale vehicle test flight, it was determined that the added mass of the system decreased the apogee to such an extent that the airbrakes were rendered unnecessary (or even detrimental); therefore, it would be more effective to simply modify ballast.

3.2.1.3 SHORTENED LOWER AIRFRAME

Given a surplus of space in the constructed lower airframe, the section length was reduced by five inches after the first vehicle test flight to save weight and reduce drag. The shorter launch vehicle was re-tested in the second vehicle test flight.

3.2.1.4 TERMINAL BLOCKS

Terminal blocks were added at easy-to-access locations in both avionics bays to facilitate rapid wiring of deployment charges without needing to disassemble the bays (besides removing the bulkhead to access the interior).

3.2.2 DESIGN FEATURES

The rocket design has not been modified substantially since submission of the CDR. The launch vehicle still consists of two separate sections, each of which are recovered under their own parachutes. The upper section consists of the nose cone, upper airframe, and upper section avionics bay. The lower section consists of the lower section avionics bay and lower airframe / fin can.

3.2.2.1 NOSE CONE

A commercially available fiberglass Von Karman profile nose cone was selected to ensure the least possible drag for the given diameter. The nose cone attaches to the upper airframe with a fiberglass shoulder that extends 5 inches into the upper airframe. The removal shoulder is bolted to the nose cone with 3 ⅝" hex bolts and houses the adjustable ballast system (ABS). The hex bolts thread into 3 weld nuts epoxied with carbon fiber reinforced 30 Minute Epoxy, as pictured in Figure 2 below.

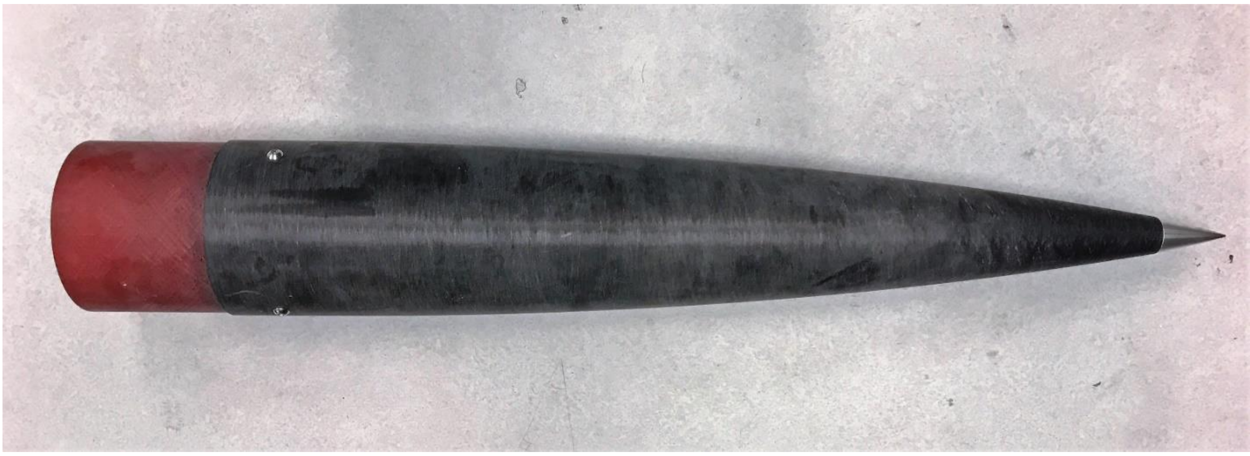


Figure 2: As-built nose cone and shoulder.

3.2.2.2 ADJUSTABLE BALLAST SUBSYSTEM (ABS)

The implementation of a rapidly adjustable ballast system enables the rocket's mass and center of gravity to be fine-tuned up to the point that the rocket is assembled for launch. The ballast system consists of several clear acrylic plates, each of which can securely hold several 1 oz. weights. The weights and plates can be removed or added as necessary, allowing for adjusting of nose cone ballast to within 1 oz. The plates stack on two threaded rods installed inside the nose cone, an area which remains accessible due to the aforementioned nose cone shoulder.

The ballast plates were cut from ⅜" thick acrylic sheets using a CNC router (except for the thin cap plate, which was cut with a laser cutter). As long as the nose cone bulkhead, which is epoxied with carbon-fiber reinforced aeropoxy to the nose cone shoulder, remains secure, the system will be protected and stable.

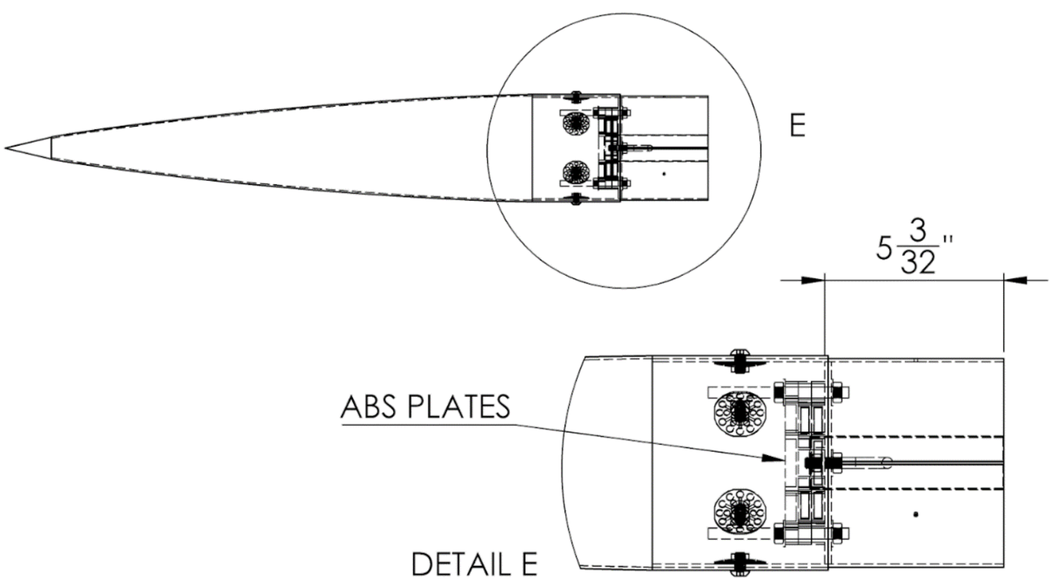


Figure 3: ABS location in nose cone assembly.

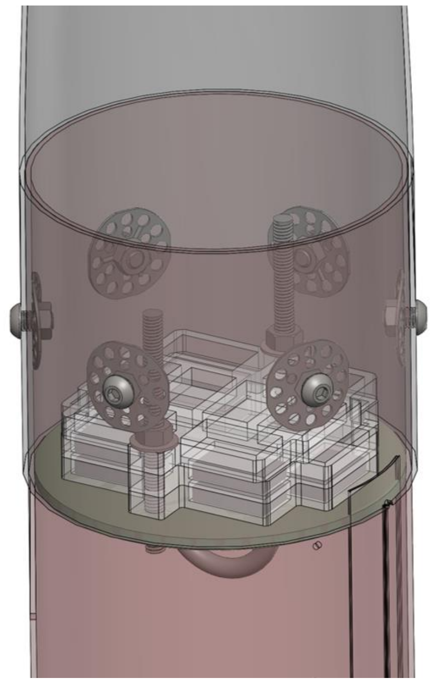


Figure 4: CAD render of adjustable ballast subsystem

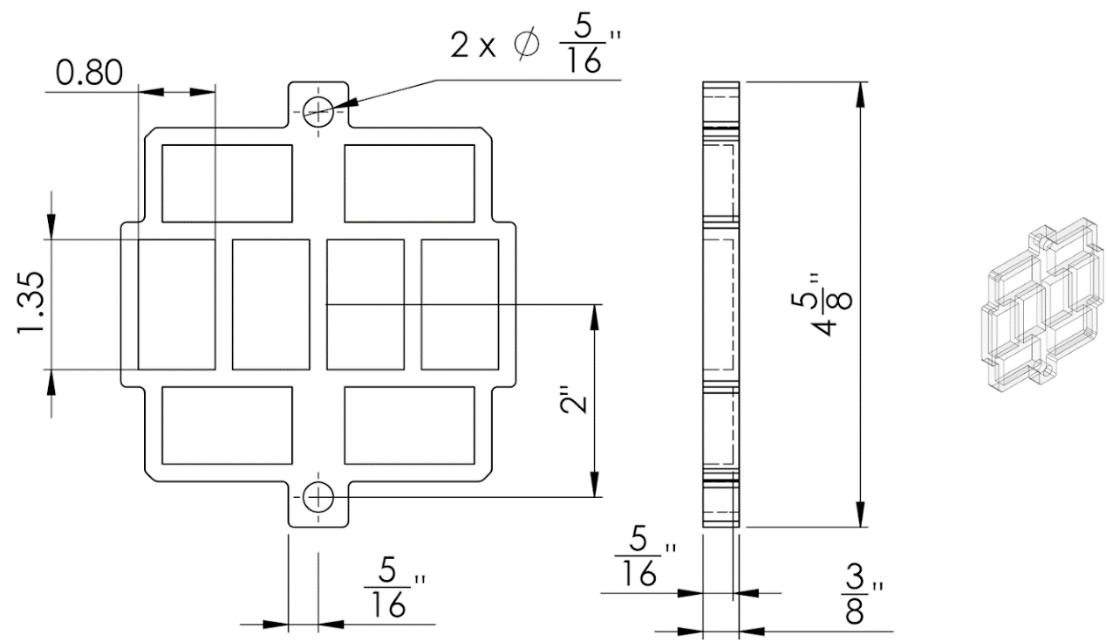


Figure 5: Typical adjustable ballast system plate dimensions.

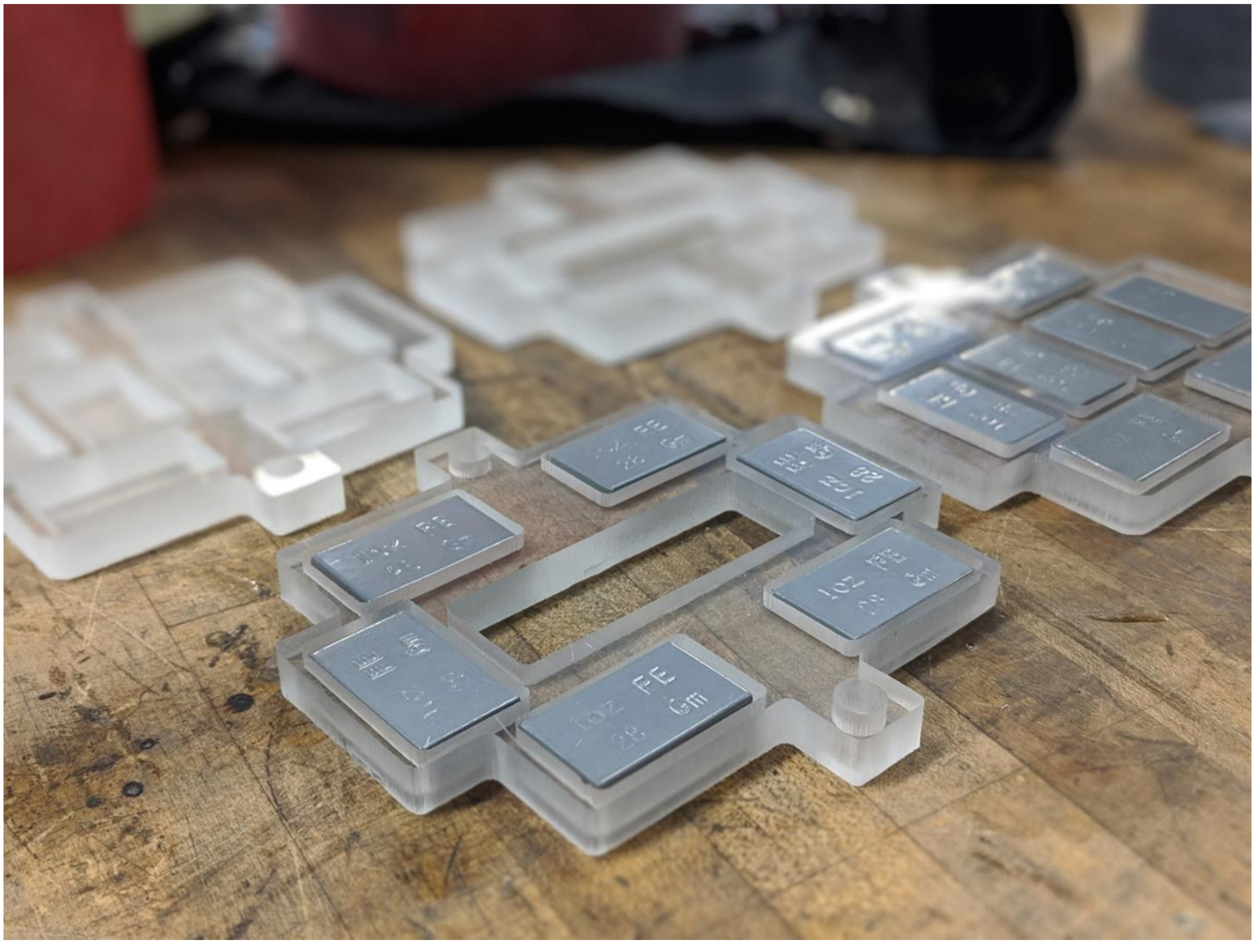


Figure 6: Loaded and unloaded adjustable ballast subsystem plates.

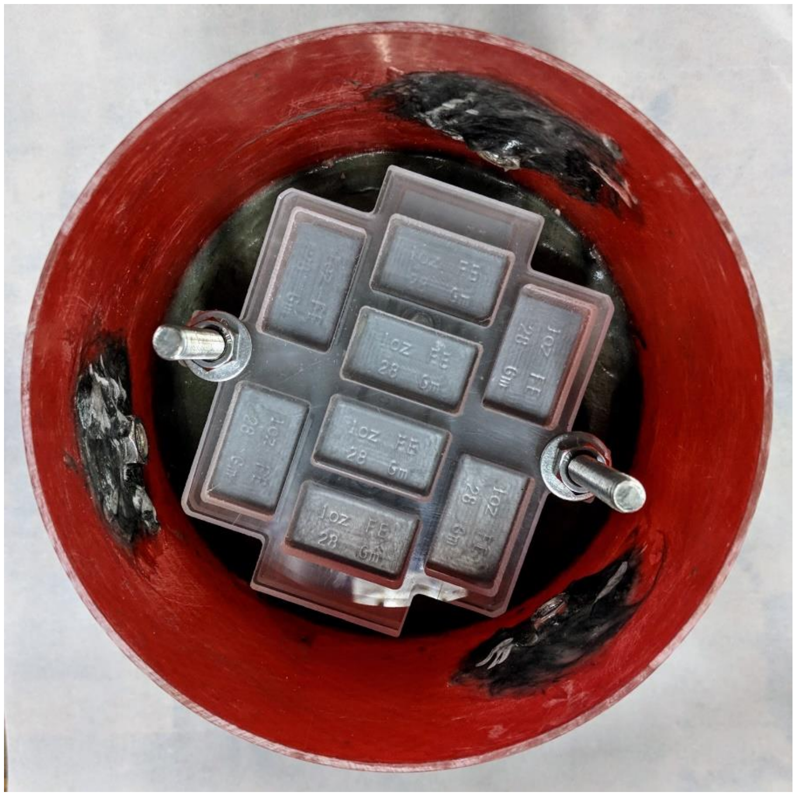


Figure 7: Partially loaded ABS installed in nose cone coupler, with epoxied nose cone weld nuts visible.

3.2.2.2.1 AIRFRAME

The airframe of the launch vehicle is constructed from G10 fiberglass tube specifically designed for rocket use. Fiberglass was selected due to its low density and significant structural strength.

The external airframe consists of two separate pieces, the 43″ lower airframe and the 57″ upper airframe. These two pieces are connected by a fiberglass coupler with a 3″ transition band between.

The lower airframe length was decreased by 5″ after the first vehicle test flight, as noted above, decreasing the overall rocket length by 5″.

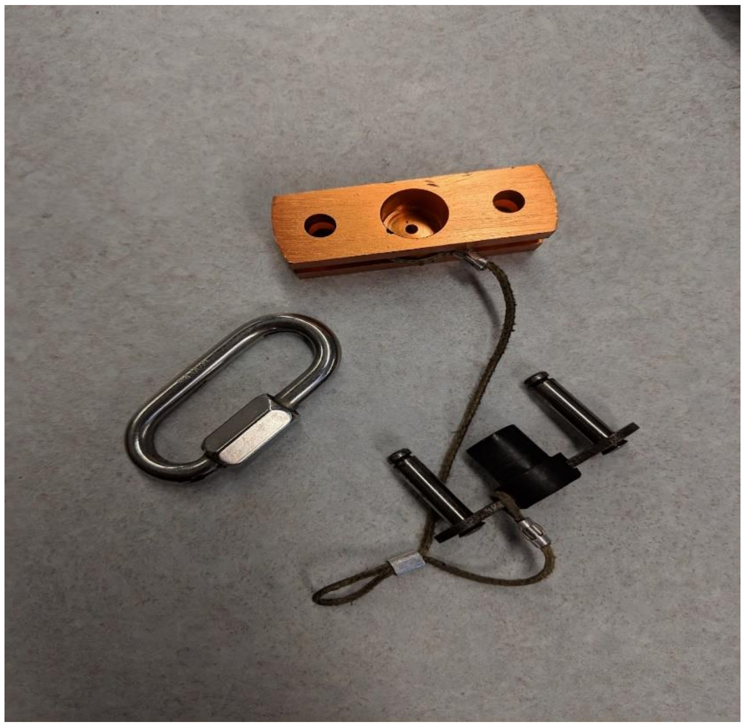
The payload is installed in the upper airframe during flight. The retention solenoids extend into holes located in this airframe piece.

3.2.2.3 PAYLOAD DESCENT LEVELING SUBSYSTEM (PDLS)

Without the PDLS system, the upper section would, after falling under the main parachute, land with the end opposite the parachute pointing into the ground. If the soil is soft, this would result in significant foreign debris entering the payload-exit side of the upper airframe. If the soil is hard (firm-packed), this would still result in high stresses on the payload.

As a result, this leveling system has been implemented to make the upper airframe land on its side instead of vertically. This system consists of a wire that runs between the nose cone shoulder and upper airframe, through the top of the upper airframe, and down to the lower end of the upper airframe. When the system deploys, the wire becomes half of a triangle formed with the rest of the shock cord, with the airframe as the base.

In order to prevent the full parachute shock force from being applied to this small wire and attachment point, the PDLS does not engage until 500 ft AGL; 200 ft lower than the main parachute deploys. This deployment is controlled by a system that is electrically isolated from the altimeters and GPS. A separate MissileWorks RRC2+ altimeter located in the upper section avionics bay but used solely for this purpose ignites a charge in a Tender Descender (Level III model), which functions as a sort of dynamically detachable link.



PDLS Tender Descender and corresponding quick link.

The stainless steel wire was attached to the upper airframe by weaving it tightly into a weld nut and securing the weld nut with a 5/16” hex bolt. This ensures that the forces of deployment are distributed over a wire area and prevents damage to the airframe. At the other end of the wire, a thimble was installed with two wire rope clamps holding it in place. To prevent the clamps from loosening, they were covered in a piece of heat-shrink tubing. During ascent, the PDLS wire is taped to the rocket with masking tape to prevent entanglement with any components of the launch rail.

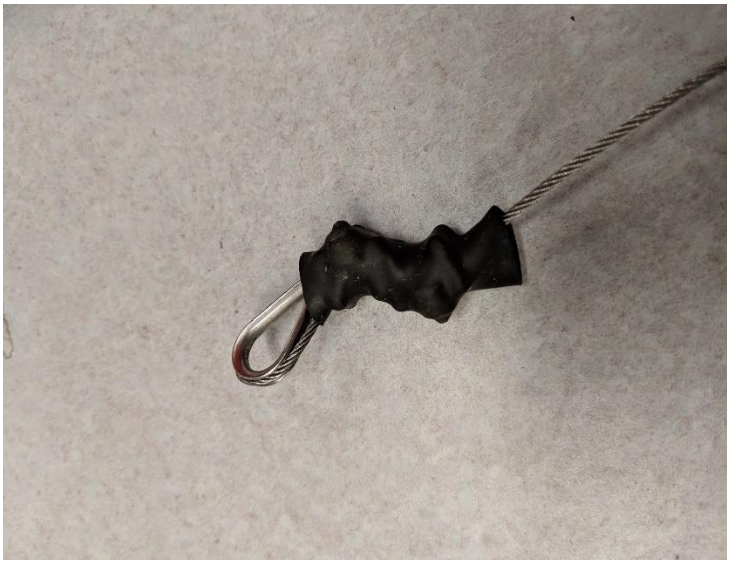


Figure 8: Upper end of PDLS wire, with heat-shrunk wire clamps and thimble.

Figure 9: The launch vehicle on the rail, highlighting the taped-down PDLS wire.

To allow the main parachute to deploy as normal, the wire runs between the coupler and airframe. This necessitated the cutting of a deep channel in the nose cone shoulder. This was performed with a diamond grinding blade on an angle grinder. After cutting the slot, the area was reinforced with carbon fiber and semi-flexible epoxy resin to prevent cracking.

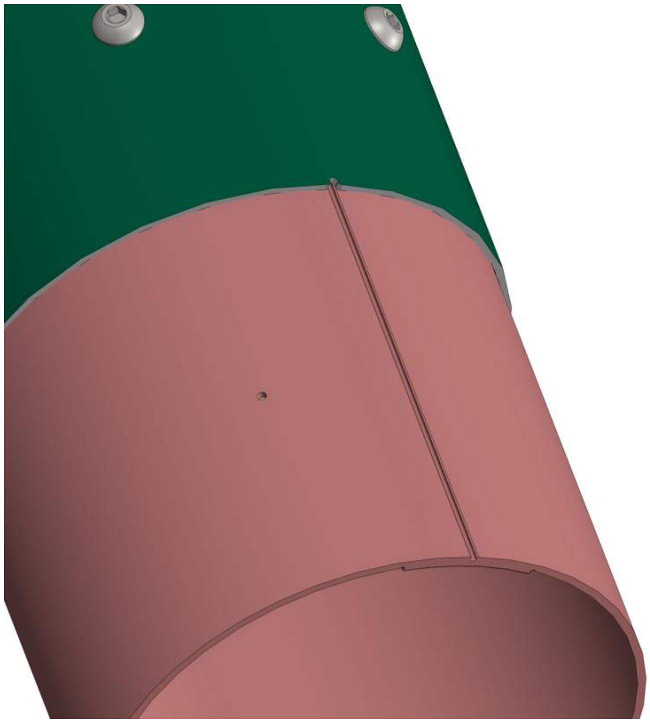


Figure 10: CAD model of reinforced PDLS wire channel.

Figure 11: As-built carbon fiber reinforcement on interior of nose cone shoulder at PDLS wire slot.

3.2.2.4 UPPER SECTION AVIONICS BAY

The upper section avionics bay acts as a container for the upper section primary and secondary altimeters, upper section GPS tracker, and PDLS altimeter. This bay is constructed from the same G10 fiberglass as the airframe and fits flush within the airframe. In order to withstand the shock forces of the upper section main parachute deployment, the bay is secured within the airframe with 6 5/16″ hex bolts. On the interior, weld nuts are epoxied to the bay in the same manner as the rail lugs so that the screws can be tightened without access to the interior of the bay.

Inside both avionics bays, altimeter sleds are secured with hex nuts and washers on 5/16″ threaded rods, which also secure bulkheads to the bays.

Figure 12: Constructed upper section avionics bay interior, with epoxied weld nuts and avionics sled visible.

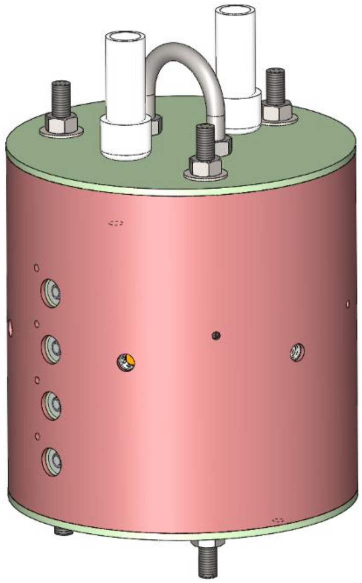


Figure 13: CAD model of upper section avionics bay.

3.2.2.5 LOWER SECTION AVIONICS BAY / COUPLER

The coupler structurally joins the upper and lower sections and also houses the lower section avionics bay. This component is also constructed from the same fiberglass tubing. It extends 6″ into the upper and lower airframes, with a 3″ transition band between. This transition band allows space for the reimplementation of the airbrakes in this rocket after the competition, allowing for the possibility of continued development. A bulkhead near the center of the bay ensures the the volume in the lower section avionics bay is similar to that of the upper section avionics bay, thus minimizing differences across the rocket.

Figure 14: As-built unpainted lower section avionics bay and coupler.

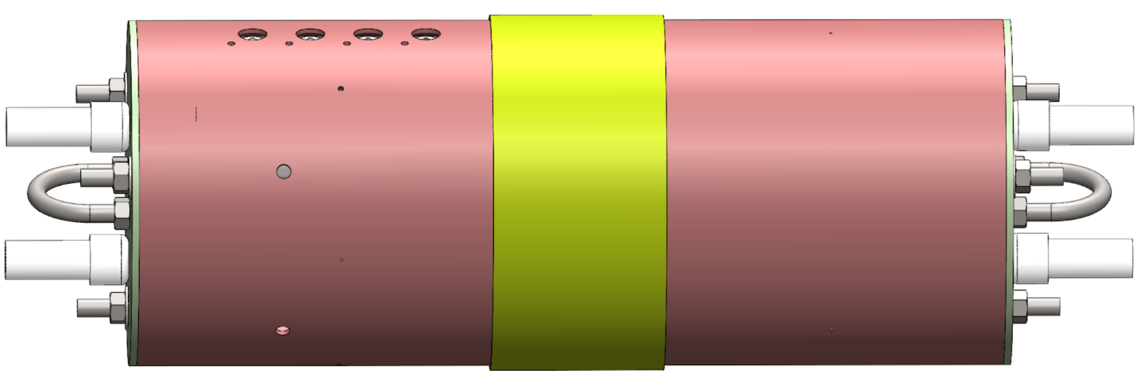


Figure 15: CAD model of lower section avionics bay and coupler.

3.2.2.5.1 RAIL LUGS

Two 1515 aerodynamic Delrin rail lugs are installed on the lower airframe. These are secured with ¼″ stainless steel screws, threaded into weld nuts epoxied to the interior of the lower airframe. The use of epoxied weld nuts allows simple removal and replacement of rail lugs without requiring access to the nuts, one of which is permanently sealed between the lower and middle centering rings. The as-built rail lugs are located 3″ and 34″ from the bottom of the airframe.

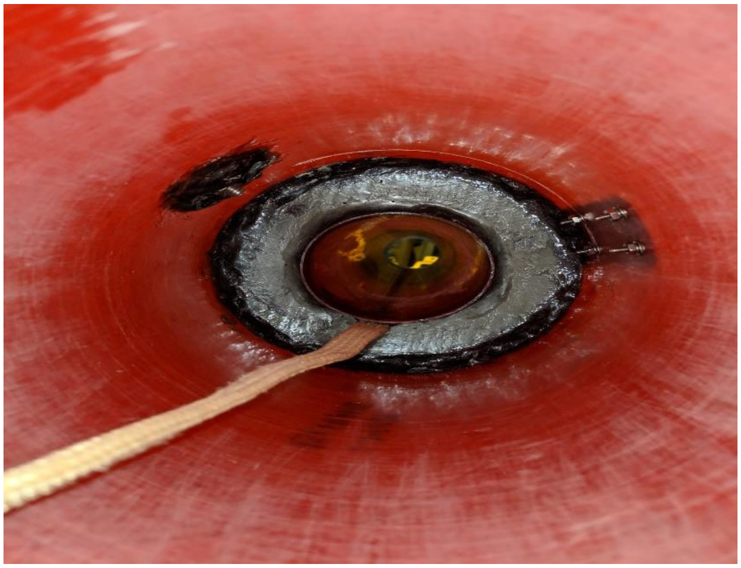


Figure 16: As-built interior of lower airframe, showing securement of forward centering ring, rail lug interior weld nut, drogue shock cord, and camera mount.

3.2.2.5.2 FINS

The three fins on the launch vehicle are constructed from ⅛" carbon fiber sheets, cut with a CNC router and manually beveled. They feature a backswept trapezoidal profile for maximum static stability and optimal drag characteristics.

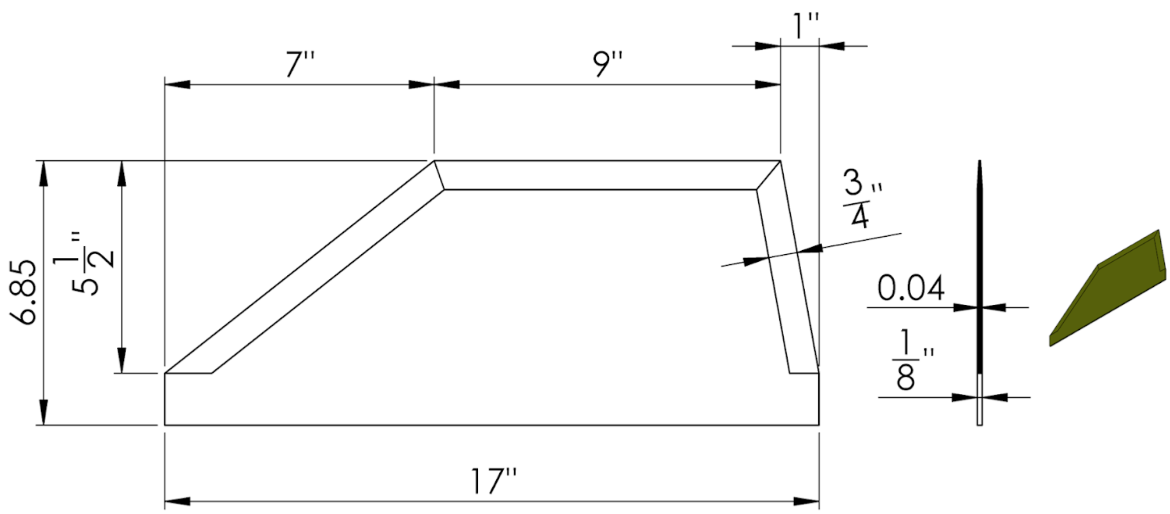


Figure 17: Backswept trapezoidal fin profile dimensions.

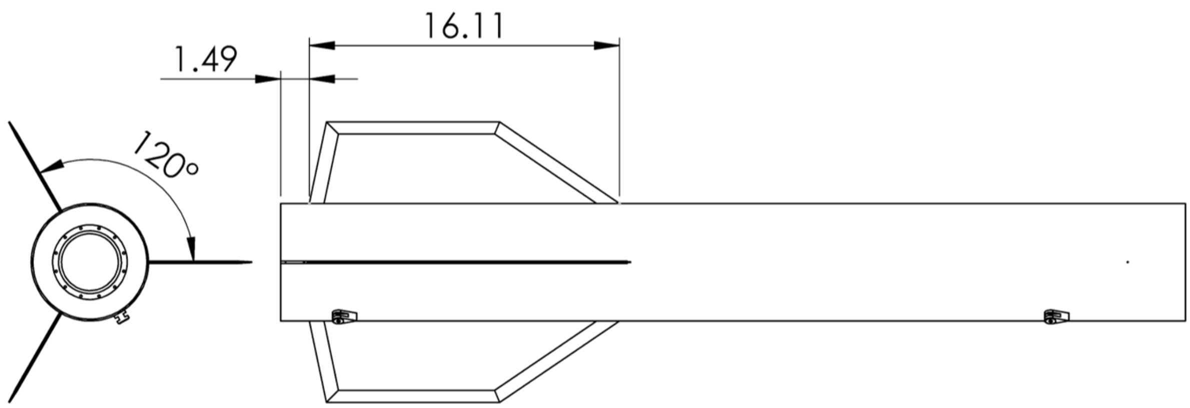


Figure 18: Location of fins on the lower section of the launch vehicle.

The fins are epoxied directly to the motor mount tube with small Aeropoxy fillets. After that epoxy set, the assembled fin can was slid into slots cut into the lower airframe. The rear centering ring was installed, and then Aeropoxy fillets were applied to all fins. The Aeropoxy was carefully treated with a heat gun to remove bubbles and smooth the material to decrease drag. Prior to epoxying, the fins were sanded with 100-grit sandpaper to ensure a secure bond.

After installing the fins in the lower airframe and allowing the epoxy to cure, the gaps behind the fins were filled with 30-Minute Epoxy to allow for painting. This purely cosmetic measure was found to be too brittle and cracked easily. This did not affect vehicle performance and a more flexible material will be used to fill the gaps prior to painting the launch vehicle.

Figure 19: As-built unpainted fin fillet and exterior rail lug detail.

Figure 20: As-built lower airframe, with fins, rail lugs, and flight camera mount.

3.2.2.5.2.1 FLUTTER

The calculated maximum safe fin flutter velocity is approximately 1289.2 feet per second. The maximum velocity of the rocket with this fin design according to simulation is 598.7 feet per second, yielding a factor of safety of 2.15 - more than sufficient for this application.

Furthermore, a careful examination of video taken by the onboard camera shows during the second vehicle test flight no indication of fin flutter during ascent.

3.2.2.5.3 MOTOR MOUNTING AND RETENTION

The AeroTech L2200 motor will be cross-loaded into a standard Cesaroni Pro75 casing. This casing will be secured into the motor mount tube, a 3" diameter fiberglass tube centered in the airframe with three 3/16" thick fiberglass reinforced-plastic centering rings. The motor mount tube is further secured by the fins, which are epoxied to the motor mount tube and airframe as described above. The use of a CNC router to cut the centering rings and motor mount screw holes directly from CAD models ensures that the motor tube is perfectly centered and straight within the rocket.

The motor is retained with a standard removal AeroPack 75mm flanged motor retainer, secured in place with 12 equally spaced screws. Each screw is tightly screwed into a threaded insert, each of which are secured in the 3/16" thick rear centering ring. After installing the threaded inserts, a layer of epoxy was bonded to the centering ring to prevent loosening due to vibration.

Both the rear and forward centering rings are securely epoxied in place to both the motor tube and the lower airframe with carbon-fiber reinforced Aeropoxy. The rear centering ring is also epoxied to the flat lower end of the fins.

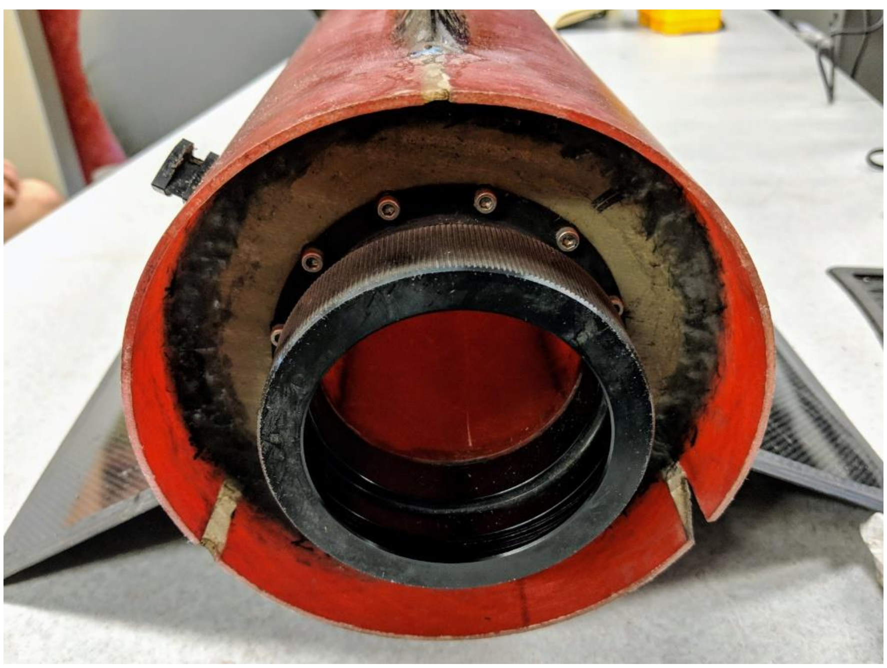


Figure 21: As-built lower end of rocket, with motor retainer and lower centering ring visible.

3.2.3 FLIGHT RELIABILITY

The full-scale launch vehicle, APIS III, has been designed and constructed effectively and efficiently for the NASA Student Launch initiative. The Student Launch team has performed a detailed analysis on each and every section of the launch vehicle. All the subsystems (PDLS, Recovery, etc.) on the vehicle have been tested at least twice to ensure a successful launch. All the materials selected for the construction of the rocket epitomizes strength and durability. All the fiberglass materials chosen have high tensile and compressive strengths exceeding into tens of thousands in terms of psi. From avionics to Aeropoxy to stainless steel hardware, all the electronics, adhesives and hardware used in the launch vehicle were selected of the highest quality and industrial grade. This is evident with a recent recovery event, where even though a section of the vehicle landed in the pond, all the parts of the section remained intact and all the electronics were functioning as expected. The analysis and guidance provided to us by our mentor has ensured the launch vehicle to withstand all ground tests and launch in any difficult conditions.

3.3 RECOVERY SUBSYSTEM

The recovery subsystem is a fully redundant dual-deployment system with two mains and one drogue parachute that will safely land the two sections of the vehicle. Each section houses its own altimeter bay that will send a charge/signal to deploy the drogue parachute upon reaching the apogee and the main parachutes after stage separation, respectively. Each section also contains its own GPS tracking system.

3.3.1 STRUCTURAL ELEMENTS

3.3.1.1 BULKHEADS

The bulkheads used for recovery are made of 3/16" fiberglass reinforced plastic. FRP has a good strength/weight ratio, making it a good material for critical components while minimizing weight. It has a tensile and compressive strength of 24,000 psi, a flexural strength of 35,000 psi, and can withstand temperatures of up to 140 degrees Fahrenheit. Because of these characteristics, the bulkheads are able to withstand the forces induced by the recovery process. This is necessary as the bulkheads are the primary distributors of the parachute deployment shock forces.

The bulkheads were cut from FRP stock sheets with a CNC router, allowing extremely precise cuts. Therefore, the bulkheads were created from a single piece, rather than two pieces of different diameters as previously done for the subscale.

All hardware on or around deployment charges is high-grade stainless steel to prevent corrosion due to powder residue.

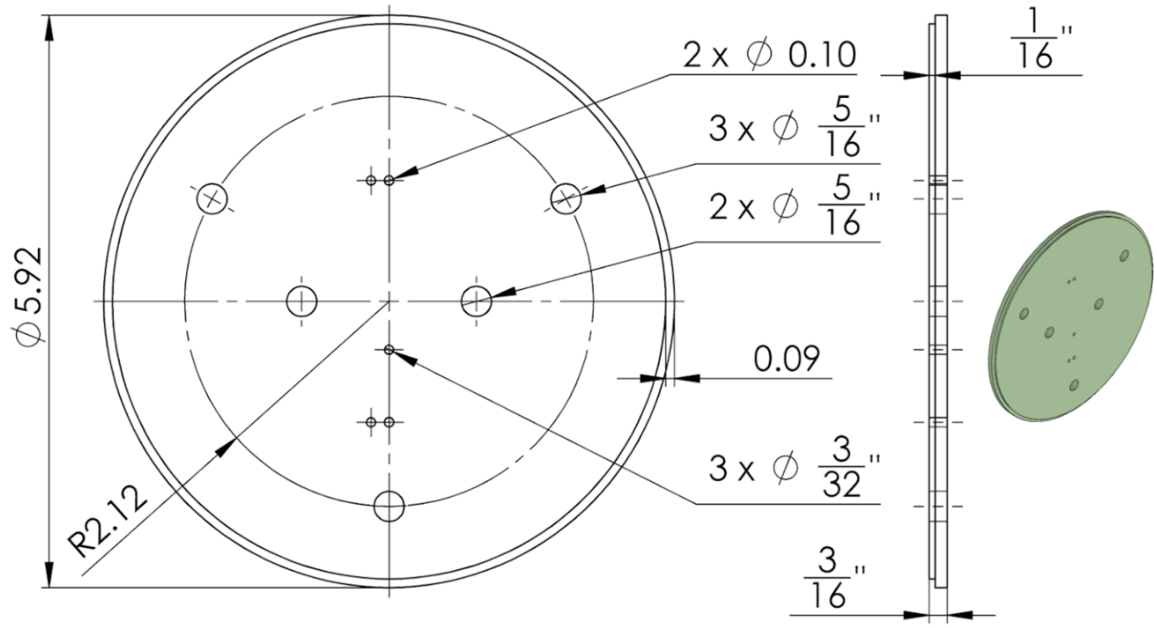


Figure 22: Dimensions of typical bulkhead.

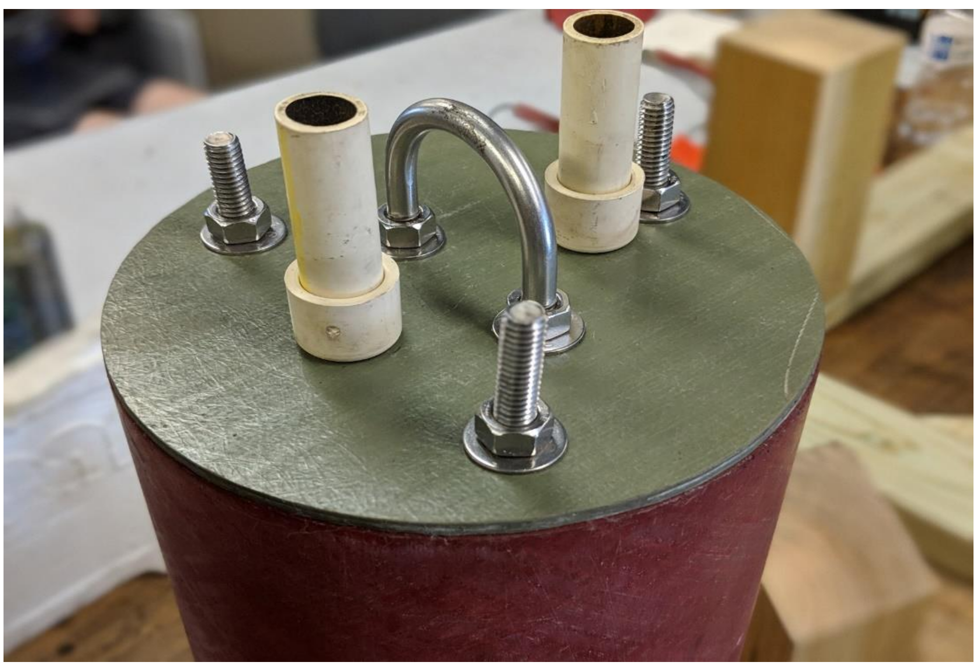


Figure 23: Typical bulkhead design installed on an avionics bay, featuring deployment charges, U-bolts, and threaded rods.

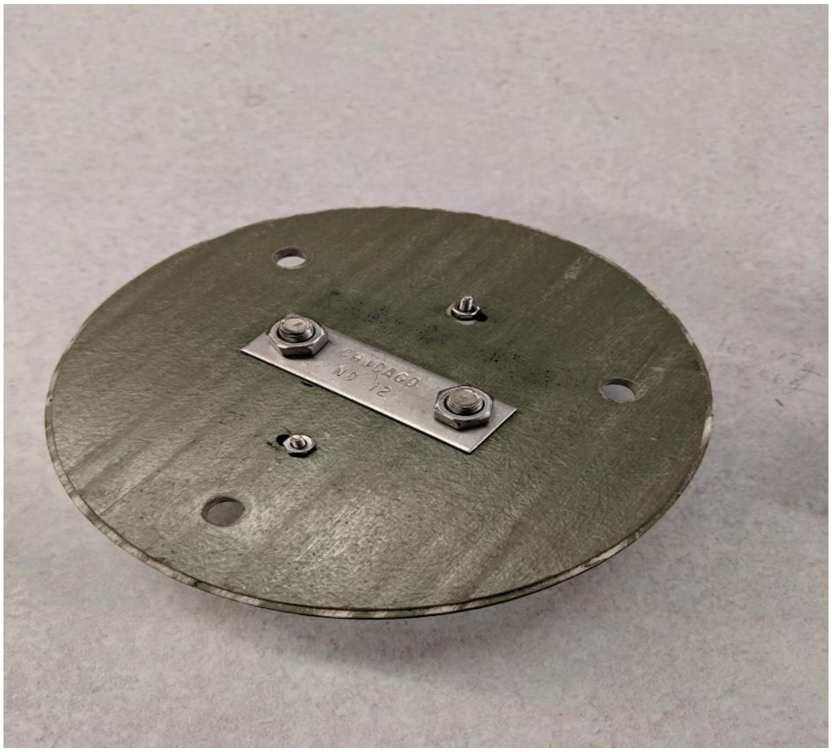


Figure 24: Reverse side of bulkhead, highlighting multi-layered design with built-in centering.

3.3.1.1.1 DEPLOYMENT CHARGE CONTAINERS

On the upper bulkhead of the upper section avionics bay and both bulkheads of the lower section avionics bay are mounted two (one primary and one backup) CPVC deployment charge containers. These charge containers are secured to the bulkhead with #4-40 18-8 stainless steel screws and lock washers. A second hole is drilled in each for an E-match to be wired through. CPVC deployment charge container pieces are expected to be lost during flight and are easily replaceable, even in the field.

3.3.1.1.2 U-BOLTS

Each bulkhead with a shock cord attachment (all except the lower bulkhead of the upper section avionics bay) is equipped with a high-strength 5/16″ 316 stainless steel U-bolt with a mounting plate to distribute applied loads. Each U-bolt is secured on both sides with hex nuts and cannot move.

3.3.1.2 THREADED RODS

Three 5/16″ threaded rods run through the entire length of both avionics bays. These threaded rods hold the bulkheads in place, transferring shock forces from one end of the bay to the other. They also serve as mounting points for avionics sleds. These rods are visible in Figure 12 and Figure 14 above.

3.3.1.3 SHOCK CORD HARNESSES

½″ tubular kevlar shock cord has been selected for the main and drogue parachutes. The kevlar shock cord is tested for 7200 lbs of shock force which is more than sufficient for the forces this rocket will encounter. All shock cords are attached to the bulkhead U-bolts using quick links. The shock cords are Z-folded for both compaction purposes and to prevent any tangling when the parachutes deploy.

All shock cord loops were tied with bowline knots before being tightly wrapped with vinyl tape to prevent loosening.

Figure 25: Typical tied shock cord loop and quick link.

Shock cords were sufficiently sized to prevent components from possibly impacting each other during descent.

3.3.1.4 QUICK LINKS

All quick links on the rocket are high-grade 316 stainless steel, rated for 1400 lbs. While the PDLS Tender Descender was sold with its own quick links, these were replaced as the included links did not have a load rating marked.

3.3.1.5 SWIVELS

All parachutes used in this launch vehicle were commercially sourced and came with swivels preinstalled. No modifications were made to these quick links.

3.3.1.6 ALTIMETER SLEDS

As previously noted, altimeter sleds are securely mounted to the three 5/16″ threaded rods that run through each bay. These sleds feature a unique interlocking design that allows for efficient use of space with rapid assembly and disassembly. Each avionics bay uses the same sled shapes, allowing the same CAD file to be cut on the CNC router for both sets. ⅛″ holes carefully placed for each altimeter allow for precise mounting locations, while larger holes for wiring prevent any possibility of a wire getting tangled and damaged.

Both avionics bays feature inset switches, allowing the entire sled assembly to be removed without any wires remaining in the rocket. Each switch has a corresponding LED wired to its device, enabling quick and reliable distinguishing of device outputs without having to listen to several sets of beeps simultaneously.

Altimeters are mounted to the FRP sleds with 18-8 stainless steel hardware and nylon spacers. #4-40 screws with lock washers hold both the avionics electronics and the battery clips.

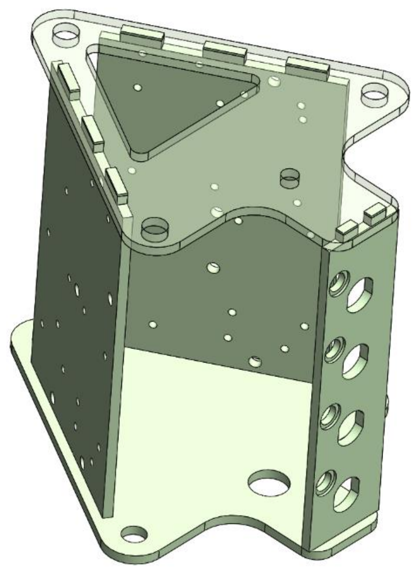


Figure 26: Interlocking avionics sled design without avionics installed.

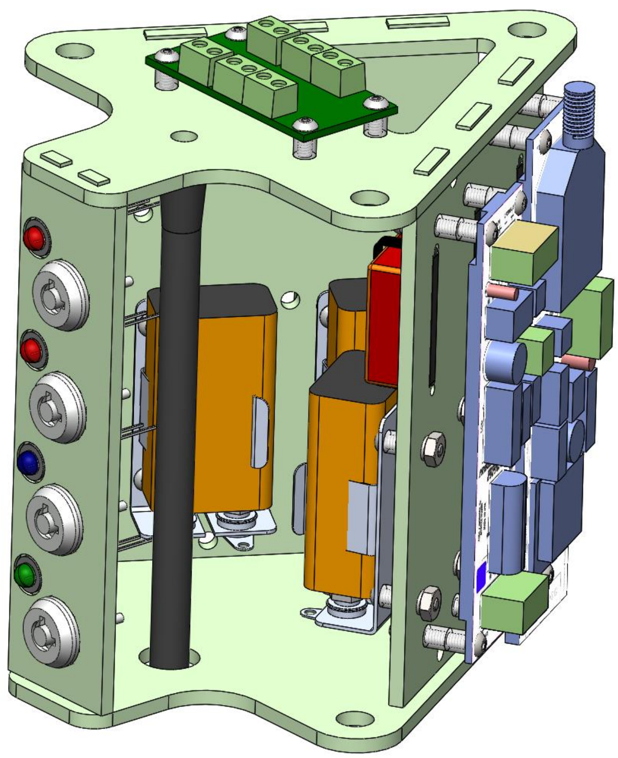


Figure 27: Avionics sleds with avionics mounted.

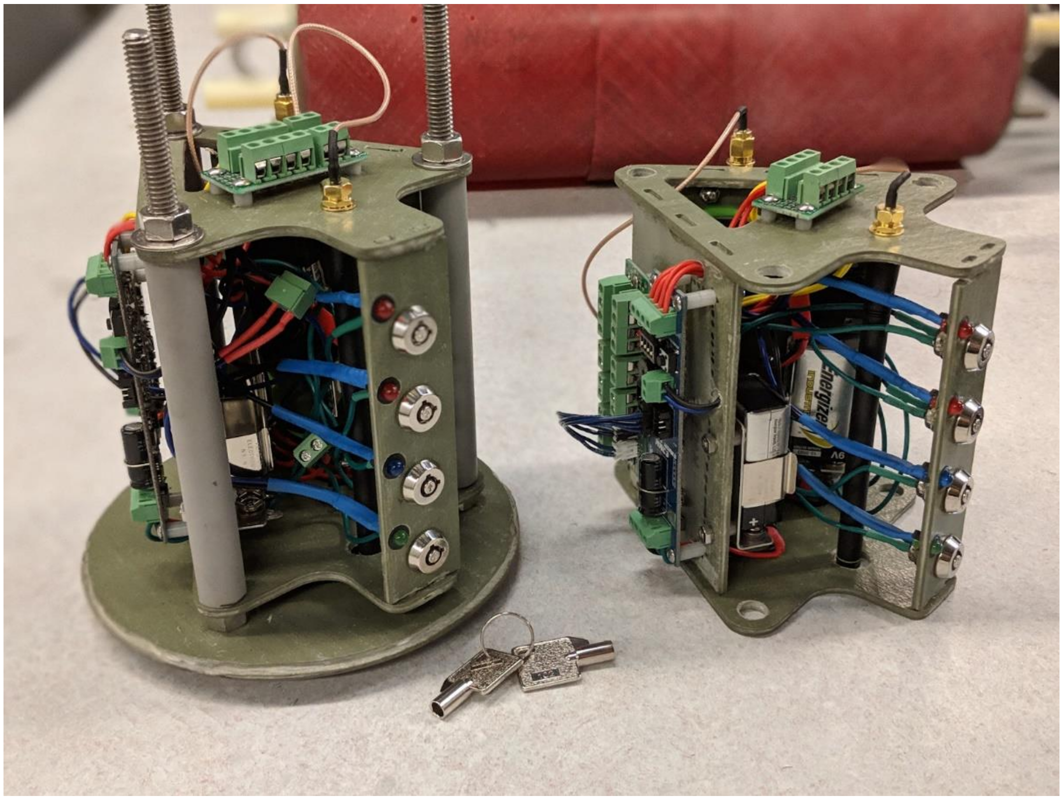


Figure 28: As-built upper (left) and lower (right) avionics sleds, both on and off the threaded mounting rods.

3.3.1.7 BATTERY RETAINMENT

All 9V avionics batteries are securely fastened with McMaster-Carr 9V battery snap holders. These aluminum components have been proven to hold batteries in place during many flights. In order to further ensure that the batteries cannot be dislodged, battery holders are oriented so that the liftoff momentum will push the batteries further into the holders.

Lithium polymer (LiPo) batteries (which power the GPS units) require special consideration, both for their lack of standard mounting components and their increased risk of fires. The two LiPo batteries on the rocket are held in place with three pieces of hook and loop fastener strips; two on the short side and and running the length of the battery. These fasteners are looped through high-strength waxed thread, weaved through a set of six holes in the sled plates.

All nuts located near LiPo batteries are acorn (cap) nuts, thus preventing any sharp edges from coming in contact with the batteries.

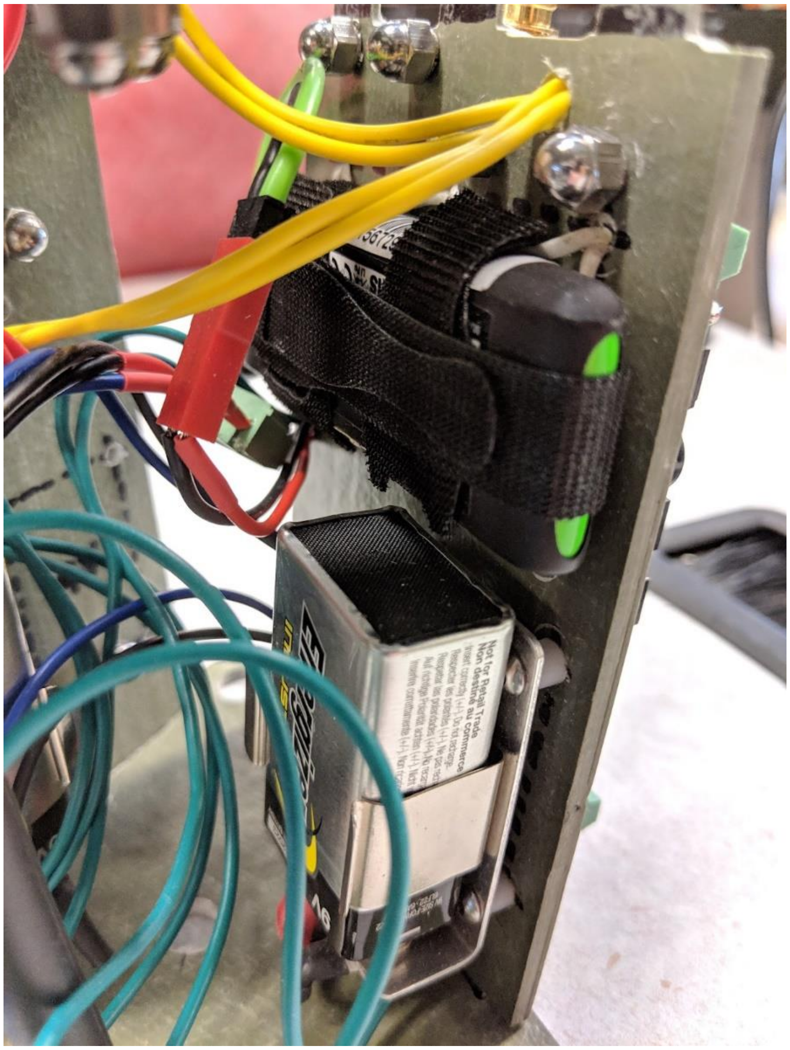


Figure 29: Avionics battery mounting methods. Batteries are not yet marked with high-visibility tape.

3.3.2 ELECTRICAL ELEMENTS

3.3.2.1 ALTIMETERS

Barometric dual-deploy Missile Works RRC3 “Sport” Altimeters are used in both avionics bays. This separation releases both main parachutes from the airframe which allows the launch vehicle to be recovered safely. One of the altimeters in each bay will also be tethered to the RTx Telematics System (GPS module) to stream real-time flight diagnostics. These altimeters have proven their reliability in one subscale and two full-scale test flights.

3.3.2.2 SWITCHES

“E-switch” rotary switches will control the avionics of the launch vehicle. These rotary switches are categorized as keylock switches which can be turned on and off using a key. These switches have a current rating of 1A (AC). When switch keys are removed, the switch cannot turn off until the key is re-inserted.

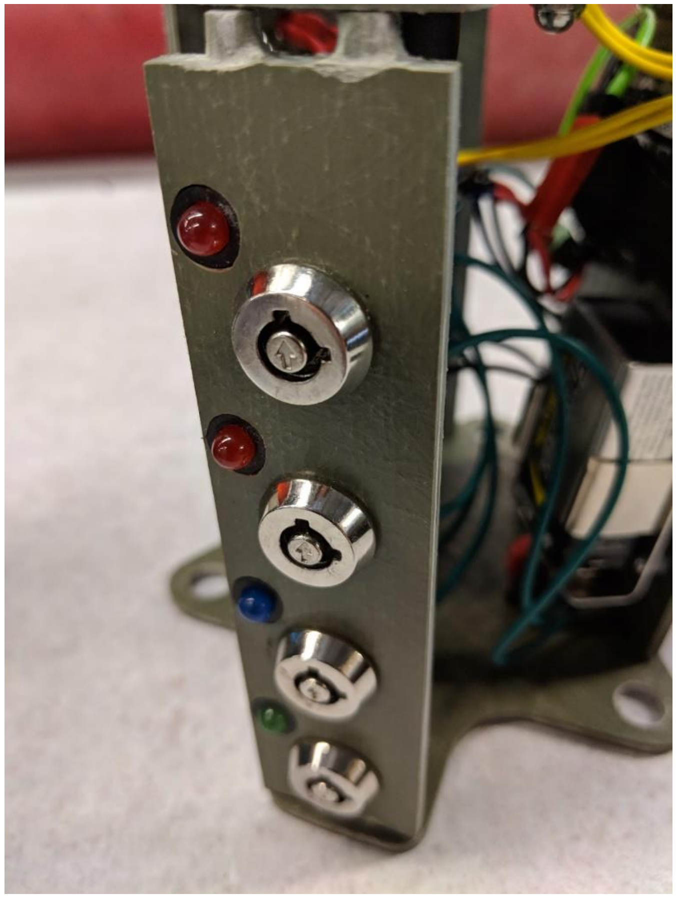


Figure 30: Avionics switches and corresponding LEDs.

3.3.2.3 BATTERIES

Per the Missile Works recommendations, each RRC3 and the PDLS RRC2+ altimeter will be powered by standard 9V batteries. To ensure sufficient pad stay time, Energizer Industrial 9V batteries will be used and tested prior to every launch.

The more sensitive RTx GPS systems cannot handle 9V, therefore, they will each use one Turnigy Graphene 950mAh 3.5V LiPo battery.

3.3.2.4 LEDS

Each avionics component (both altimeters, the RTx unit, and the PDLS/payload switch) has a corresponding LED. These LEDs are mounted with standard mounting brackets into the switch plate and are visible through small holes in the rocket. When powered, the altimeters should flash red, the GPS locators blue, and the payload items green. The RRC3 LED output does not feature a built-in resistor, therefore 1 kOhm resistors are included in series with the red LEDs.

3.3.2.5 WIRING

Standard 22 gauge stranded wiring is used in all avionics wiring instances. The wiring is color coded for fast diagnostics:

Table 7: Avionics wiring legend.

Colors	Meaning
Red and Black Pair	Power (Black Negative)
Blue and Black Pair	LED Output (Black Negative)
Green	Switch
Red	Primary Deployment Charge
Yellow	Secondary Deployment Charge

3.3.2.5.1 ELECTRICAL SCHEMATIC

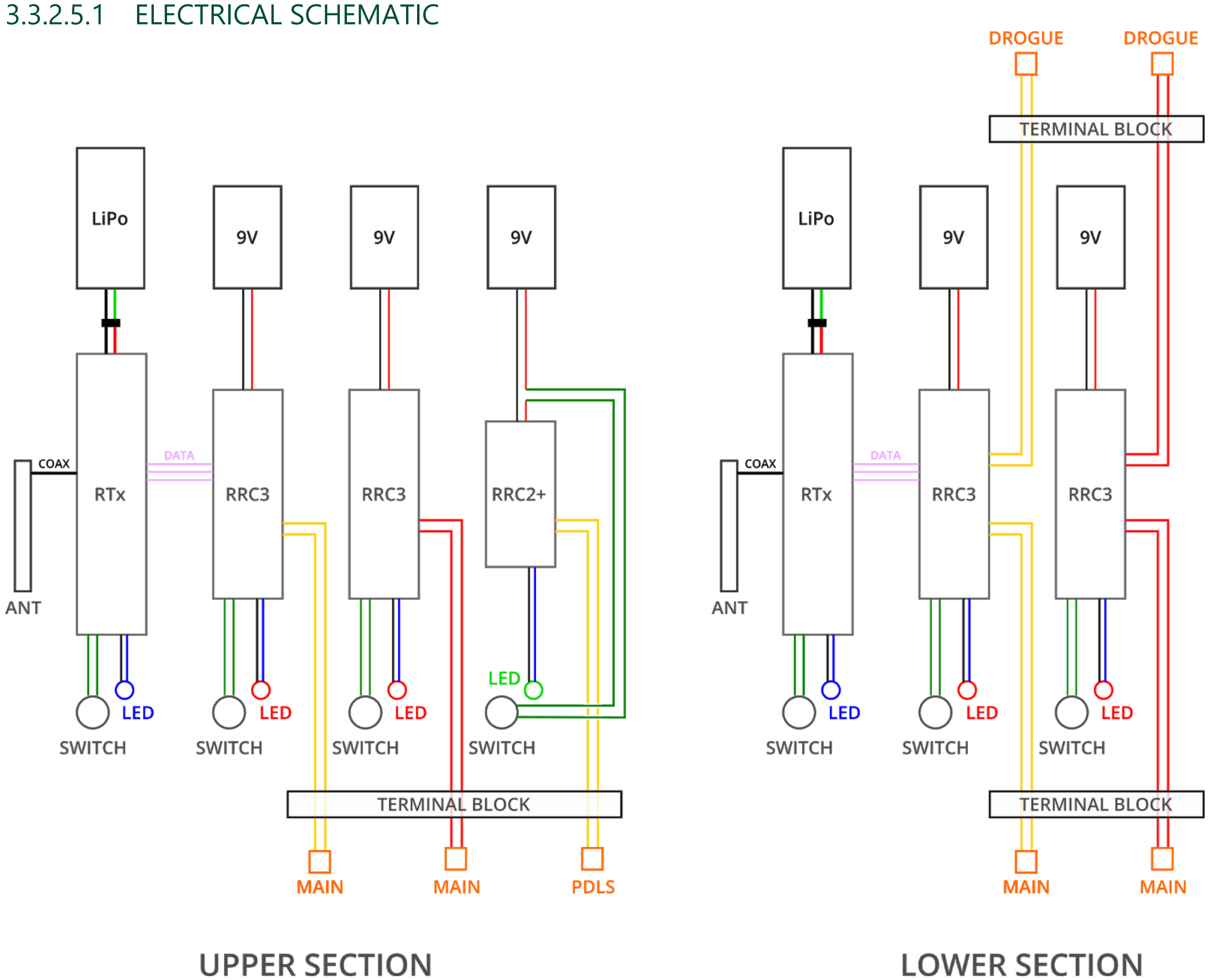


Figure 31: Vehicle electrical schematic, with colors as-wired.

3.3.2.5.2 SYSTEM REDUNDANCY

To ensure the data received from the avionics system is accurate, each recovery subsystem will have a redundant and parallel component. Each avionics bay includes two Missile Works RRC3 altimeters and an RTx GPS unit. If one of the altimeters were to fail, the other RRC3 will send a signal to a redundant deployment charge which will ensure that the shear pins break and deploy the drogue parachute at apogee. It will also cause a deployment charge to ignite at 700 feet so that the main parachutes deploy once the booster section and main altimeter bays have separated. Each altimeter will be powered by a separate 9V battery. In the event of failure of any individual electronic component, there exists a redundant system to perform the proper task. This redundancy is shown in the above electrical schematic.

3.3.3 PARACHUTES

Three parachutes are included in the full-scale launch vehicle. In the upper airframe is a 96" FruityChutes Iris Ultra Standard parachute. This will deploy at 725 ft when the nose cone separates from the upper airframe.

In the lower airframe is an 84" FruityChutes Iris Ultra Standard parachute. This will deploy at 750 ft when the upper airframe separates from the lower section avionics bay.

Also in the lower airframe is a 20" SkyAngle Classic Drogue parachute. This will deploy at apogee when the lower airframe separates from the lower section avionics bay.

Each of these parachutes come with detailed guides of how to fold and pack them, and do not take up much room in the airframe cavity, making them easy and convenient to use for our purposes.

The parachutes used for the recovery system have been selected keeping in mind the kinetic energy criteria at landing, safety of the vehicle and payload, and packing volume admissible inside the vehicle. Also, these parachutes have been extensively tried and tested with numerous data available commercially. All the parachute data is based on the L-2200 motor flight simulation and under conditions detailed previously.

The kinetic energy criteria at landing determined the descent velocity of the vehicle after the parachute deployment. In order to calculate that, we used the formula,

$$v = \sqrt{\ } (2E/m)$$

Equation 1: Relationship between velocity and energy

The maximum descent velocity was used to calculate the minimum coefficient of drag and canopy area of the parachute required for selection by the following formula,

$$A{\cdot}Cd = 2gm/\rho v\hat{\ }2$$

Equation 2: Relationship between descent velocity and drag coefficient times canopy area

The minimum drag coefficient times canopy area for the two sections of the rocket are given below:

Table 8: Area Coefficient of Drag for Separate Vehicle Sections

Section	Minimum A.Cd (ft^2)
Nose cone and Payload	116.23
Main Altimeter and Booster	69.5

This result was compared to the manufacturer's data and the following parachutes were selected for the vehicle.

Table 9: Nose cone and Payload section parachute characteristics

FruityChutes Iris Ultra Standard 96"	
Deployment Altitude (ft)	725
Area x Drag coefficient (A.Cd) (ft^2)	110.53
Material	0.66oz ripstop nylon
Surface Area (A) (ft^2)	50.24
Diameter (in)	96
Drag coefficient	2.2
Mass (lb)	1.53
Packing volume (in^3)	139.5
Number of lines	12
Line material	400lb Flat Nylon
Attachment type	3000lb swivel

Table 10: Main Altimeter and Booster section parachute characteristics

FruityChutes Iris Ultra Standard 84"	
Deployment Altitude (ft)	750
Area x Drag coefficient (A.Cd) (ft^2)	84.63
Material	0.66oz ripstop nylon
Surface Area (A) (ft^2)	38.47

Diameter (in)	84
Drag coefficient	2.2
Mass (lb)	1.5
Packing volume (in^3)	105.1
Number of lines	12
Line material	400lb Flat Nylon
Attachment type	3000lb swivel

Table 11: Drogue parachute characteristics

SkyAngle Classic 20"	
Deployment Altitude (ft)	Apogee
Area x Drag coefficient (A.Cd) (ft^2)	3.52
Material	1.3 oz. silicone-coated ripstop nylon.
Surface Area (A) (ft^2)	4.4
Diameter (in)	20
Drag coefficient	0.8
Mass (lb)	0.18
Packing volume (in^3)	78
Number of lines	3
Line material	3/8" tubular nylon (950 lbs)
Attachment type	Heavy-duty 1,500 lb. size 12/0 nickel-plated swivel

3.3.4 LOCATING TRANSMITTER

The MissileWorks RTx Telematics System is installed in the launch vehicle for locating the rocket. The RTx GPS Rocket unit communicates to a Base unit using 900 MHz ISM radio band (902-928 MHz). These radio modules use FHSS (Frequency Hopping Spread System) technology which is a method of transmitting radio signals by rapidly switching a carrier among frequency channels. This system uses a standard 250mW XBee 900 MHz ISM Radio system. The radio operational range for the units is up to 9 miles. These GPS units will be tethered to the RRC3 altimeters to livestream flight diagnostics to the base station.

3.3.5 ELECTRONIC SENSITIVITY

After performing a detailed analysis on all the electrical elements of the recovery system, proper measures have been taken to ensure proper functioning of all the onboard electronics. In order to avoid electromagnetic interference in the signals sent by the transmitter to the base unit, all the metal rods in the altimeter bay will be covered by polypropylene spacers. Also considering the fact that the rocket might have to be on the launch rail for longer than usual on the launch day, Energizer 9V and Turnigy Graphene 950mAh 1S LiPo batteries will be used to power the altimeters and the RTx system respectively to ensure that they have power during flight.

3.4 MISSION PERFORMANCE PREDICTIONS

3.4.1 FLIGHT DYNAMICS

3.4.1.1 FLIGHT PROFILE SIMULATIONS

The simulation for the full-scale rocket show very favorable results for reaching the chosen altitude. Using 12 foot 1515 launch rails, the OpenRocket simulation shows the apogee to between 4996 and 5006 feet, when the chosen altitude is 5000 feet. The launch vehicle is also simulated to reach a maximum speed of approximately 0.54 Mach, so it will never come close to exceeding Mach 1.

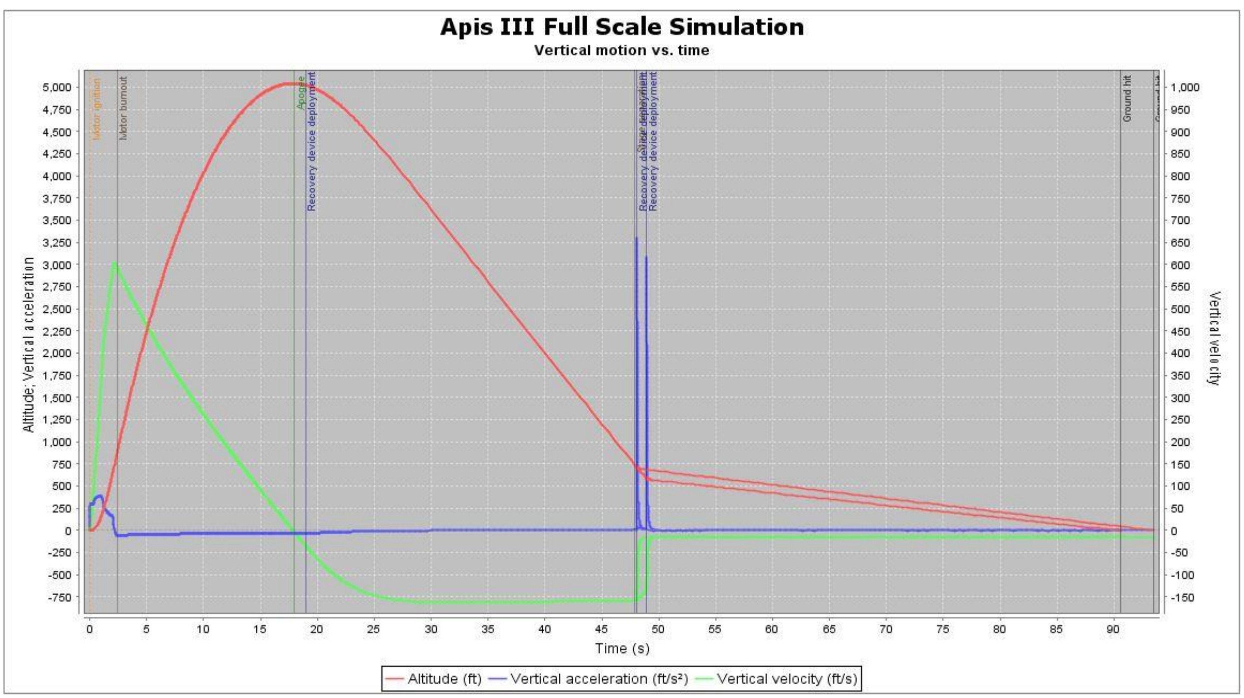


Figure 32: OpenRocket Simulation of Full-Scale rocket

3.4.1.2 ALTITUDE PREDICTIONS

The projected altitude based on the OpenRocket simulation under the conditions used below is 5006 feet.

1. Average windspeed: 4.47 miles per hour
2. Wind direction: Perpendicular to the launch vehicle.
3. Turbulence intensity: 10%
4. Atmospheric conditions: 59 degrees Fahrenheit, 1013 mbars
5. Launch rails: 8 foot 10x10 launch rails
6. Launch angle: 5 degrees

These are conditions that are reasonable to assume given what has been noted at NASA Student Launch competitions in past years and what options are available to the team on competition day.

3.4.1.3 COMPONENT WEIGHTS

Table 12: Table of Component Weights of Launch Vehicle

Component	Weight (lbs)
Nose cone	3.25
Shoulder	1.75
Upper Section Shock Cord	1.12
Upper Section Main Parachute	1.56
Upper Airframe	7.12
Payload Descent Leveling System	0.312
Upper Section Avionics Bay	2.37
Upper Section Avionics	1.12
Rover	3.75
Payload Deployment System	3.44
Lower Section Avionics Bay	4.69
Lower Section Main Parachute	1.31
Lower Section Shock Cord	0.5
Lower Section Avionics	1.12
Drogue Parachute	0.331

Lower Airframe + all components	11.2
Motor	10.5

3.4.1.4 SIMULATED MOTOR THRUST CURVE

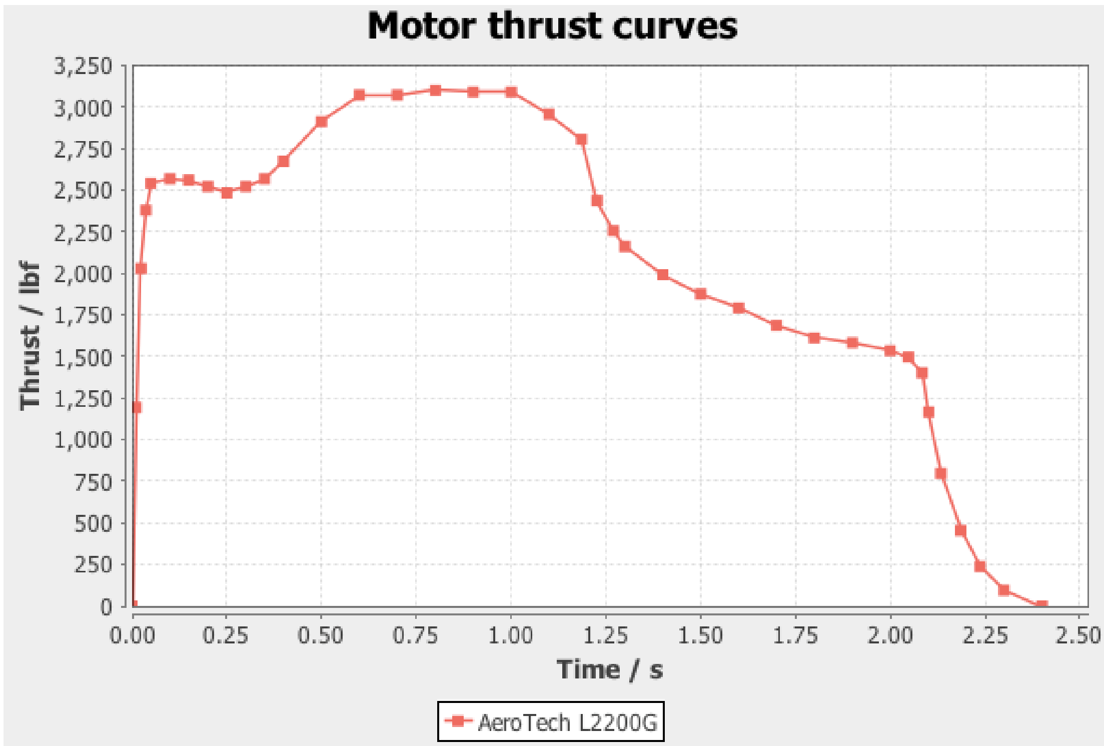


Figure 33: Simulated Aerotech L2200 Motor Thrust Curve from OpenRocket Simulation Software

3.4.2 STABILITY

The static stability of the as-built full-scale rocket is 2.39 calibers. This is greater than the required static stability margin of 2 calibers, so the rocket will maintain stability in flight. The locations of the center of gravity and center of pressure which determine the static stability are shown in the OpenRocket simulation below.

Figure 34: Static Stability derived from CG and CP locations in OpenRocketKinetic Energy

The kinetic energy during descent of the two sections of the rocket has been calculated using the formula

$$KE = 1/2mv^2$$

Table 13: Kinetic energy for the two sections, note descent velocity is taken from the open rocket simulation

Section	Nose cone	Payload	Main Altimeter	Booster
Drogue	129.42	304.2	134.12	188.24
Main #1 deployment (96”)	26.9	63.24	27.95	33.13
Main #2 deployment (84”)	32.55	76.52	33.82	47.35
Landing	22.34	52.52	28.9	40.45

These values are well under the competition requirements.

3.4.3 DESCENT TIME

The descent time for the two sections have been calculated from the instance where the drogue parachute is deployed (apogee) to the landing.

Table 14: Descent time for the two sections

Section	Descent time (sec)
Nose cone and Payload	72.7
Main Altimeter and Booster	75.6

3.4.4 DRIFT

3.4.4.1 CALCULATION 1

The drift analysis is done by calculating the descent time from Open rocket and applying it in the formula

$$d = v \times t$$

They are calculated separately for the two sections of the vehicle.

Table 15: Drift analysis of Nose cone and Payload section at various wind speeds

Wind speed (mph)	Wind speed (fps)	Drift (ft)
0	0	0
5	7.33	532.89

10	14.66	1065.78
15	22	1598.67
20	29.33	2131.56

Table 16: Drift analysis of Main altimeter and booster section at various wind speeds

Wind speed (mph)	Wind speed (fps)	Drift (ft)
0	0	0
5	7.33	554.15
10	14.66	1108.3
15	22	1662.44
20	29.33	2216.59

3.4.4.2 CALCULATION 2

An alternative calculation method is by using this online descent rate calculator https://www.rocketreviews.com/descent-rate-calculator.html . The total descent time for the Nose cone and payload section was 79.9 sec and for the main altimeter and booster section was 81.1 sec. The drift was then calculated using the same formula above.

Table 17: Alternate drift analysis of Nose cone and Payload section at various wind speeds

Wind speed (mph)	Wind speed (fps)	Drift (ft)
0	0	0
5	7.33	585.67
10	14.66	1171.33
15	22	1757
20	29.33	2342.67

Table 18: Alternate drift analysis of Main altimeter and booster section at various wind speeds

Wind speed (mph)	Wind speed (fps)	Drift (ft)

0	0	0
5	7.33	594.46
10	14.66	1188.93
15	22	1783.4
20	29.33	2377.85

3.4.4.3 DISCREPANCIES BETWEEN CALCULATIONS

Discrepancies between the drift calculations can largely be explained by the fact that the first calculations were done taking data from open rocket simulation where other correction factors and launch conditions are included in the formulation of the descent time. Whereas, the second calculations were done by the descent rate calculator which probably does not include the launch conditions. However, as both calculations place the drift area well within the designated parameters, this should not be a significant issue.

3.4.4.4 SIMULATIONS

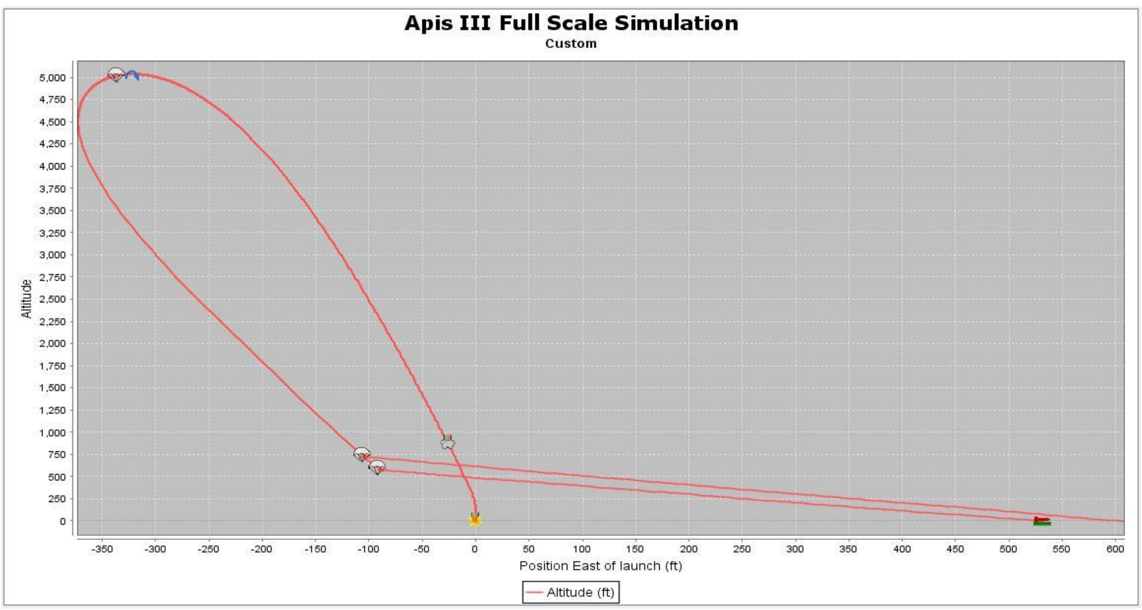


Figure 35: Graph of flight profile under Aerotech L2200G motor

3.5 VEHICLE DEMONSTRATION FLIGHT

3.5.1 FLIGHT 1 (02/23/2019)

3.5.1.1 LAUNCH DAY CONDITIONS & SIMULATION

The weather on February 23, 2019, the launch day, at Varn Ranch in Plant City, FL was quite unstable. It was a clear day for the most part with some cloud cover at times and the temperature was ranging between 67°F - 72°F. The wind speeds ranged from 7-11 mph. Weather data was obtained from the Weather Channel at the time of launch.

Flight simulations predicted an apogee of 4,020 ft on launch day, as shown below.

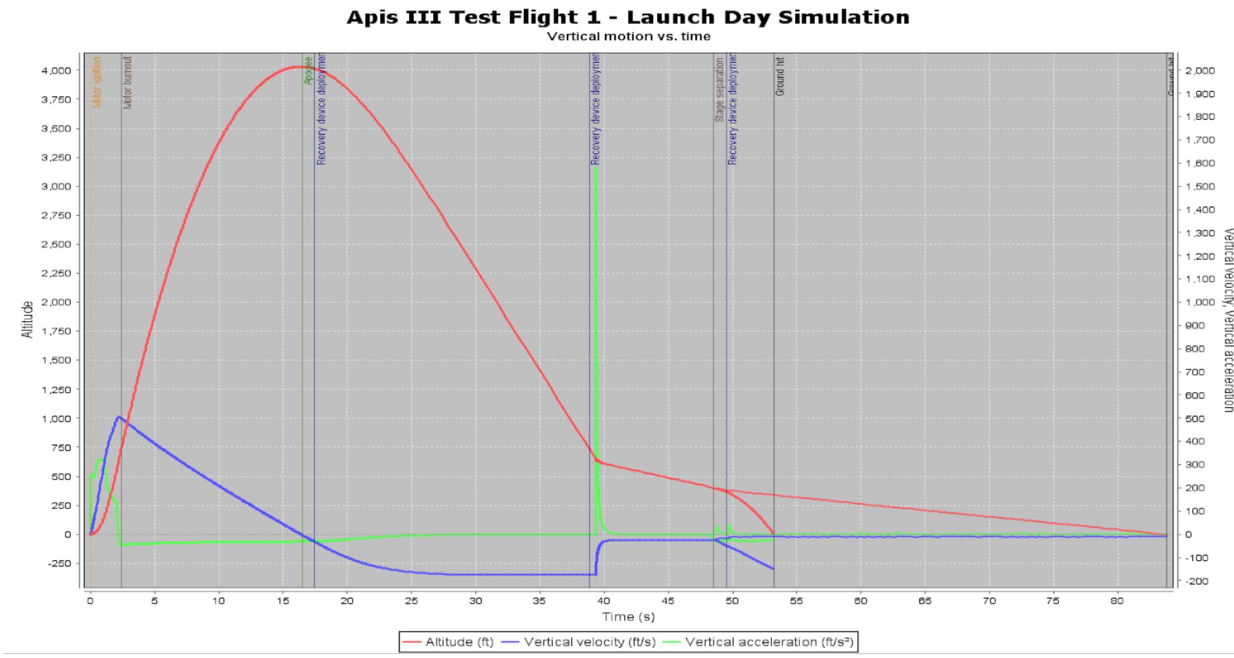


Figure 36: Launch day simulations for full-scale vehicle test flight 1.Vehicle Flight Analysis

The rocket flew almost perfectly straight, despite 10mph winds at the moment of launch. It left the pad extremely stable and remained as such until apogee at 3875 ft. At apogee, the drogue charge fired as programmed, however, the shear pins holding the upper section to the main altimeter bay proved to be insufficient to prevent the main parachute from deploying immediately after the drogue.

Because the sections separated at apogee, the lower section main parachute deployed early and the rocket drifted nearly two miles, while the upper section fell ballistically until its own parachute deployed successfully at 500 feet.

The upper section landed in a pond, which was an unavoidable and unfortunate occurrence that required replacement of all avionics systems at significant cost and loss of flight data.

The lower section was successfully located with the help of the Hillsborough County Sheriff, and sustained no damage. No damage whatsoever to the rocket was sustained due to flight or landing, and the payload was retained in the vehicle successfully. Had the rocket not landed in a lake, the PDLS would have worked perfectly as well.

3.5.1.1.1 FLIGHT DATA VS. SIMULATION

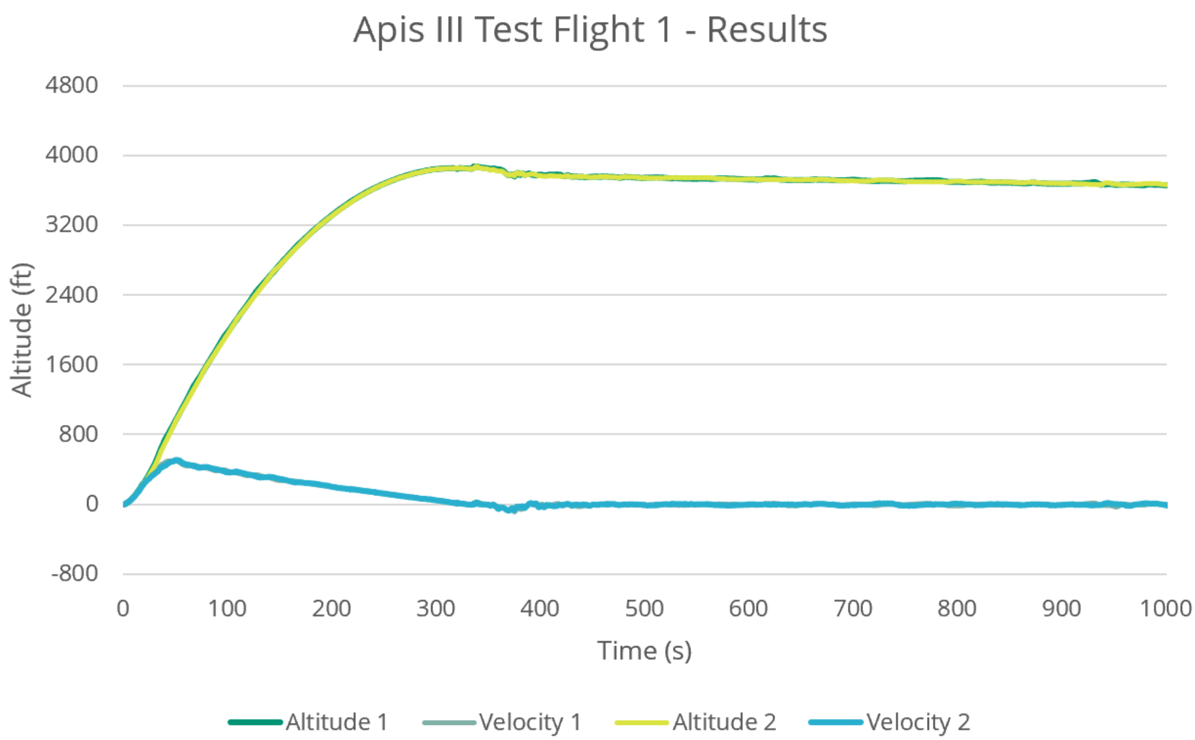


Figure 37: Full-scale vehicle test flight 1 results from lower section altimeters. Drift under parachute lasted until altimeters timed out.

The flight data results resulted in 145 ft of difference between the simulated and achieved apogee. This 145 ft adjustment will be applied to future simulations to obtain a more accurate result.

3.5.1.1.2 FULL SCALE VS. SUBSCALE RESULTS

The subscale rocket had an identical deployment method to this vehicle, therefore one can easily compare performance of the recovery system. Because this scenario never occured in a subscale test flight, it is clear that the problem can be resolved. The method of resolution is yet to be determined.

3.5.2 FLIGHT 2

3.5.2.1 LAUNCH DAY CONDITIONS & SIMULATION

The weather on March 3rd was almost completely clear skies, with just a few high-flying clouds present. The wind was blowing North at approximately 7 mph, and it was 78 °F. Under these conditions, the newly modified launch vehicle (without DAAS, any ballast, or the 5” on the lower airframe) simulated to launch to 4,605 ft.

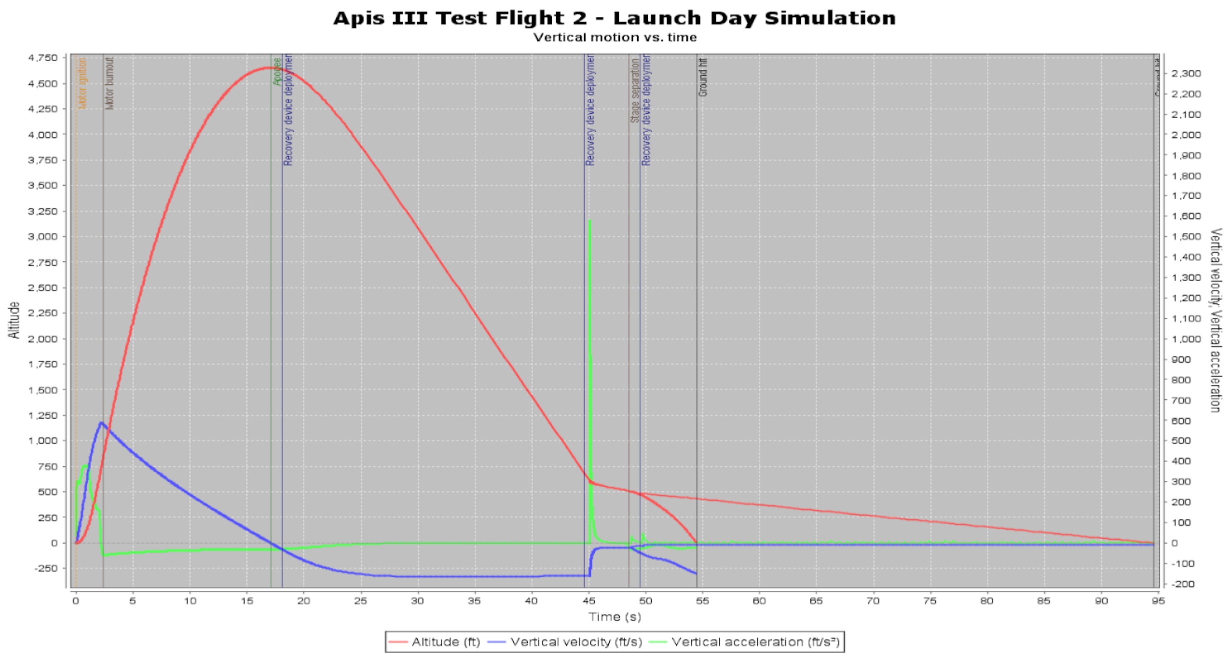
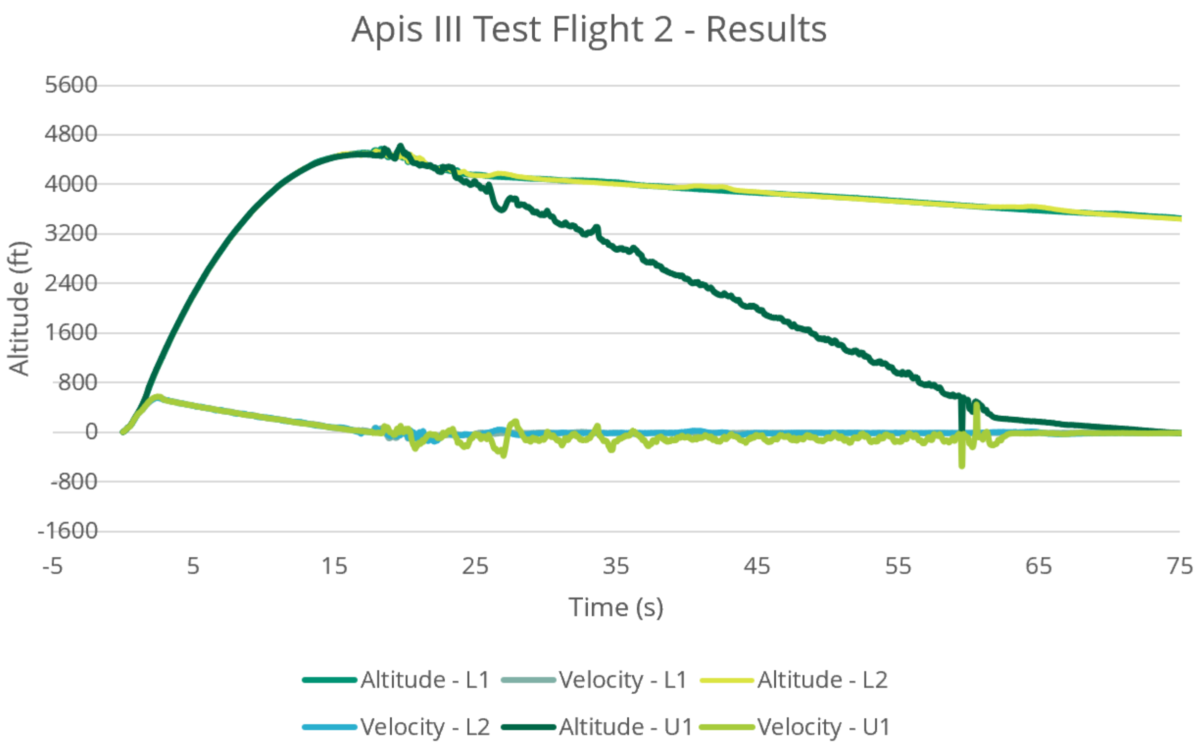


Figure 38: Launch-day simulations for full-scale vehicle test flight 2.

3.5.2.2 VEHICLE FLIGHT ANALYSIS

Once again, the rocket flew perfectly straight, soaring to apogee (4,580 ft) almost directly over the launch pad. However, the same problem occurred as on flight 1, with the lower section main parachute deploying at apogee. This was despite an increase from 4 to 6 shear pins and a decreased drogue deployment charge of 2 grams of black powder. This time, however, GPS tracking and low winds aided in a speedy recovery and all vehicle components were recovered unscathed.

3.5.2.2.1 FLIGHT DATA VS. SIMULATION



Full-scale vehicle test flight 2 results from three RRC3 altimeters.

Figure 39: Full-scale vehicle test flight 2 results from three RRC3 altimeters.

The average apogee reported by the altimeter is less than 30 feet from the projected altitude. Therefore, no adjustments need to be made to this simulations in the future, assuming that that no significant changes are made to the rocket besides minor mass changes.

3.5.2.2.2 FULL SCALE VS. SUBSCALE RESULTS

The comparison of full-scale to subscale results is the same as with flight 1.

4 SAFETY AND PROCEDURES

4.1 SAFETY AND ENVIRONMENT (VEHICLE AND PAYLOAD)

4.1.1 RISK IDENTIFICATION

4.1.1.1 SEVERITY

The severity of each potential risk is determined by comparing the possible outcome to criteria based on human injury, vehicle and payload equipment damage, and damage to environment. Severity is based on a 1 to 3 scale, with 1 being the most severe. The severity criteria are provided below.

Table 19: Risk Severity Level Definitions

Description	Personnel Safety and Health	Facility or Equipment	Range Safety	Project Plan	Environmental
– 1 – Catastrophic	Loss of life or a permanent disabling injury.	Loss of facility, systems or associated hardware that result in being unable to complete all mission objectives.	Operations not permitted by the RSO and NFPA 1127 prior to launch. Mission unable to proceed.	Delay of mission critical components or budget overruns that result in project termination.	Irreversible severe environmental damage that violates law and regulation.
– 2 – Critical	Severe injury or occupational related illness.	Major damage to facilities, systems, or equipment that result in partial mission failure.	Operations not permitted by the RSO and NFPA 1127 occur during launch. Mission suspended, or laws and regulations are violated.	Delay of mission critical components or budget overruns that compromise mission scope.	Reversible environmental damage causing a violation of law or regulation.
– 3 – Marginal	Minor injury or occupational related illness.	Minor damage to facilities, systems or equipment that will not compromise mission objectives.	Operations are permitted by the RSO and NFPA 1127, but hazards unrelated to flight hardware design occur during launch.	Minor delays of non-critical components or budget increase.	Mitigatable environmental damage without violation of law or regulations where restoration activities can be accomplished.
– 4 – Negligible	First aid injury or occupational-related illness.	Minimal damage to facility, systems, or equipment.	Operations are permitted by the RSO and NFPA 1127, and hazards unrelated to flight hardware design do not during launch.	Minimal or no delays of non-critical components or budget increase.	Minimal environmental damage not violating law or regulation.

4.1.1.1.1 PROBABILITY

The probability of each potential risk has been assigned a level between A and E, A being the most certain. The scale of probabilities is determined by analyzing the risks and estimating the possibility of the accident to occur. Table depicts the levels of probability for each risk.

Table 20: Risk Probability Levels and Definitions

Description	Qualitative Definition	Quantitative Definition	Letter

– A – Frequent	High likelihood to occur immediately or expected to be continuously experienced.	Prob. (P) > 90%	A
– B – Probable	Likely to occur or expected to occur frequently within time.	90% ≥ P > 50%	B
– C – Occasional	Expected to occur several times or occasionally within time.	50% ≥ P > 25%	C
– D – Remote	Unlikely to occur but can be reasonably expected to occur at some point within time.	25% ≥ P > 1%	D
– E – Improbable	Very unlikely to occur and an occurrence is not expected to be experienced within time.	1% ≥ P	E

4.1.1.2 RISK ASSESSMENT LEVELS

Each risk is finally assigned a risk assessment code (RAC) based upon a combination of the risk severity and probability. From the RAC, a color-coded risk level is assigned. These levels range from high (**red**) to minimal (**white**) and are assigned using the below tables.

Table 21: Risk assessment classification definitions

Level of Risk	**Definition**
High Risk	Highly Undesirable. Documented approval from the RSO, NASA SL officials, team faculty adviser, team mentor, team leads, and team safety officer.
Moderate Risk	Undesirable. Documented approval from team faculty adviser, team mentor, team leads, team safety officer, and appropriate sub-team lead.
Low Risk	Acceptable. Documented approval by the team leads and sub-team lead responsible for operating the facility or performing the operation.
Minimal Risk	Acceptable. Documented approval not required, but an informal review by the sub-team lead directly responsible for operating the facility or performing the operation is highly recommended.

Table 22: Risk assessment classification matrix

Probability	Severity			
	– 1 – Catastrophic	– 2 – Critical	– 3 – Marginal	– 4 – Negligible
– A – Frequent	1A	2A	3A	4A
– B – Probable	1B	2B	3B	4B
– C – Occasional	1C	2C	3C	4C
– D – Remote	1D	2D	3D	4D
– E – Improbable	1E	2E	3E	4E

4.1.2 PERSONNEL HAZARD ANALYSIS

Table 23: Personnel Hazard Analysis

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Sharp edges on the launch pad	Failure to pay attention, faulty equipment	Minor cuts or scrapes to personnel working with, around, and transporting the launch tower.	3D	Sharp edges of the launch pad will be filed down and deburred if possible. If not possible, personnel working with launch tower will be notified of hazards.	3E	REFERENCE: {Launch procedure checklist}
Injury from premature separation charge	Altimeters powered on prematurely	Severe burns, possible cuts from materials.	2E	Altimeters will only be powered on by a designated individual after all other personnel have left.Altimeters will only be powered on to conduct testing.	2E	REFERENCE: {Launch procedure checklist}

Injury from Recovery System Failure	Failure of separation charges, faulty equipment, parachutes not properly attached.	Injury to personnel from ballistic rocket component or piece of equipment.	1E	Launch preparation checklist will be used for launch preparation. Should the rocket become ballistic, all personnel at the launch field will be notified immediately.	1E	REFERENCE: {Launch procedure checklist}
Injury from premature motor ignition	Incorrect installation of motor, incorrectly prepared motor.	Severe burns or cuts from shrapnel possible loss of life.	1E	Launch preparation checklist will be used for launch preparation. Motors will be prepared under supervision of our mentor.	1E	REFERENCE: {Launch procedure checklist and Motor prep checklist}
Workshop Injury	Improper training on the use power and hand tools such as blades, saws, drills, etc	Mild to severe cuts or burns to personnel.	2D	Individuals will be trained on the tool being used. Those not trained will not attempt to learn on their own and will find a trained individual to instruct them. Proper PPE must be worn at all times. Shavings and debris will be swept or vacuumed up to avoid cuts from debris.	2E	Training will be documented for designated individuals. {REFERENCE: Shop waiver}
Inhalation or contact with carbon fiber, fiberglass dust, or other particles	Failure to use protective equipment or follow proper protocol	Mild to severe rash. Irritated eyes, nose or throat with the potential to aggravate asthma. Mild to severe cuts or burns from a Dremel tool or sanding wheel.	2C	Long sleeves will be worn at all times when sanding or grinding materials. Proper PPE will be utilized such as safety glasses and dust masks with the appropriate filtration required. Individuals will be trained on the tool being used. Those not trained will not attempt to learn on their own and will find a trained individual to instruct them.	2E	Training will be documented for designated individuals. {REFERENCE: Shop waiver}
Soldering Iron Burn	Lack of attention, faulty equipment	Minor burns	3D	The temperature on the soldering iron will be controlled and only on when in use. Only personnel trained to use the soldering iron will operate it.	3E	Training will be documented for designated individuals. {REFERENCE: Shop waiver}

Inhalation or contact of chemicals	Failure to use protective equipment or follow proper protocol	Mild to severe burns on skin or eyes. Lung damage or asthma aggravation due to inhalation.	2D	MSDS documents will be readily available at all times and will be thoroughly reviewed prior to working with any chemical. All chemical containers will be marked to identify appropriate precautions that need to be taken. Chemicals will be maintained in a designated area. Proper PPE will be worn at all times when handling chemicals. Personnel involved in motor making will be supervised by mentor.	2E	Training will be documented for designated individuals. {REFERENCE: Shop waiver}
Electrical shock or burns	Failure to correctly regulate power to circuits during testing or exposed electrical components	Burns or heart arrhythmia	1D	The circuits will be analyzed before they are powered to ensure they don't pull too much power. Power supplies will also be set to the correct levels. Team members will use documentation and checklists when working with electrical equipment.	1E	When available, an electrical engineering student will supervise electrical operations.
Metal shards	Improper use of equipment and lack of protective wear when machining metal parts.	Metal splinters in skin or eyes.	1D	Team members will wear long sleeves and safety glasses whenever working with metal parts. Individuals will be trained on the tool being used. Those not trained will not attempt to learn on their own and will find a trained individual to instruct them.	1E	Training on this equipment is provided by the university through the Design for X Labs orientation and safety training program.

4.1.3 FAILURE MODES AND EFFECTS ANALYSIS

Table 24: Vehicle Failure Mode and Effects Analysis

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Parts fail or break	Normal wear and tear, Improper installation or handling	Delay to construction or testing.	2C	When practicable, maintain suitable replacement parts on hand. Be cautious when handling materials or assembling components.	2E	REFERENCE: {Checklists}

Inability to retrieve resources	Long shipping times and delays, failure to order parts in timely fashion	Delay to construction or testing, possibility of not being able to complete certain subsystems.	2C	Shared calendar will be used to keep all personnel apprised of deadlines. Reminder notifications will be sent to technical leads well in advance of deadlines.	2E	REFERENCE: {Timeline}
Unstable launch platform	Uneven terrain or loose components	Rocket's path may be unpredictable, launch data may not be usable, possible injury.	2E	Confirm that all personnel are at a distance allowed by the Minimum Distance Table as established by NAR. Ensure that the launch pad is stable and secure prior to launch.	3E	REFERENCE: {Launch Procedure Checklists}
Rocket gets caught in launch tower or experiences high friction forces.	Misalignment of launch tower joints. Deflection of launch platform rails. Friction between guide rails and rocket.	Rocket may not exit the launch tower with a sufficient exit velocity or may be damaged on exit.	2E	During setup, the launch tower will be inspected for a good fit to the rocket. The launch vehicle will be tested on the launch rail. If any resistance is noted, adjustments will be made to the launch tower, allowing the rocket to freely move through the tower.	2E	REFERENCE: {Launch Procedure Checklists}
Pivot point bearings seize	Load is larger than specifications, debris enters bearings.	Launch platform will experience higher resistance to motion causing a potential hindrance the vehicle raising.	2D	Bearings will be sized based on expected loads with a minimum factor of safety. The launch platform will be cleaned following each launch and will be cleaned prior to each launch. Proper lubrication will be applied to any point expected to receive friction.	2E	REFERENCE: {Launch Procedure Checklists}
Damage to fins	Unexpected force on fins, improper installation and securement of fins.	Altered flight trajectory, damage to launch vehicle.	1D	Inspect fins for damage before flight, ensure the vehicle is in a safe drift range, free from possibly damaging landing spots. Run simulation to ensure the fins can withstand any necessary forces.	2E	REFERENCE: {Launch Procedure Checklists, Launch vehicle design, launch vehicle construction}

Motor CATO (catastrophic failure)	Improper motor manufacturing.	Launch vehicle is destroyed and motor has failed. Moderate explosion. Possible Injury.	1D	Ensure nozzle is unimpeded during assembly. Inspect motor for cracks and voids prior to launch. Ensure all team members are a safe distance away from the launch pad upon ignition of the rocket. Wait a specified amount of time before approaching the pad after a catastrophe. All fires will be extinguished before it is safe to approach the pad.	1E	REFERENCE: {Motor preparation checklist}
Motor Retention Failure	The drogue parachute ejection charge applied a sufficient force to push the motor out the back of the launch vehicle	The motor is separated from the launch vehicle without a parachute or any tracking devices.	2D	Ensure that the centering rings have been thoroughly epoxied to both the motor mount and to the inner walls of the airframe. Ensure that motor is properly secured using motor mount adapter and retainer ring.	2E	REFERENCE: {Motor preparation checklist}
Loss of stability during flight	Improper construction of fins or launch vehicle body	Failure to reach target altitude, destruction of vehicle.	2D	The CG of the vehicle will be measured prior to launch. Launch vehicle will be inspected prior to launch. Proper storage and transportation procedures will be followed.	2E	REFERENCE: {Launch Vehicle Construction, checklists}
Motor fails to ignite	Faulty motor. Delayed ignition. Faulty e-match. Disconnected e-match.	Rocket will not launch. Rocket fires at an unexpected time.	3D	Checklists and appropriate supervision will be used when assembling. NAR safety code will be followed and personnel will wait a minimum of 60 seconds before approaching rocket. If there is no activity after 60 seconds, safety officer will check the ignition system for a lost connection or a bad igniter.	3E	REFERENCE: {Launch procedures}

Sufficient exit rail velocity not achieved	Rocket is too heavy. Motor impulse is too low. High friction coefficient between rocket and launch tower	Unstable launch	3D	Simulations will be run before every launch to ensure the exit rail velocity will be sufficient. Full scale testing ensures launch stability. Should the failure mode still occur, the issue should be further examined to determine if the cause was due to a faulty motor or in the booster needs to be redesigned.	3E	REFERENCE: {Launch procedures}
Internal bulkheads or centering rings fail during flight	Forces encountered are greater than the bulkheads or center rings can support	Internal components supported by the bulkheads will no longer be secure. Parachutes attached to bulkheads will be ineffective.	3D	The bulkheads and centring rings have been designed to withstand the force from takeoff with an acceptable factor of safety. Additional epoxy will be applied to ensure security and carbon fiber shreds will be added where appropriate.	3E	REFERENCE: {Launch Vehicle Construction}
Rocket does not fit launch rail	Improper size for rail buttons	Cancelled launch, reconstruction of rail buttons.	3D	During construction rail buttons were carefully measured and placed precisely to fit the appropriate rail size. Full scale testing has been completed to ensure rocket can safely fit on rail.	3E	REFERENCE: {Launch Vehicle Construction, Vehicle Demonstration FLight}

Table 25: Recovery Failure Mode and Effects Analysis

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Parachute deployment failure	Altimeter failure. Electronics failure. Parachutes snag on shock cord.	Parachute deployment failure. Sections fail to separate. Damage to the launch vehicle.	2D	Shroud lines and shock cord will be measured for appropriate lengths. Altimeter and electronics check will be conducted with checklist several hours prior to launch. Deployment bags will be secured low on shroud lines to prevent entanglement. Main parachutes will deploy at different altitudes.	2E	Follow checklist for proper recovery precautions: {Checklists, ground testing}

Sections fail to separate at apogee or at other designated altitudes	Black powder charges fail or are inadequate. Shear pins stick. Launcher mechanics obstruct separation. Altimeter programming incorrect.	Parachute deployment failure. Sections fail to separate. Damage to the launch vehicle.	2D	Correct amount of black powder needed for each blast charge will be calculated. Couplings between components will be sanded to prevent components from sticking together. Fittings will be tested prior to launch to ensure that no components are sticking together. In the event that the rocket does become ballistic, all individuals at the launch field will be notified immediately.	2E	Follow checklist for proper recovery precautions: {Checklists, ground testing}
Sections separate prematurely	Construction error. Premature firing of black powder due to altimeter failure or incorrect programming.	Structural failure, loss of payload, target altitude not reached.	1D	Use multiple shear pins to prevent drag separation. Verify altimeter altitudes. Use launch preparation checklist when preparing for launch.	1E	Follow checklist for proper recovery precautions: {Checklists, ground testing}
Altimeter or e-match failure	Improper programing of altimeters, faulty equipment	Parachutes will not deploy. Rocket follows ballistic path, becoming unsafe.	1E	Dual altimeters and e-matches are included in systems for redundancy to eliminate this failure mode. E-matches will be tested for continuity prior to installation. Should all altimeters or e-matches fail, the recovery system will not deploy and the rocket will become ballistic, becoming unsafe. All personnel at the launch field will be notified immediately.	1E	Follow checklist for proper recovery precautions: {Checklists, ground testing}
Rocket descends too quickly	Improper parachute size	The rocket falls with a greater kinetic energy than designed for, causing components of the rocket to be damaged.	2E	The parachutes have each been carefully selected and designed to safely recover its particular section of the rocket. Extensive ground testing was performed to verify the coefficient of drag is approximately that which was used during analysis.	2E	REFERENCE: {Mission Performance Predictions}

Rocket descends too slowly	Improper parachute size	The rocket will drift farther than intended, potentially facing damaging environmental obstacles.	3D	The parachutes have each been carefully selected and designed to safely recover its section of the rocket. Extensive ground testing was performed to verify the coefficient of drag is approximately that which was used during analysis.	3E	REFERENCE: {Mission Performance Predictions}
Parachute has a tear or ripped seam	Rough packing, damage from previous flight missed during inspection	The rocket falls with a greater kinetic energy than designed for, causing components of the rocket to be damaged.	2D	Through careful inspection prior to packing each parachute, this failure mode will be eliminated. One spare large parachute will be on hand. Deployment bags will be used to prevent damage from black powder charges. In the incident that a small tear occurs during flight, the parachute will not completely fail.	2E	Follow checklist for proper recovery precautions: {Checklists}
Recovery system separates from the rocket	Bulkhead becomes dislodged, failure to attach parachute to U-Bolt	Parachute completely separates from the component, causing the rocket to become ballistic.	1E	The cables and bulkhead connecting the recovery system to each segment of the rocket are designed to withstand expected loads with an acceptable factor of safety. Launch preparation checklist will be used for launch preparation. Should the rocket become ballistic, all personnel at the launch field will be notified immediately.	1E	Follow checklist for proper recovery precautions: {Checklists:parachute folding instructions}
Lines in parachutes become tangled during deployment	Improper parachute packing	The rocket has a potential to become ballistic, resulting in damage to the rocket upon impact.	1D	Deployment bags will be used between parachutes to avoid entanglement. Ground testing will be performed to ensure that the packing method will prevent tangling during deployment prior to test flights. Parachutes will be deployed at different altitudes.	1E	Follow checklist for proper recovery precautions: {Checklists:parachute folding instructions}

Parachute does not inflate	Improper parachute packing or parachute is damaged	Parachute does not generate enough drag.	2E	Parachute lines will be carefully folded in accordance with checklist. Nomex covers will be secured at lower end of shroud lines.	2E	Follow checklist for proper recovery precautions: {Checklists:parachute folding instructions}

Table 26:Rover Failure Mode and Effects Analysis

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Parts fail or break	Normal wear and tear, Improper installation or handling	Delay to construction or testing.	2C	When practicable, maintain suitable replacement parts on hand. Be cautious when handling materials or assembling components.	2E	REFERENCE: {Checklists}
Inability to retrieve resources	Long shipping times and delays, failure to order parts in timely fashion.	Delay to construction or testing, possibility of not being able to complete certain subsystems.	2C	Shared calendar will be used to keep all personnel apprised of deadlines. Reminder notifications will be sent to technical leads well in advance of deadlines.	2E	REFERENCE: {Timeline}
Deployment system fails to operate	No communication or dead batteries	Rover cannot exit the vehicle, mission failure.	2D	The deployment system will be tested extensively with different variables. Batteries will be tested to ensure they can stay on long enough.	2E	REFERENCE: {Vehicle Testing}
Failure of on board electronics	Overheating from compacted space, direct sunlight, water damage.	Rover cannot operate properly, mission failure.	2E	On board electronics will be covered and in a protective housing.	2E	{Payload Testing}
Rover leaves rocket prematurely	The rover or deployment system breaks causing them to become detached.	Loss of rover, mission failure. Possible injury due to falling rover.	1E	Multiple retention tests have been conducted and the rover has stayed secured during flight.	3E	REFERENCE: {Payload retention flight}

Rover fails to detach from the deployment system	The rover wheel become stuck on the deployment system	Rover cannot operate properly, mission failure.	1D	Deployment system tests will be conducted to find the best configuration and eliminate any faults.	1E	REFERENCE: {Deployment Test}
Signal connection between rover and ground station fails	Signal not strong enough. Distance to rocket from ground station too far.	Rover cannot operate properly, mission failure.	1D	External antenna will be used, which has several miles of range. Extensive testing will be conducted to determine maximum range. Ensure batteries are fully charged.	1E	REFERENCE: {Project Planning, Testing}
Rover becomes stuck on ground obstacle	Uneven terrain. Low ground clearance, slippery soil	Rover cannot operate properly, mission failure.	1C	Sensors will be installed to determine if rover is successfully moving forward and will trigger redirection if not. Test have been conducted to create the best traction and ground clearance.	1E	REFERENCE: {Project Planning: Testing}
Rover fails to move 10 feet	Obstacles, rover dies, inability to move	Rover fails mission	1C	Multiple drive tests will be conducted to ensure rover can move 10 feet on current design.	1E	REFERENCE: { Testing, rover design}
Rover fails to collect 10 mL of soil	Vacuum failure, no loose soil.	Rover fails mission	1D	Multiple soil collection tests will be conducted to ensure the design and equipment can complete the mission.	1E	REFERENCE: {Project Planning: Testing, Rover soil collection}
Rover fails to exit launch vehicle	Debris inside launch vehicle, rover stuck on something inside launch vehicle, deployment system fails	Rover fails mission	1C	Deployment system tests will be conducted to find the best configuration and eliminate any faults.	1E	REFERENCE: {Deployment Test}
PDLS fails to make upper airframe horizontal	Wire does not fully extend, tender descender does not operate as planned	Upper airframe may land vertically and become filled with debris resulting in an undeployable rover thus mission failure.	1D	Multiple tests have been conducted to prove the efficiency of the PDLS	1E	REFERENCE: {Payload leveling system, project plan: testing}

Damage to rocket at PDLS wire exit points	PDLS wire abrades on fiberglass at airframe exit points	Wear and damage to airframe	3D	The wire from the PDLS will be secured down with masking tape to prevent abrasion, a trench will be cut into the fiberglass section where the nosecone and upper airframe connect.	3E	REFERENCE: {Payload leveling system, project plan: testing}
Failure of PDLS wire or small Tender Descender quick links	Improperly sized hardware or excessive deployment shock force	PDLS system fails and rocket descends vertically, as normal	3D	Engineering analysis of hardware and wire; drop testing prior to launch.	3E	REFERENCE: {Payload leveling system, project plan: testing}

4.1.4 ENVIRONMENTAL HAZARD ANALYSIS

Table 27: Environmental Hazard Analysis

Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Minimal Visibility	Fog/ low cloud cover	Unable to track rocket trajectory in order to determine a recovery site.	1C	Launching will not be conducted if there is complete cloud coverage or if our RSO does not recommend launching.	1E	REFERENCE: {Safety procedures}
Bad weather	Weather fronts	Unable to launch. Damage electrical components and systems in the rocket.	2C	Place electrical components in water tight bags. Have a location prepared to store the entire rocket to prevent water damage. Electronics on the ground station are all stored in water tight control boxes to seal out any moisture. Bring a canopy for protection against possible rain.	2E	REFERENCE: {Field Packing checklist}
High winds	Weather front	Higher possibility of drifting out of required range. Possibility for a nonlinear flight path.	2C	If high winds are present but allowable for launch, the time of launch should be planned for the time of day with the lowest winds. No launch will occur with winds over 20 mph.	2E	REFERENCE{Drift}

Terrain	Launch field terrain such as groups of trees or large amount of foliage	Irretrievable rocket components if in an area we are unable to get to. Possible damage to thin parachutes and other materials.	1D	The rocket should not be launched if trees are within the estimated drift radius. If the rocket happens to land in a bad arr of terrain the proper personnel must be notified to retrieve the rocket.	1E	REFERENCE: {Drift calculations,}
Terrain	Launch field terrain.	Rover is unable to move around thus unable to fulfill mission	1C	The rover has the capability to move around some obstacles but is limited to what it can gain traction on.	1E	References: {Rover ground testing}
Wet/damp ground	Rain or irrigation system	Damage to electronics, slippery terrain for members and rover.	3B	With the potential of the ground being extremely soft at local launch sites and in Huntsville, the rocket should not be launched if there is swampy ground within the predicted drift radius that would prevent the team from retrieving a component of the rocket or deploying the rover.	3E	REFERENCE: {Drift calculations,}
Ponds, creeks, and other bodies of water.	Launch site terrain and possible recent rain	Loss of rocket component and damaged electronics.	1D	The exact recovery location is never known but if drift can be minimized to stray away from bodies of water that would be ideal. If a known body of water is nearby then procedures should be followed if the rocket lands in or near that area.	1E	REFERENCE: {Procedure for water retrieval}
Humidity	Weather fronts	Motors or black powder charges become saturated and will not ignite.	2D	Motors and black powder should be stored in an water resistant container.	2E	REFERENCE: {Field packing list}
UV exposure	High UV index at launch site	Possibly weakening materials or adhesives.	3D	Rocket should not be exposed to sun for long periods of time. A canopy should be used for all launches to ensure a covered area is designated for rocket preparations.	3E	REFERENCE: {Field packing list}

Extremely cold temperatures.	Weather fronts	Completely discharged batteries will cause electrical failures and fail to set off black powder charges, inducing critical events. Rocket will not separate as easily..	3E	Batteries will be checked for charge prior to launch to ensure there is enough charge to power the flight. Should the flight be delayed, batteries will should be rechecked and replaced as necessary. If the temperatures are below normal launch temperature, black powder charges should be tested to ensure that the pressurization is enough to separate the rocket. If this test is successful, the rocket should be safe to launch.	3E	REFERENCE: {Launch checklists}
Loss of Rocket	Unexpected drift to an off property site	Inability to recover rocket right away and possibility even at all.	1B	Perform drift calculations prior to launching and ensure the proper personnel form the launch site are notified before going off to recover the rocket.	1E	REFERENCE: {Launch checklists, Drift }
Loss of Rocket	Landing in tree or power line	Inability to recover rocket right away and possibility even at all.	1B	Perform drift calculations prior to launching and ensure the proper personnel form the launch site are notified before going off to recov the rocket.	1E	REFERENCE: {Launch checklists, Drift }

4.2 LAUNCH OPERATIONS PROCEDURES

The procedures in this section will be brought to all launches and followed carefully every time.

4.2.1 CAUTION STATEMENTS

Warnings, cautions, and notes are used to emphasize important and critical instructions and are used for the following conditions. These caution statements will be used to emphasize crucial elements of launch operations procedures.

4.2.1.1 WARNING

An operating procedure, practice, etc., which, if not correctly followed, could result in personal injury or loss of life. Warnings will be shown in red and appear just prior to the step, procedure, or equipment to which they apply, the warning will include possible consequences of failure to heed warning and list any appropriate personal protective equipment required.

4.2.1.2 CAUTION

An operating procedure, practice, etc., which, if not strictly observed, could result in damage to or destruction of equipment. Cautions will be typed in orange and appear just prior to the step, procedure, or equipment to which they apply, the caution will include possible consequences of failure to heed caution.

4.2.1.3 NOTE

An operating procedure, condition, etc., which is essential to highlight. Notes will be typed in bold black and appear just prior to the step, procedure, or equipment to which they apply.

4.2.1.4 PPE REQUIRED

Denotes proper protective equipment that must be worn prior to initiating the following steps.

PPE Required notices will be typed in green and appear prior to the step, procedure, or equipment to which they apply.

4.2.2 FIELD PACKING LIST

All items in this packing list should be brought to every launch.

Tools

- Power drill and drill bits
- Dremel tool with attachments
- Sheet sander
- Screwdrivers
- Wire cutters/strippers
- Scissors
- Small funnel
- 1-gram scoop
- Pliers
- Wrenches
- PVC cutters

Parts

- Vehicle components
- Quick links
- E-matches
- Igniter (in water resistant container)
- Parachutes
- Main × 2
- Drogue × 1
- Parachute deployment bags
- Nomex protectors
- Spare parts toolkit (nuts, bolts, washers, etc.)
- Shear pins (2-56, 4-40)Motor retainer adapter
- Batteries

Consumables

- Charge insulation (in water resistant container)
- Black powder (in water resistant container)
- Duct tape
- Electrical tape
- Sandpaper
- Electrical wire
- Silicone
- Graphite powder
- White lithium grease
- Rail lubricator
- Extra CPVC
- Extra launch lug

Motor Parts

- 3 - 1/16" O rings
- 1 - 1/8" O rings
- 2 - 3/16" O rings
- Grease
- Motor Liner
- Motor Casing
- Nozzle
- Nozzle Retaining Ring
- Forward Closure
- Forward Closure Seal Disk
- Forward Retaining Ring
- Retaining Ring Tightening Tool
- Delay Grain
- Motor Grains

4.2.3 FULL SCALE LAUNCH SAFETY CHECKLISTS

4.2.3.1 GENERAL MATERIALS AND SAFETY CHECKLISTS

Table 28: General pre-flight inspection checklist.

Task	SO Verification
Airframe	
Inspect fins for damage and security	

Task	SO Verification
Inspect rocket body for dents, cracks, or missing parts	
Inspect bulkheads for cracked epoxy or epoxy separation from airframe tube	
Inspect motor retaining ring for security or cracked epoxy	
Clean all components of debris and carbon residue	
Recovery	
Inspect parachutes for holes and parachutes cords for abrasions or tears	
Inspect shock cords for abrasion or tearing	
Inspect all quick links for operation, corrosion, or damage and replace if necessary	
Attach all quick links to respective shock cords using secure knots and duct tape if desired OR If quick links are already installed, inspect all quick links for attachment knot and/or tape security and condition	
Inspect all bulkhead U-bolts for security	
Test altimeters for operation and continuity	
Check altimeter programming for correct altitudes	
Electrical	
Check all batteries for full charge	
Check electrical connections for continuity and security	

4.2.3.2 RECOVERY AND FINAL VEHICLE SAFETY CHECKLISTS

Table 29:Final assembly and launch checklist.

Task	Warning/Caution	SO Verification
Recovery Preparation		
Warning: E-matches may ignite during test. **PPE Required**: Eye protection, latex gloves.		
Perform continuity check of all E-matches	Parachutes may fail to deploy. Mission failure.	
Recovery Preparation – Lower Avionics Bay and Lower section		
Weave lower section drogue shock cord into deployment bag in accordance with manufacturer's instructions.		
Attach quick link to drogue parachute swivel.	Ensure parachute remains properly folded during this process.	
Connect E-matches to altimeters	Ensure E-matches are dry. Parachutes may fail to deploy. Mission failure.	
Warning: Keep away from flames. E-matches may ignite during test. Black powder may ignite during preparation. **PPE Required**: Eye protection, gloves.		
Measure 2.5 grams of black powder and deposit in each of the CPVC tube inserts on lower section side of avionics bay.	Amount of charge to be determined during ground testing. Ensure black powder is dry. Insufficient charge will result in failure of separation or ejection. Parachutes may fail to deploy. Mission failure.	
Pack insulation tightly on top of black powder and secure with pressure sensitive tape.	Ensure insulation is dry. Packing too loosely may result in insufficient force to separate or eject. Parachutes may fail to deploy. Mission failure.	

Task	Warning/Caution	SO Verification
Measure 3.5g of black powder and deposit in each of the CPVC tube inserts on upper section side of avionics bay.	Amount of charge to be determined during ground testing. Ensure black powder is dry. Insufficient charge will result in failure of separation or ejection. Parachutes may fail to deploy. Mission failure.	
Pack insulation tightly on top of black powder and secure with pressure sensitive tape.	Ensure insulation is dry. Packing too loosely may result in insufficient force to separate or eject. Parachutes may fail to deploy. Mission failure.	
Attach quick link to U-bolt on lower section side of avionics bay.		
Close quick link locking gate securely.		
Completely insert booster section lower shock cord into lower section.		
Insert the drogue parachute into the lower section.	Ensure that Nomex protector completely covers parachute.	
Slide avionics bay into lower section.	Ensure that shear pin holes are aligned.	
Insert shear pins in shear pin holes.	Number and type of shear pins to be determined during ground testing. Please reference ground test report.	
Weave lower section main shock cord into deployment bag in accordance with manufacturer's instructions.		

Task	Warning/Caution	SO Verification
Secure quick link to U-bolt on upper side of altimeter.		
Close quick link locking gate securely.		
Secure quick link to swivel of lower section main parachute.		
Close quick link locking gate securely.		
Set aside lower section assembly.		
Recovery Preparation – Upper Avionics Bay and Upper Section		
Ensure E-matches are dry. Parachutes may fail to deploy. Mission failure.		
Warning: Keep away from flames. **PPE Required**: Eye protection, gloves.		
Amount of charge to be determined during ground testing. Ensure black powder is dry. Insufficient charge will result in failure of separation or ejection. Parachutes may fail to deploy. Mission failure.	Ensure screw, air pressure, and access holes are aligned.	

Task	Warning/Caution	SO Verification
Ensure insulation is dry. Packing too loosely may result in insufficient force to separate or eject. Parachutes may fail to deploy. Mission failure.		
See Tender Descender manual.		
Caution: During assembly, ensure that all launch vehicle body sections fit snugly but not tightly. If fit is too tight, sand with fine grit sandpaper until fit is properly adjusted and apply a small amount of graphite powder if necessary.		
Calculate ballast needed based on wind and atmospheric conditions.		
Load ballast weights onto ballast sleds.		
Slide ballast sleds onto threaded rod in nose cone shoulder as needed.		
Secure ballast sleds to threaded rod with threaded nuts.		
Secure nose cone shoulder to nose cone with screws.		
Attach quick link to U-bolt on nose cone.		

Task	Warning/Caution	SO Verification
Attach nose cone quick link to swivel of upper section main parachute.		
Close quick link locking gate securely.		
Weave upper section main shock cord into deployment bag in accordance with manufacturer's instructions.		
Slide upper section main parachute and shock cord into the upper section.	Ensure parachute remains properly folded and shroud lines are unencumbered. Ensure Nomex protector completely covers parachute to prevent entanglement with landing module parachute.	
Slide nose cone into upper section.	Ensure shear pin holes are aligned.	
Insert shear pins in shear pin holes.	Number and type of shear pins to be determined during ground testing. Please reference ground test report.	
Retrieve lower airframe assembly.		
Weave upper section main shock cord into deployment bag in accordance with manufacturer's instructions.		

Task	Warning/Caution	SO Verification
Slide upper main parachute and shock cord into the upper section.	Ensure parachute remains properly folded and shroud lines are unencumbered. Ensure Nomex protector completely covers parachute to prevent entanglement with landing module parachute.	
Slide upper side of main avionics bay into upper section of airframe.	Ensure shear pin holes are aligned.	
Insert shear pins in shear pin holes.	Number and type of shear pins to be determined during ground testing. Please reference ground test report.	

4.2.3.3 ROVER SAFETY CHECKLISTS

Table 30: Rover Safety Checklist

Task	Warning/Caution	SO Verification
Check battery for full charge		
Check electrical connections for continuity and security		
Secure Solenoid latch onto Payload		
Ensure holes line up when inserting the payload into the payload compartment		
Ensure solenoids both solenoids are inserted into the proper holes. "+" marked solenoid to "+" marked hole.		

4.2.3.4 PLDS SAFETY CHECKLISTS

Table 31: PDLS Safety Checklist

Task	SO Verification
Check cable for fraying, damage, or corrosion	
Check battery for full charge	
Check electrical connections for continuity and security	
Test altimeters for operation and continuity	
Check altimeter programming for correct altitudes	
Check connection hardware: quick links and U-bolts	

4.2.3.5 MOTOR INSTALLATION CHECKLIST

Table 32:4.2.3.5 MOTOR INSTALLATION CHECKLIST

Motor		
Warning: Keep away from flames. Motor grains may ignite during preparation. **PPE Required: Eye protection, gloves when using grease.**		
Task	**Warning/Caution**	**SO Verification**
Test fit motor grains to liner.	If they are too snug and are not easily loadable into the motor, then peel off the outer paper layer.	
Inset 1 grain into the motor casing, then place 1/16" O ring on top and insert second grain. Repeats process until all four grains are inside of the motor casing.	Ensure the top and bottom of the motor casing have even spacing.	

Grease forward closure, remaining O rings, and smoke/delay grain. Then, place one 3/16" O ring on the forward closure and insert the delay grain.		
Place 1/8" O ring on toward seal disk. Place toward seal disk on one side of liner.		
Place one 1/8" O ring on nozzle and place nozzle holder onto nozzle with the lip insert towards O ring.		
Grease outside of linear and slide liner into motor case	Grease for easier cleaning.	
Grease threads of motor casing		
Insert forward closure on end with forward seal disk.	Ensure it goes past threads.	
Insert forward retaining ring onto forward end of casing.		
Insert nozzle into bottom end of liner and place after retaining ring.		
Use retaining ring tool to tighten both retaining rings.	Ensure it is very tight.	

Wipe motor casing down to remove any grease.		
Insert completed motor assembly into the booster section.		
Securely screw on motor retainer ring.		

4.2.3.6 LAUNCH PAD SETUP CHECKLISTS (INCLUDE IGNITOR INSTALLATION, SETUP ON LAUNCH PAD)

Table 33: Launch Pad Setup Checklist

Task	Warning/Cautions	SO Verification
Have the launch vehicle inspected by the RSO		
Be sure power is turned off from launch control.	Motor may ignite prematurely causing critical injury to personnel and equipment damage.	
Inspect launch pad and rail for debris, corrosion, and stability.	Adjust as necessary. Lubricate as necessary.	
Place the launch vehicle on the rail.	Test launch vehicle on launch rail for resistance or friction. Adjust as necessary. Lubricate as necessary.	
Upper section altimeter Bay		
Use switch key to arm first switch of upper section, wait for two beeps every 5 seconds and for the LED to match then move on to next switch	Parachutes may fail to deploy. Mission failure.	

Use switch key to arm 2nd switch of upper section, wait for two beeps every 5 seconds and for the LED to match.	Parachutes may fail to deploy. Mission failure.	
Use switch key to arm GPS and arm the “u” switch on ground systems and wait for screen to display sync message.	Before arming 3rd switch, ensure display of ground systems is connected. If no sync message reference trouble shooting checklist.	
Use switch key to arm 4th switch of upper section, wait for two beeps every 5 seconds and for the LED to match.	Parachutes may fail to deploy. Mission failure.	
Lower section		
Use switch key to arm 1st switch of lower section, wait for two beeps every 5 seconds and for the LED to match.	Parachutes may fail to deploy. Mission failure.	
Use switch key to arm 2nd switch of lower section, wait for two beeps every 5 seconds and for the LED to match.	Parachutes may fail to deploy. Mission failure.	
Use switch key to arm GPS and arm the “L” switch on ground systems and wait for screen to display sync message.	Before arming 3rd switch. Make sure display of ground systems is connected. If no sync message reference trouble shooting checklist.	

Do nothing to the 4th switch.		
Turn on camera by pressing power button and wait for a solid amber color. Then press video button and wait for blinking amber button.		
Insert ignitor into the launch vehicle and check for continuity.	Ensure that the igniter is inserted up the motor until it reaches a dead-end and then pull back about 1-2 in. Failed or delayed ignition possible.	
Use the manufacturer cap to secure the E-match cord to the motor retainer.	Conduct final check to ensure security of E-match. Possible tape bottom of the e-match cord to the cap to ensure it stays on if loose.	
Ensure igniter wires attached to power source.		
Arrange wires carefully to ensure continued attachment to igniter throughout launch sequence.		
Ensure ignitor power switch is on at launch control.		
Ensure all personnel are at safe standoff distance.		
Ensure ignitor power switch is on at launch control.		

Monitor drift and locate launch vehicle after flight.	Ensure launch vehicle is recovered in a timely manner.	
Measure drift from launch pad.		
Deactivate all altimeters.		
Recover launch vehicle.		
Deactivate all electronics.		

4.2.3.7 POST FLIGHT INSPECTION CHECKLIST

Post-flight inspection checklist.

Task	SO Verification
Warning: Be aware that undeployed charges may be present. Deactivate all altimeters prior to post-flight inspection. PPE Required: Eye protection, gloves.	
Check altimeter black powder charges for undeployed charges and carefully dispose of unused black powder	
Remove all e-matches from altimeter bays.	
Wipe down bulkheads. Remove PVC and remove electrical tape from inside of bulkhead. If PVC was lost then cut and replace it. Wipe down inside of altimeter bays.	
Inspect fins for damage and security.	
Inspect rocket body for dents, cracks, or missing parts.	
Inspect parachutes for holes and parachutes cords for abrasions or tears.	

Rinse off parachutes and Nomex and hang to dry if necessary.	
Inspect shock cords for abrasion or tearing.	
Wipe down all shock cord with paper towels.	
Clean all components of debris and carbon residue.	
Check batteries with voltmeter.	
Remove motor from motor casing after it has cooled long enough to be handled but before completely cooled.	
Disassemble motor casing after it has cooled long enough to be handled but before completely cooled. Take out forward closure, forward seal disk and retaining rings and set aside for cleaning.	
Remove delay grain liner from forward closure and all O-rings. Dispose of linear and any remaining unusable parts of the motor.	
Place components except for motor casing tube into soapy water to remove carbon residue.	
After soaking, clean components with neutral cleaner, dry and reassemble.	
Check altimeters for damage.	
Download and analyze data from altimeters.	

5 PAYLOAD CRITERIA

Our rover payload has been officially named *'Nautilus'*, and will be referred to as such throughout further documentation.

5.1 PAYLOAD DESIGN

5.1.1 CHANGES SINCE CDR

Since the CDR, refinements have been made to the set up of the vacuum collection system to increase internal volume. Additionally, a separate area was created to house the Arduino control board, relays, and motor control board. This will provide protection for the electronics from dust created by the vacuum system, as well as allow access for troubleshooting electrical issues without taking the rover apart. A vertical wall was added to the inside of the rover body to provide increased support and to decrease the spread of dust inside the rover body.

5.1.1.1 STRUCTURAL ELEMENTS

5.1.1.1.1 MAIN BODY

To allow for increased clearance while driving across rough terrain, the rover body is a cylinder with a flatten side facing the ground. The body is shaped to maximize internal space for the batteries and vacuum collection system. A section of the upper rover body is removable to allow for convenient access to rover internals, and a sealed compartment on the bottom of the rover contains the Arduino, motor driver board, and relay for the vacuum system. The rover is constructed from 3D-printed PLA.

5.1.1.1.2 WHEELS

The rover wheels are optimized to gain traction in rough and uneven terrains. The wheel treads are printed from PLA and feature a cutout in the tread to allow the rover to clear the leveling system nut. The wheels are bolted to a metal hub that slides over the axle of the drive motor. A set screw locks the hub to the axle and is accessed by a hole in the tread of the wheel.

5.1.1.1.3 VACUUM SYSTEM

The soil collection system is constructed from components of a portable hand vacuum, with the addition of a large, sealed collection bin 3d printed into the bottom of the upper rover body. Filters are used to prevent soil from reaching the vacuum impeller, and a valve on the inside of the collection bin will be designed to automatically close when suction is removed. A 3d printed coupling connects the motor for the vacuum system to the collection box. The intake hole is mounted on the top of the rover body; therefore, the rover must flip over to engage the soil collection mode. This allows the hole to be placed as close to the soil as possible when running, while still allowing for significant under-body clearance when not in use.

5.1.1.1.4 STABILIZING LEG

A collapsible stabilization arm will prevent the rover from rotating when in motion. The arm is spring loaded, so that it can be collapsed to fit inside the airframe and then automatically deployed mechanically upon exiting the launch vehicle. The stabilization arm is made from an off-the-shelf steel gate hinge available from local hardware stores that has been cut down to reduce weight.

5.1.1.2 ELECTRICAL ELEMENTS

5.1.1.2.1 ELECTRICAL DIAGRAM OVERVIEW

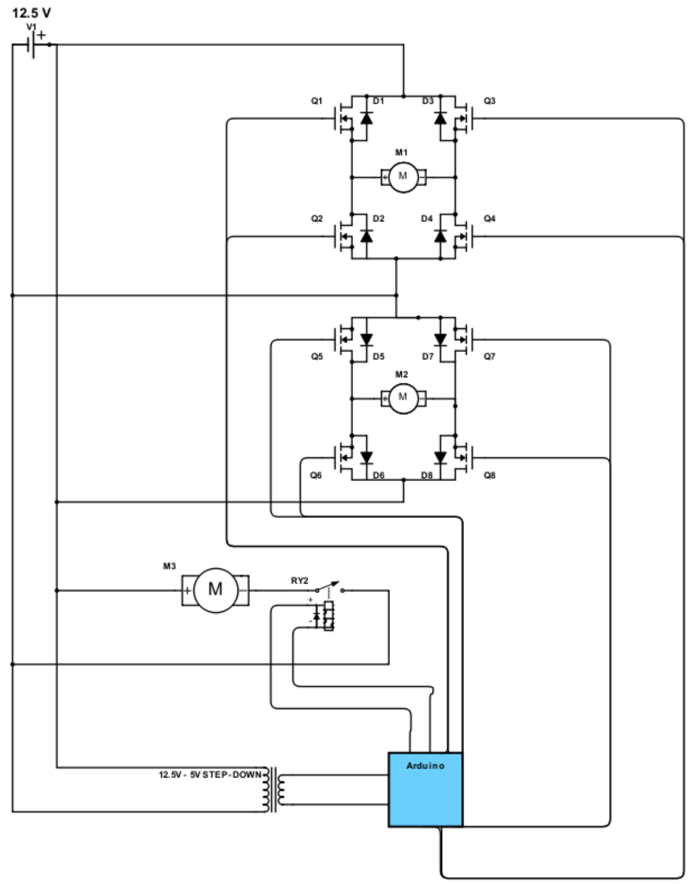


Figure 40:Driving and Vacuum System

The driving system for the payload utilizes two DRV8871 3.6-A Brushed DC Motor Drivers which function using four N channels MOSFETs and 4 catch diodes per motor driver. This configuration is known as an H-bridge and by following the truth table below, the current path will switch between entering the positive terminal and negative terminals of the motor.

Table 34:Motor driver logic table

Input 1: Q1 & Q2 or Q5 & Q6	Input 2: Q3 &Q4 or Q7 & Q8	Motor Terminal (+)	Motor Terminal (-)	Function
0	0	H-brdge disabled (current flows through catch diodes)		Coast in present direction
0	1	Low	High	Reverse
1	0	High	Low	Forward

1	1	Low	Low	Brake

Two dc motors are used for the payload and by using the motor drivers, the motors become bidirectional through programming an Arduino to send low voltage high and low signals. Therefore our payload has turning capabilities for steering.

The vacuum system consist of a dc motor and a relay. The relay used is a normally open connection; therefore, upon receiving a signal high signal from an Arduino, the circuit will be completed and the motor will turn on. The vacuum motor is unidirectional since the positive and negative terminals are fixed. This decision was made because this motor only needs to create a pressure difference to pull dirt into the rover's soil container for selection. The relay can handle up to 10 A of current and by using a relay, the vacuum can draw much more current than what was possible with the motor drivers used in the driving system. By allowing up to 10 A of current, a much more powerful more can be used, which allows for collection of more dense soils. The relay receives its low voltage power from the ground and Vcc connections on the Arduino.

5.1.1.2.2 MOTOR

Four dc motors are being used between the driving of the payload, the vacuum system and the deployment system. The driving system is using two Greartisan DC 12V 300RPM Gear Motors. These motors allow for high torque, so it is easier to overcome obstacles. By increasing the torque the speed at which the motors rotate the wheels decreases. This design is desirable to allow for smoother acceleration and braking. Additionally, the slower rotation design prevents unnecessary skidding caused by spinning the wheels too fast.

The vacuum system motor is of unknown brand and specifications because it was salvaged from an old vacuum. However, tests have been conducted to ensure that the motor can be used safely. At 12.5 V DC, the free current or current draw when no load is present on the motor is approximately 2.5A . The motor was stalled using clamps and was found to be on average 5 A. To ensure safety, while conducting the test, DC power supplies with fuses were used, so that if there was too much current draw, the fuses would burn and open the circuit. To handle the high current draw of this motor a relay that can handle up to 10 A of current is being used for switching the vacuum motor on and off. This powerful motor is being used to account for the clay-like soil collection, of which can be present in Huntsville, Alabama.

The Greartisan DC 12V 300RPM Gear Motor is also being used for the deployment system. The high torque of this motor allows for the deployment system to pull the payload out of the vehicle with ease. A relay is used for this system, not because of high current draw, rather because it only need to be unidirectional

5.1.1.2.3 BATTERIES

The deployment system and the payload will both be powered by their own 12.5 V lithium ion battery with a 1300 mAh capacity. The batteries have been tested with all the components together and are able to sit idle for at least 4 hours. The Greartisan DC 12V 300RPM Gear Motor was tested for 30 minutes while connected to the battery and a 0.3 V drop in the voltage supplied to the motor was observed. The batteries are also capable of sourcing enough current to the vacuum motor.

5.1.1.2.4 SENSORS

Accelerometer - Sensor primarily for detection of payload orientation and can determine whether the rover must be reorientated. The accelerometer will also be used as a failsafe if the payload encounters stoppage during the mission and requires attempts to dislodge it.

5.1.1.2.5 CALCULATIONS

5.1.1.2.6 MICROCONTROLLERS

Arduino Uno - microcontroller board based on the ATmega328P. Used to control all aspects of the payload including receiving the start signal, movement, and collection system.

Xbee-PRO 900HP Modules - Used for long range RF communication from a remote location to signal the start of deployment and start of the autonomous rover functions.

Table 35: Summary of Electronics

Specification	Value
Ideal RF line-of-site range	10 kb/s: up to 9 miles 200 kb/s: up to 4 miles (with 2.1dB dipole antennas)
Operating frequency band	902 to 928 MHz
Transmit power output	24dBm
RF data rate (high)	200 kb/s
RF data rate (low)	10 kb/s
Serial interface data rate	9600 - 230400 baud
Supply voltage	2.1 to 3.6 VDC
Transmit current	60 to 215 mA
Idle/receive current	29 mA at 3.3V
Sleep current	2.5 µA

7. CODE FLOW CHART

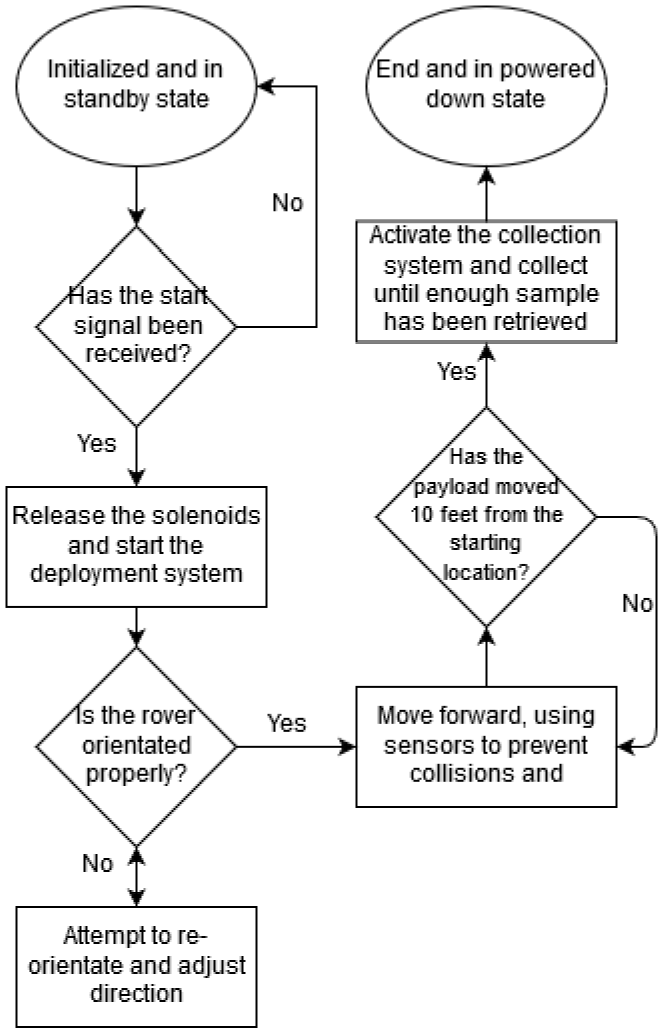


Figure 41: Code Flow chart

5.1.1.3 FLIGHT RELIABILITY CONFIDENCE

After multiple retention test we are confident the rover will be able to stay retained throughout the flight. So far the payload has been launched twice, during the first time it experienced some water damage and during the second it got a crack in its body frame (unknown if due to flight, recovery, or post launch inspection) which was already set to be re-printed anyway.

5.1.1.4 PAYLOAD CONSTRUCTION

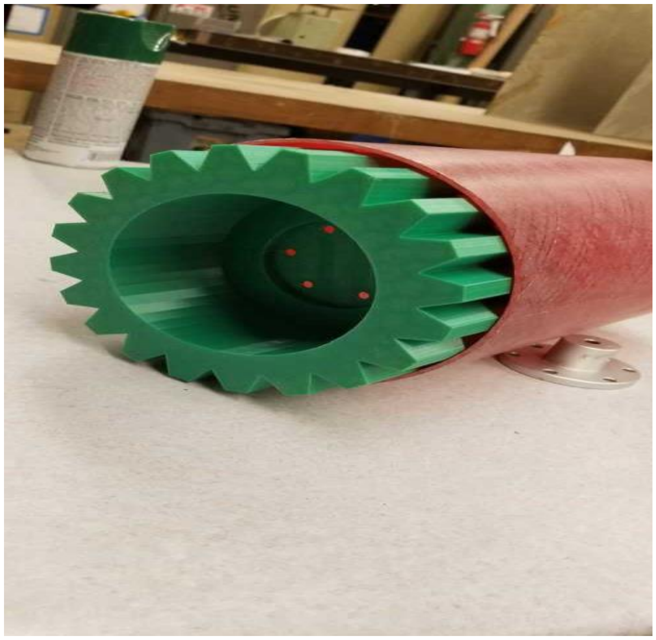


Figure 42:Test fitting our old wheel design in our 6" airframe, wheel is 3D printed PLA.

Figure 43:Comparison of old (right) versus new (left) wheel design, saving 3" from payload length

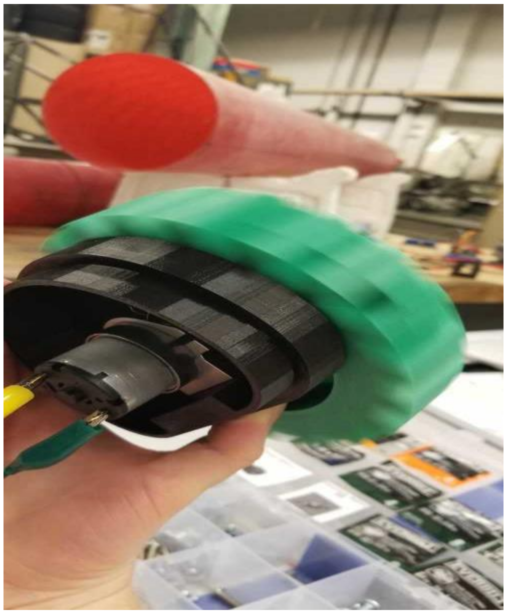


Figure 44: Test fit of the side connector with a wheel, in motion

Figure 45:Construction of a Nautilus prototype, before the mounting of the second wheel

Figure 46:Taken prior to the Feb Full Scale Launch, during drive test

5.1.1.5 PAYLOAD SCHEMATICS

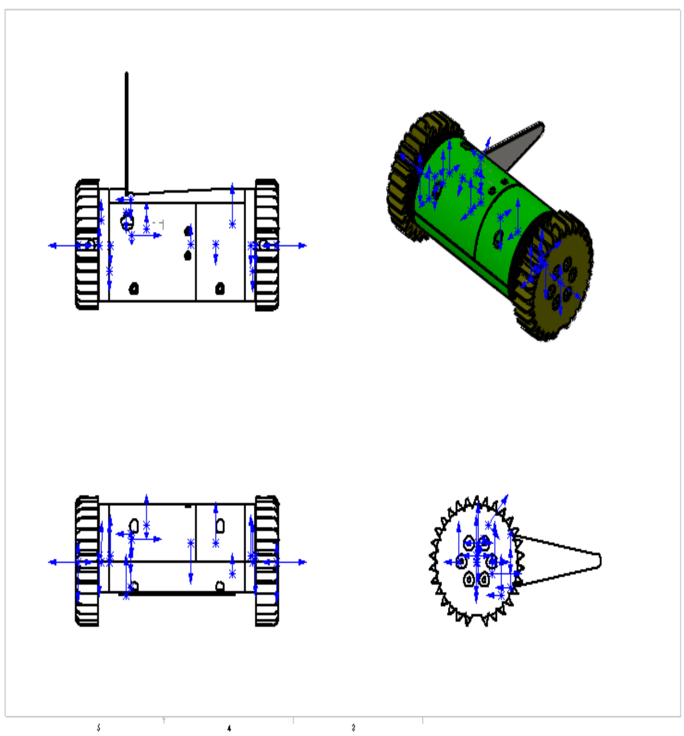


Figure 47:Overview of the entire assembly of Nautilus

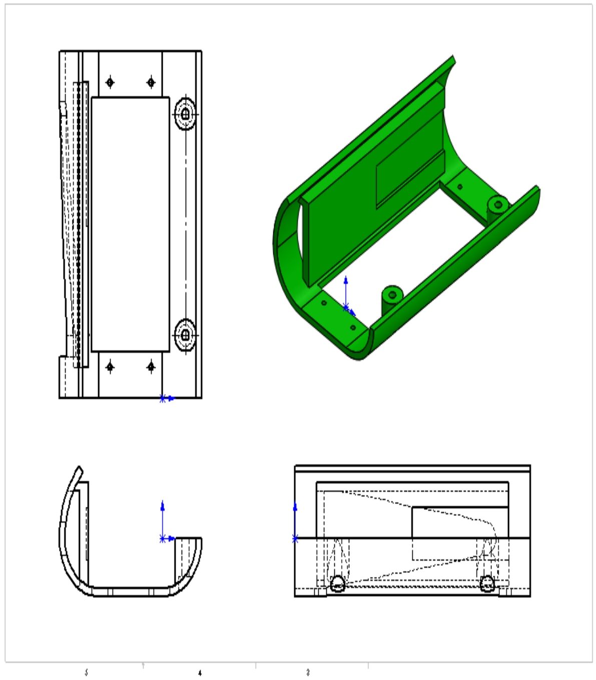


Figure 48: Lower Section of Main Body, includes space for electronics and stabilizing leg

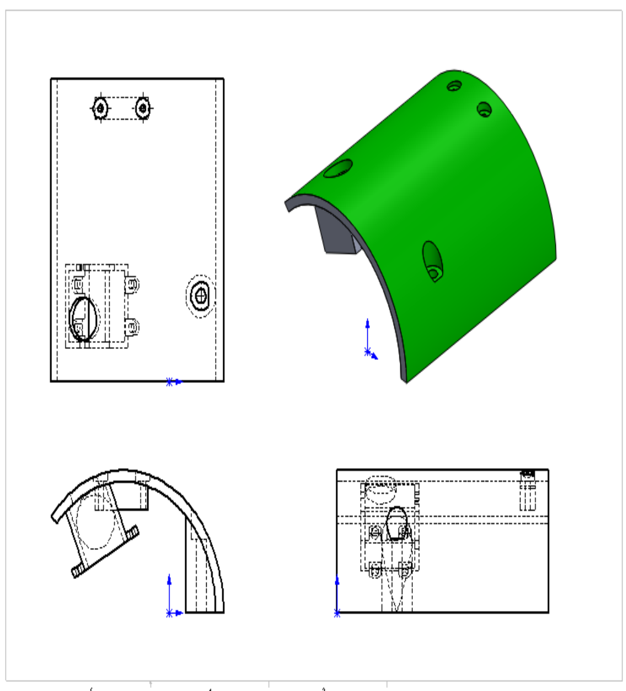


Figure 49: One of the upper Sections of Main Body, includes soil collection chamber and vacuum mount

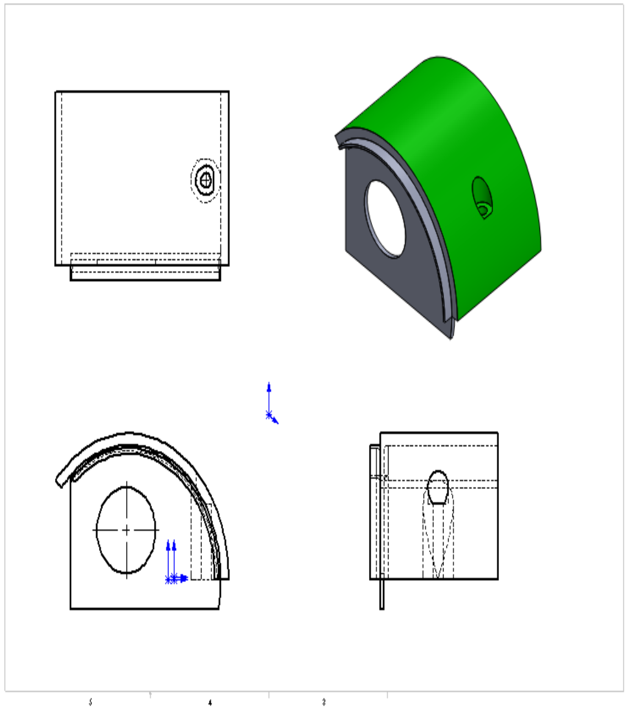


Figure 50: The other section of the upper Main Body, includes wall to seperate electronics from vacuum system

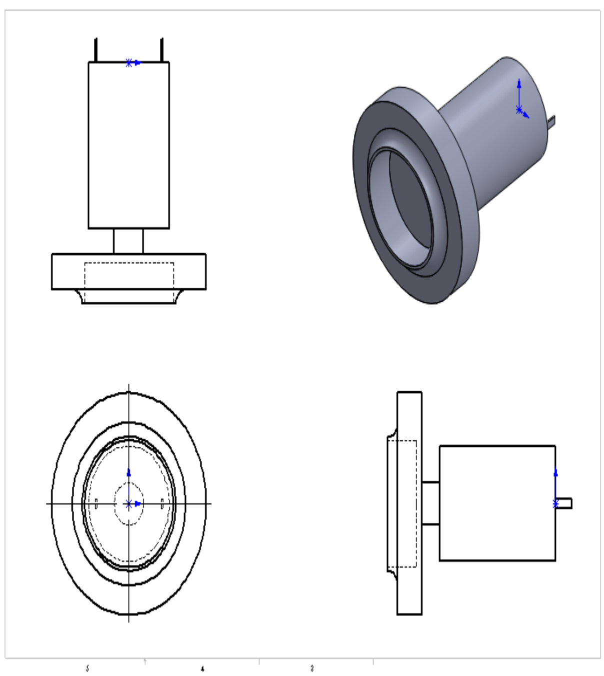


Figure 51:Rendering of vacuum motor with impeller attached

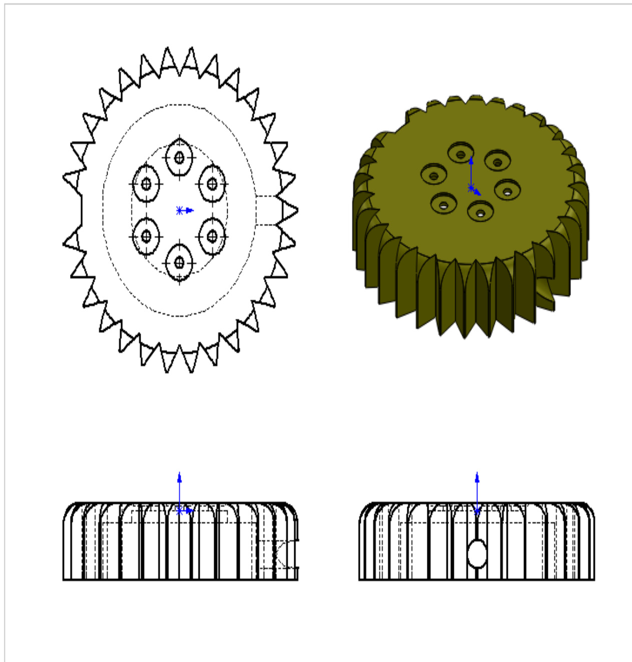


Figure 52: Wheel, edited with a set screw hole, mounting holes, and gap to avoid PDLS mounting nut on deployment

5.1.1.6 DISCREPANCIES

The current Nautilus design has changed on an almost weekly basis for several months. Some of the small changes include a electronics compartment in the base of the body to isolate the electronics, a wall has been added to compartmentalize the internal space, further separating all electronic components from the vacuum impeller. Wheel tread has been changed after ground test showed earlier models experiences slippage over rough terrain.

5.1.1.7 PAYLOAD DEMONSTRATION FLIGHT

5.1.1.7.1 FLIGHT INFORMATION

Two payload retention flights have been conducted, one on February 23rd 2019 and one on March 3rd 2019. Both flights were conducted under the same motor we will be using on launch day and with the same payload (some 3D printed parts may be replaced but they are the exact same design). The launches were at our launch site in Plant City Florida at Varn Ranch.

5.1.1.7.2 SUCCESS CRITERIA

A successful flight would consist of a successful launch in which the following conditions are met:

1) *(Absolute minimum for a successful payload demonstration flight):* retention system securely retains itself and Nautilus throughout the flight, with no risk of the payload becoming unlatched during any part of the flight.
2) (Prefered conditions to be met in order to prepare for the competition in April)

3) Recover upper airframe successfully and run through complete deployment system, completed when Nautilus has cleared body and is ready to complete her mission.
4) Nautilus is able to travel under her own power at least 10 feet from the vehicle, turn over, and power vacuum to collect at least 10 mL of soil.

5.1.1.7.3 FLIGHT RESULTS

Nautilus was successfully retained during both flights. During the first flight the the upper airframe landed in a small pond leaving us unable to test deployment and having to replace all electronics. Due to having to re-order parts and configure the electronics we were also unable to conduct this test on the March 3rd Launch.

5.1.1.7.4 PAYLOAD RETENTION PERFORMANCE

Payload retention performed perfectly, with solenoids remaining extended throughout the launch and recovery as shown in the pictures below. The hook that connected the payload to the deployment system (shown in deployment system construction) remained anchored as designed in addition.

Figure 53: Nosecone and Upper Airframe in the pond before retrieval

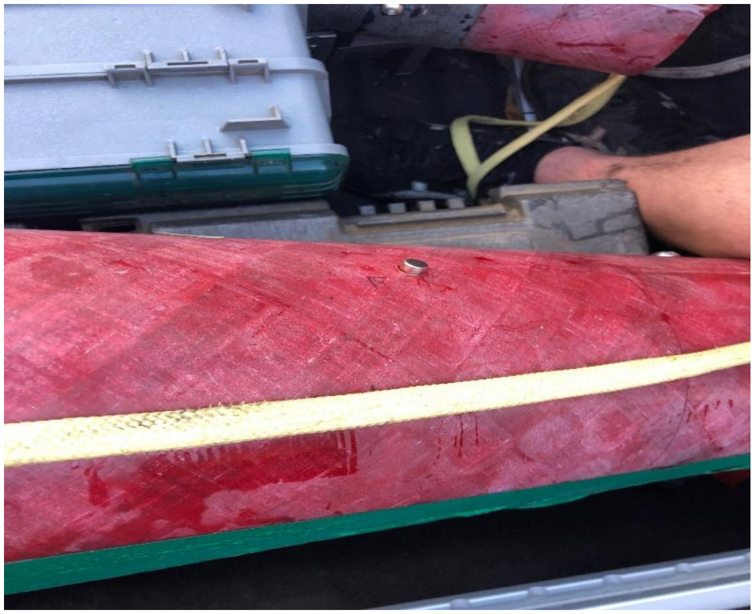


Figure 54:The Solenoid stayed in the locked position securing the deployment system and Nautilus after flight 1

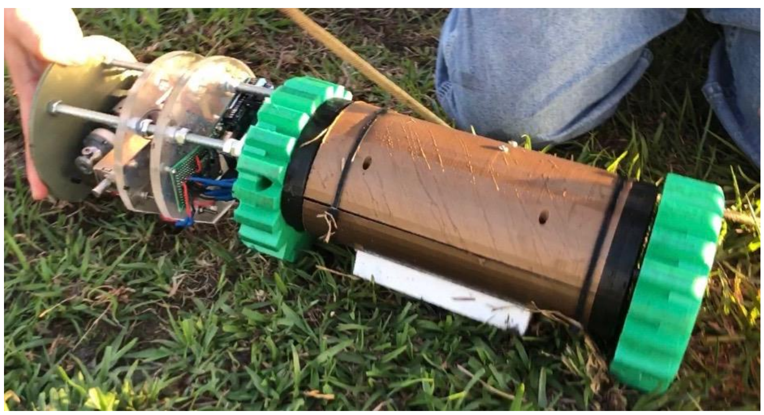


Figure 55: Nautilus and the deployment system after removing them from the Upper Airframe after the water rescue (note the water on the body of Nautilus)

Figure 56: Successful retention of Nautilus and the deployment system after the second test flight.

5.2 PAYLOAD DEPLOYMENT SYSTEM DESIGN

5.2.1 CHANGES SINCE CDR

Since the CDR, the paylost retention system has taken on a different design than previously planned. The current system now consists of three acrylic bulkheads held together by threaded rods, with a winch motor, solenoids, and electronics mounted to their own plate. Instead of complete modeling several pieces to be 3D printed like previous years, we made a decision to build the system out of laser-cut acrylic plates.

5.2.2 STRUCTURAL ELEMENTS

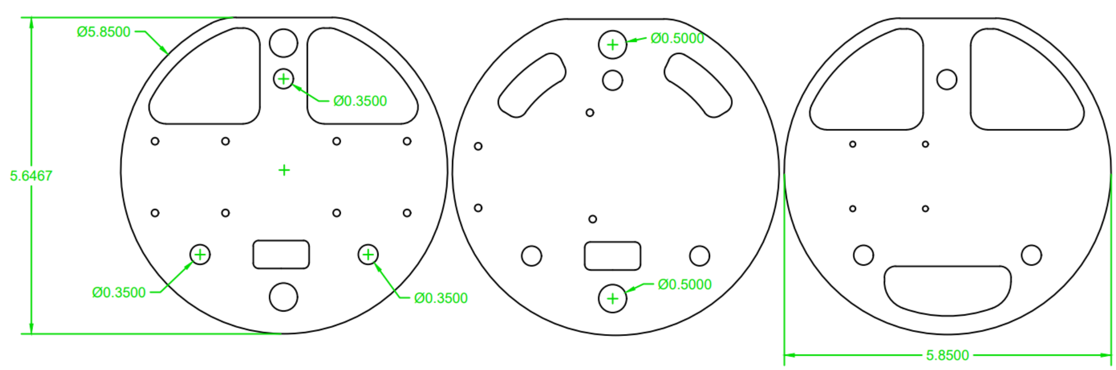


Figure 57: Deployment System Laser Cut Plates Diagram

5.2.3 ELECTRICAL ELEMENTS

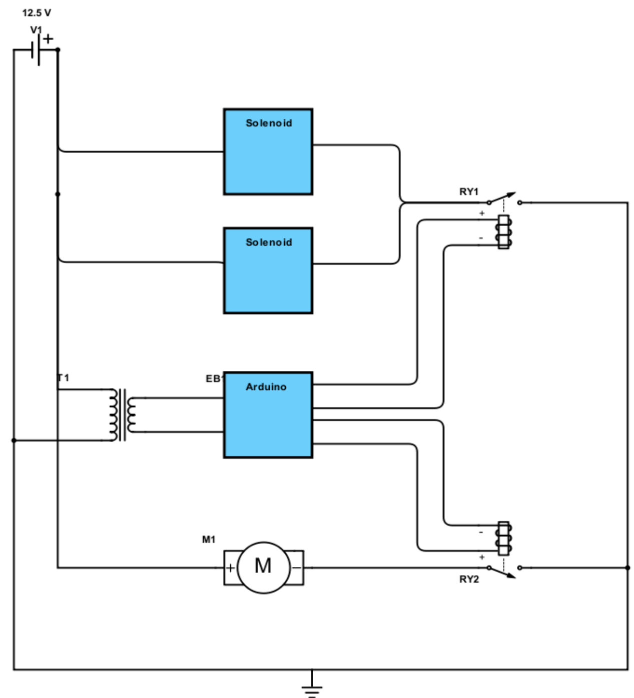


Figure 58: Deployment System Electrical Diagram

The deployment system consists of two solenoids, two relays, and a dc motor. Controlling the deployment system is an Arduino, which will be powered by the same lithium ion battery powering the motors and solenoids. The rated voltage for the arduino is 12 V, so a variable DC to DC converter is being used to step down the voltage being supplied to the Arduino to 5 V.

The deployment system has been designed as a redundant system that will keep the payload secured in the rocket even the system malfunctions. The default state of the solenoids are fully extended and the pins of the solenoids will retract only when current passes through the internal coils to generate a magnetic field. At the instant the solenoids retract, the dc motor begins to pull the rover out of the vehicle through a which system. The fail-safe of this system has already been successfully utilized when the payload was retained in the vehicle body throughout a launch and landing in a lake on 2/23/19 at Varn Ranch.

The deployment process will be initiated wirelessly using Arduino compatible Digi Xbee's which all for RF communication. The final rover will utilize wireless communication at 900 MHz. The wireless signal will allow for the Arduino to send low voltage signals to the normally open relays that will then close upon receiving the proper signal.

5.2.4 CONSTRUCTION

Figure 59: Deployment System Construction, featuring three plates (two acrylic, one fiberglass in this prototype) and assorted equipment mounted.)

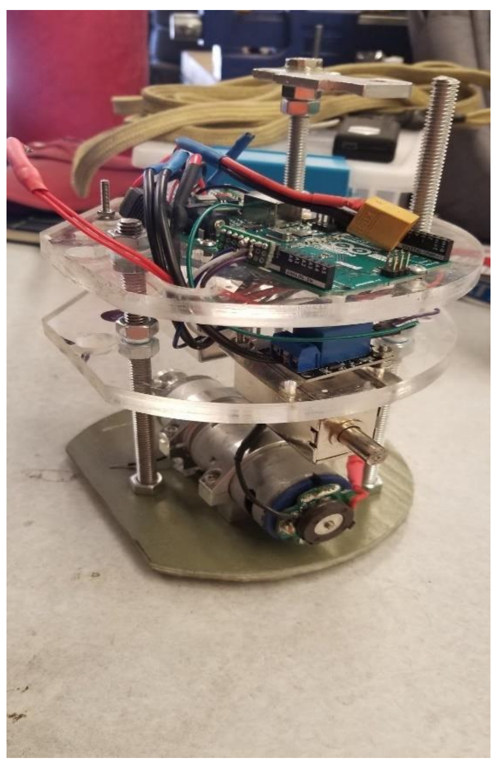


Figure 60: Deployment System

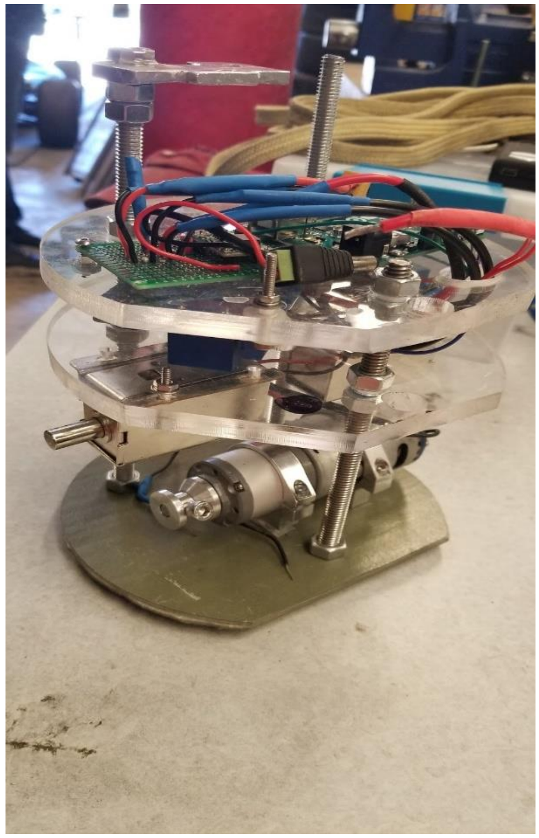


Figure 61: Deployment System Side Angle

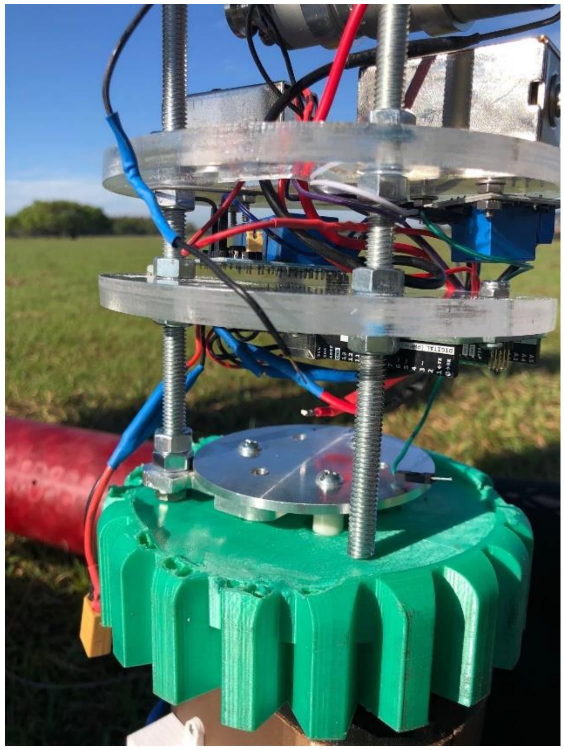


Figure 62: Deployment system attached to rover before flight

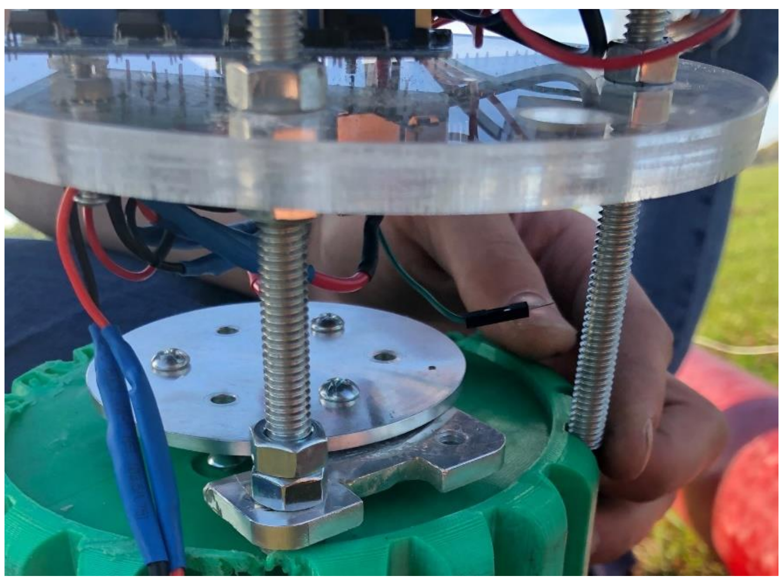


Figure 63: Attachment is made by a sliding a hooked piece mechanism underneath the wheel cap which is bolted to the rover.

6 PROJECT PLAN

6.1 TESTING

Prove that all testing is complete and provide test methodology and discussion of results. Discuss whether each test was successful or not. Discuss lessons learned from the tests conducted. Discuss any differences between predicted and actual results of the tests conducted.

6.1.1 VEHICLE TESTS

6.1.1.1 FULL SCALE FLIGHT TEST

REFERENCE: Vehicle Demonstration Flight

6.1.1.2 FULL SCALE PARACHUTE GROUND TEST

6.1.1.2.1 TEST OBJECTIVE

The objective of this test is to determine the amount of black powder is necessary to eject the components out of the airframe. There are 3 parachutes that need black powder charges in order separate and deploy the parachutes at their projected altitudes. The drogue parachute which is attached to shock cord that is attached to a U-bolt on booster section and the lower end of the main altimeter bay. The Lower Section Main parachute which is attached to a U-bolt on the upper end of main altimeter bay. The Upper Section Main parachute which is attached to shockcord that is attached to nosecone U-bolt and payload altimeter bay U-bolt. This will be done through demonstration.

6.1.1.2.2 TESTED ITEMS

- Quantity of black powder used in order to separate the main altimeter bay and booster section to deploy the drogue parachute
- Quantity of black powder used in order to separate the main altimeter bay and the payload section to deploy the Lower Section Main parachute
- Quantity of black powder used in order to separate the nosecone and payload section to deploy the Upper Section Main parachute all need various different quantities of black powder

6.1.1.2.3 MOTIVATIONS

- To ensure the correct amount of black powder to properly separate the vehicle sections so the parachutes will deploy and does not damage any vehicle components
- To ensure no vehicle component falls ballistically
- To ensure a decreased chance of any of the vehicle components breaking on landing
- To ensure nearby personnel's safety is not endanger by ballistic vehicle components
- The success of this test will verify that the amount of black powder used will be sufficient in deploying the drogue parachute
- The failure of this test will cause for the vehicle team to increase the quantity of black powder used for deployment until a sufficient but safe amount is used.

6.1.1.2.4 SUCCESS CRITERIA

Table 36: VT1 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results
VT1	Ground tests to determine if the amounts of black powder is sufficient to separate the two sections and deploy the parachute	Pass: The complete separation of each section and deployment of the parachute without any damage to the components being tested. Fail: If pass criteria is not met or if the vehicle body or parachute is damaged in this test the test is a failure and the construction and materials used with have to be reviewed and replaced or less black powder needs to be used	Completed February 23, 2018.

6.1.1.2.5 TESTING PROCEDURES

6.1.1.2.5.1 EQUIPMENT

The equipment needed for this is a rocket stand, the vehicle, black powder, 1 gram scoop, e-matches, cellulose insulin, wire, 9V battery, wire cutters, electrical tape, blue tape, voltmeter, skrewdriver and shear pins.

6.1.1.2.5.2 SETUP

The section being tested will be placed onto a stand at an angle with the end that it to be propelled forward raised. Weight will be placed behind the stand in order to secure the stand. All e-matches are to be tested for continuity beforehand.

6.1.1.2.5.3 SAFETY NOTES

- Proper PPE is to be used when handling black powder
- No personnel should be standing in front or behind the rocket as the test is being conducted so they do not end up getting hit by one of the sections
- No personnel are to be within 10 feet of the vehicle when the test as the test is being conducted
- There is to be a minimum of 10 feet of wire between the vehicle body and the battery that will discharge the black powder
- The battery cannot be in any contact with the e-match or connecting wire until all personnel are at a safe distance away and the test is about to be conducted
- All electrical components are to be kept away from the e-match once the black powder is loaded into the section

6.1.1.2.5.4 PROCEDURE

1. Prepare sections about to be tested. Fold and load parachute in nomex and then place the wrapped parachute and shock cord into section.

2. Place an e-match into the black powder cap and run the wire through to the opposite side of the altimeter bay. Separate the end of the e-match wire and strip it of 1 inch of insulation. Cut at least 10 feet of wire, separate the 2 sides at least 6 inches from each other and strip both ends of 1 inch of insulation. Connect the e-match to the 10 feet long wire by entwining the bare wire. Wrap the entwined exposed wire in electrical tape so it is insulated.
3. Load black powder and then cellulose insulation into the black powder cap. Use blue tape to secure the top of the cap so no insulation or black powder is able to spill out.
4. Join the two sections being tested and place them onto the stand with the end that is to be expelled forward raised. Make sure any sections that need to be covered or taped over are covered or tapped over. Secure sections with shear pins.
5. Ensure all participants are at least 10 feet away.
6. Touch one wire to the battery's positive end and then touch the other wire to the battery's negative end.
7. Survey section to determine success or failure as well as for any damage.
8. If the test is a failure repeat the procedure with more black powder until enough black powder is used to successfully separate the two sections and deploy the parachute.

6.1.1.2.6 RESULTS

All fullscale ground tests was successfully completed January 23rd, 2018. This will allow for the vehicle team to confirm the design of the rocket and be certain no section will become ballistic.

The test plan for the drogue parachute was to place an e-match through the altimeter bay and have 10ft of wire extending out and have 3.5 grams of black powder ignite when the ends of the the e-match were touched to a battery. For the Upper Section Main Parachute was to place an e-match through the payload altimeter bay and have 10ft of wire extending out and have 2 grams of black powder ignite when the ends of the the e-match were touched to a battery. For the Lower Section Main Parachute was to place an e-match through the altimeter bay connecting to the payload section and have 10ft of wire extending out and have 2.5 grams of black powder ignite when the ends of the the e-match were touched to a battery. The result of these tests confirmed that 2.5 grams of black powder is sufficient to separate the altimeter bay from the booster section and deploy the drogue parachute, 2 grams of black powder is sufficient to separate the nosecone from the payload section and deploy the upper section main parachute and 3.5 grams of black powder is sufficient to separate the altimeter bay from the payload section and deploy the lower section. This will allow for the vehicle team to confirm the design of the rocket and be certain this section will not become ballistic.

Figure 64: Ground testing for Nosecone section

Figure 65: Ground testing for Upper Airframe

Figure 66: Ground testing for Booster Section

6.1.1.3 FULLSCALE TENDER DESCENDER STRESS TEST

6.1.1.3.1 TEST OBJECTIVE

The objective of this test is to determine the durability of the tender descender and determine if it will remains intact after launch. This will be done through demonstration.

6.1.1.4 TESTED ITEMS

- The tender descender

6.1.1.4.1 MOTIVATIONS

- To ensure the durability of the tender descender
- To ensure the Payload Descent Leveling Subsystem does not fail
- To ensure no debris blocks the exit of the payload section
- To ensure the payload is able to exit the payload section
- The success of this test will verify that the tender descender will level the rocket so that when the vehicle lands the end where the payload will exit the body is free of any debris
- The failure of this test will cause the vehicle team to look at a different tender descender that can withstand more impact or another design for the PDLS

6.1.1.4.2 SUCCESS CRITERIA

Figure 67: VT2 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results
VT2	The tender descender will be launched in the vehicle and activated	Pass: The tender descender will have no cracks or damage to it after launch Fail: If the pass criteria is not met	Completed February 23th, 2019 and March 3rd, 2019.

6.1.1.4.3 TESTING PROCEDURES

6.1.1.4.3.1 EQUIPMENT

The equipment needed for this the full assembled vehicle with the PDLS in place, rail rod and the vehicle motor.

6.1.1.4.3.2 SETUP

The vehicle will be full assembled and prepared to launch.

6.1.1.4.3.3 SAFETY NOTES

- If the tender descender were to break in the launch it would create NO new safety concerns so long as the parachutes are deployed.
- Wear proper PPE when handling the black powder and motor before launch

- Ensure all systems are NOT armed when placing vehicle on launch pad
- Ensure all personnel are a safe distance away from the launch pad when systems are armed and the vehicle is launched
- Ensure all parachutes are properly folded and attached
- Ensure SO does a safety check before launch

6.1.1.4.4 PROCEDURE

1. Prepare the vehicle for launch.
2. Launch the Vehicle
3. Examine tender descender on landing.

6.1.1.4.5 RESULTS

The tender descender stress test was competed February 23rd, 2019 and March 3rd, 2019. The tender descender remain intact and unbroken after the launch. This confirmed the integrity of the main component of the current leveling system.

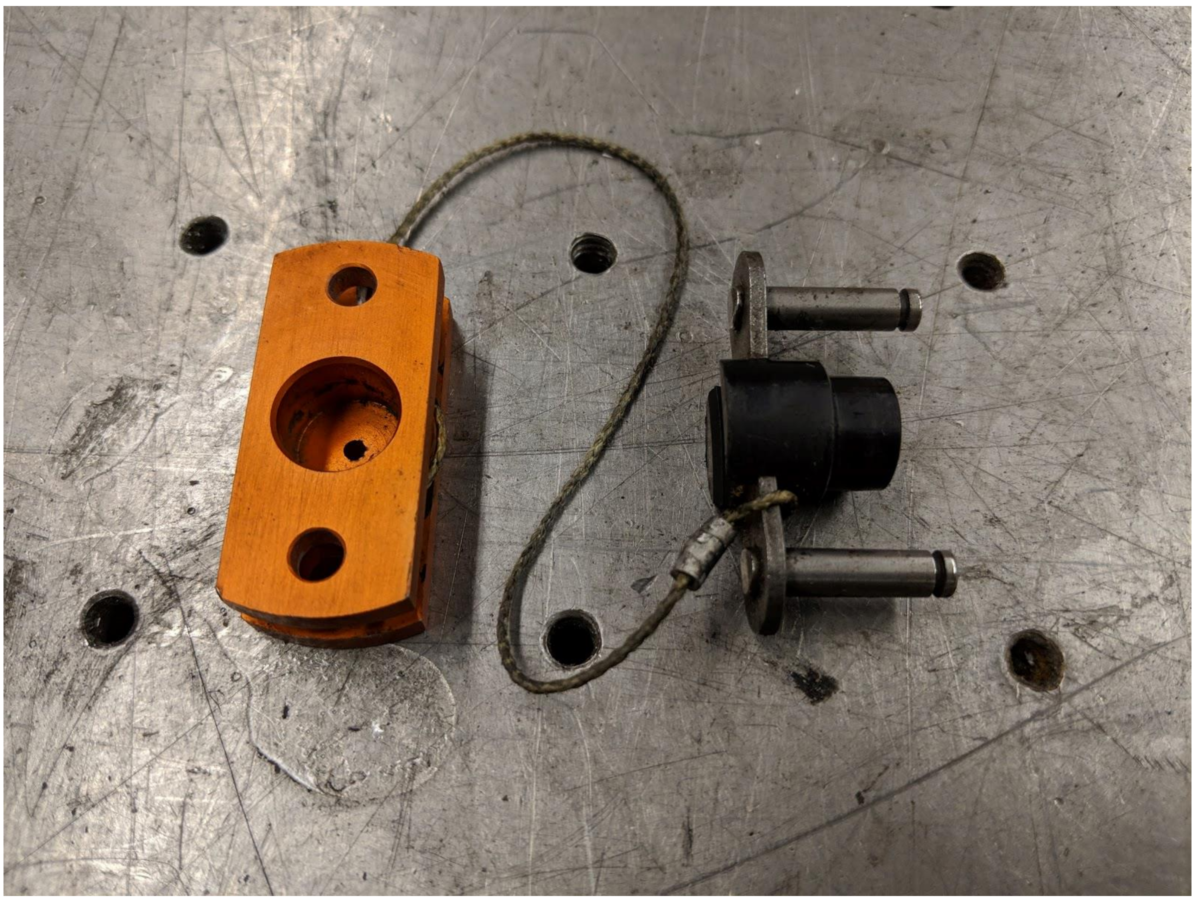


Figure 68: Tender Descender after Launch

6.1.1.5 FULL SCALE PDLS TEST

6.1.1.6 TEST OBJECTIVE

The objective of this test is to determine whether the PDLS will lower the rocket so that the payload exit is clear of debris that might impede the payload from leaving the vehicle. This will be done through demonstration.

6.1.1.7 TESTED ITEMS

- The angle at which the PDLS lowers the payload section so the the payload exit is above 0 degrees from the horizontal and has minimal risk of landing before end attached to the upper section main parachute.
- The amount of debris covering the payload exit

6.1.1.7.1 MOTIVATIONS

- To ensure there don't need to be adjustments in the cord used, the length of the cords used, or if a different design needs to be implemented
- The success of this test will verify the effectiveness in the current PDLS design
- The failure of this test will result in the design of the PDLS to be altered so that the payload exit is free of debris

6.1.1.7.2 SUCCESS CRITERIA

Figure 69: VT3 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results
VT3	The PDLS will be launched in the vehicle and activated	Pass: Upon landing the payload exit will be clear and free of all debris Fail: If the pass criteria is not met	Completed February 23th, 2019 and March 3rd, 2019.

6.1.1.7.3 TESTING PROCEDURES

6.1.1.7.3.1 EQUIPMENT

The equipment needed for this is the full assembled vehicle with the PDLS in place and masking tape.

6.1.1.7.3.2 SETUP

Prepare the vehicle for launch with the PDLS secured and in place. Ensure all wires are safely secured and fastened.

6.1.1.7.3.3 SAFETY NOTES

- Wear proper PPE when handling the black powder and motor before launch
- Ensure all systems are NOT armed when placing vehicle on launch pad
- Ensure all personnel are a safe distance away from the launch pad when systems are armed and the vehicle is launched
- Ensure all parachutes are properly folded and attached
- Ensure SO does a safety check before launch

6.1.1.7.3.4 PROCEDURE

1. Prepare the vehicle for launch.
2. Launch the Vehicle
3. Examine payload section exit upon landing.

6.1.1.7.4 RESULTS

The payload descent leveling subsystem test was competed February 23th, 2019 and March 3rd, 2019. The test was a success and the payload exit was free of any debris. This confirmed that the PDLS will allow for the payload exit to be free of debris and the likelihood of the payload successfully leaving the vehicle body is significantly increased.

6.1.1.8 SOLENOID RETENTION LAUNCH TEST

6.1.1.8.1 TEST OBJECTIVE

The objective of this test is to ensure the retention of the payload within the vehicle body during launch and while airborne. This will be done through demonstration.

6.1.1.8.2 TESTED ITEMS

- The 2x push/pull solenoids (3mm diameter rod)
- The remote signal which will activate the solenoids

6.1.1.8.3 MOTIVATIONS

- To ensure the rover will be retained within the vehicle utilizing a fail-safe active retention system
- To ensure that the retention system is durable enough to retain the rover
- The success of this test will ensure the payload does not go ballistic
- The failure of this test will mean that the solenoids were not robust enough and will have to be replaced or there was an error in the wiring, programming or in the remote signal that will need to be resolved.

6.1.1.8.4 SUCCESS CRITERIA

Figure 70: VT4 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results
VT4	The payload will be placed within the vehicle and will be launched with solenoids holding it in place	Pass: The retention of the payload in the vehicle body while airborne Fail: If the pass criteria is not met	Completed February 23th, 2019 and March 3rd, 2019.

6.1.1.8.5 TESTING PROCEDURES

6.1.1.8.5.1 EQUIPMENT

The equipment needed for this is the full assembled vehicle, mock payload, meta hook, pronged extension, 2 x 0.25” threaded rods + lock nuts/washers, 12-volt battery, Insulated wire

6.1.1.8.5.2 SETUP

Prepare the vehicle for launch with the payload in place of the rover. Solder insulated wire to the solenoids and place them in the preplanned spot. Feed the threaded rods through the mock payload. Ensure solenoids are secure.

6.1.1.8.5.3 SAFETY NOTES

- Ensure solenoids are placed in a failsafe position
- A metal clamp placed on one end of the payload is used to prevent the payload from exiting the rocket body prematurely. This is done by securing the entire system the the bulkhead. The fishing line is just long enough to not contribute to the holding force of the retention system of the deployment system but not too long where the mock payload will have enough slack to be partially/fully outside the launch vehicle if the solenoids fail.
- If the payload were to become ballistic, no personnel are to stand around the landing site
- Wear proper PPE when handling the black powder and motor before launch
- Ensure all systems are NOT armed when placing vehicle on launch pad
- Ensure all personnel are a safe distance away from the launch pad when systems are armed and the vehicle is launched
- Ensure all parachutes are properly folded and attached
- Ensure SO does a safety check before launch

6.1.1.8.5.4 PROCEDURE

1. Secure metal clamp to the bulkhead and attatch to the U-bolt and payload.
2. Retract solenoids with battery pack and slide payload through the rocket body.

3. Remove power to solenoids and tug on payload to make sure it is secure.
4. Prepare the vehicle for launch.
5. Launch the Vehicle
6. Examine solenoids upon landing.

6.1.1.8.6 RESULTS

The solenoid retention test was completed on February 23th, 2019 and March 3rd, 2019. Nautilus and the payload retention system were loaded into the upper airframe and solenoids locked into place. Once secure, entire section went through rigorous jerk testing to ensure both the solenoids and attachment hook were flight worthy. This will ensure that the payload stays locked in the vehicle during launch and does not become ballistic.

Figure 71: PDLS Tet during February 23rd, 2019 launch

Figure 72: PDLS Tet during March 3rd, 2019 launch

6.1.1.9 DYNAMIC APOGEE ADJUSTMENT SUBSYSTEM TEST

6.1.1.9.1 TEST OBJECTIVE

The objective of this test is to see how much the DAAS will affect the altitude. If the DAAS deploys but fails to change the altitude then a different design will need to be used. If the DAAS doesn't employ then the component preventing it from fully deploying needs to changed. This will be done through demonstration.

6.1.1.9.2 TESTED ITEMS

- The change in altitude with the deployment of the DAAS

6.1.1.9.3 MOTIVATIONS

- To ensure the integrity of the DAAS and increase the accuracy of the altitude
- The success of this test will verify the necessity of the DAAS and allow for a fullscale version to be constructed
- The failure of this test will mean that the DAAS is not effective in decreasing altitude and that the system is redundant or a component of the DAAS design needs to be modified or fixed

6.1.1.9.4 SUCCESS CRITERIA

Table 37: VT5 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results

VT5	The DAAS will be launched in the vehicle and remain inactive for one flight and in a sequential flight will be activated	• Pass: The DAAS will decrease the the altitude of the vehicle by at least 2 feet. • Fail: If the pass criteria is not met.	Incomplete and Discontinued

6.1.1.9.5 TESTING PROCEDURES

Two launches will we completed on the same day with the same size motor so that launch conditions are as similar as possible. The second launch of the vehicle will occur after the recovery, post launch inspection, vehicle reassembly and safety check. For the first launch the DAAS will not be activated but will remain in the vehicle and for the second launch it will be activated.

6.1.1.9.5.1 EQUIPMENT

The equipment needed for this is the full assembled vehicle with the DAAS in place.

6.1.1.9.5.2 SETUP

Prepare the vehicle for launch with the DAAS secured and in place. Disconnect the DAAS from the batteries for the control flight and reattach them for the test flight.

6.1.1.9.5.3 SAFETY NOTES

- Wear proper PPE when handling the black powder and motor before launch
- Ensure all systems are NOT armed when placing vehicle on launch pad
- Ensure all personnel are a safe distance away from the launch pad when systems are armed and the vehicle is launched
- Ensure all parachutes are properly folded and attached
- Ensure SO does a safety check before launch

6.1.1.9.5.4 PROCEDURE

1. Prepare the vehicle for launch.
2. Launch the Vehicle with the DAAS inactive
3. Upon landing, collect altimeter data
4. Prepare the vehicle for a second launch with the DAAS activated.
5. Launch the Vehicle
6. Upon landing, collect altimeter data

6.1.1.9.6 RESULTS

The vehicle was launched with the DAAS inside but inactive on January 23rd, 2019. There was no launch of the DAAS activated. This test was not completed due to the removal of the DAAS from the overall vehicle design after the February 23rd, 2019 launch. This launch reached an apogee of approximately 3900ft which is significantly under the target apogee. The DAAS added too much weight onto the vehicle and the vehicle was not reaching expected the target altitude. The DAAS is only to slow down the rocket to ensure it does not go too far over the target altitude but since the added weight was causing the vehicle to underperform significantly the DAAS become redundant and detrimental to the success of the vehicle and was removed from the rocket.

6.1.2 PAYLOAD TESTS

6.1.2.1 PAYLOAD WET CONDITIONS TEST

6.1.2.1.1 TEST OBJECTIVE

The objective of this test is to determine which wheels and soil collection method is necessary for the payload to be able to operate in water saturated terrain. This will be done through testing.

6.1.2.1.2 TESTED ITEMS

- Wheel traction
- Motor strength
- Soil collector

6.1.2.1.3 MOTIVATIONS

- To ensure the durability of the payload to withstand different conditions due to unknown launch day terrain conditions and the soil that the payload must traverse may be wet
- The success of this test will verify the choice in wheel type and soil collection method.
- The failure of this test will result notify the payload team as to whether they must change the wheel type and/or the soil collection method.

6.1.2.1.4 SUCCESS CRITERIA

Table 38: PT1 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results
PT1	The payload will drive 10 feet over 5 different saturated terrain conditions and collect 10 ml of soil	Pass: The payload is able to move 10 ft in a water saturated terrain and collect the 10 ml of soil. Fail: If the pass criteria is not met	Completed February 23, 2019

6.1.2.1.5 TESTING PROCEDURES

6.1.2.1.5.1 EQUIPMENT

The equipment needed for this is the payload rover, dirt, water and the laptop which will activate the signal.

6.1.2.1.5.2 SETUP

The payload team will create (or locate) a water saturated terrain.

6.1.2.1.5.3 SAFETY NOTES

- The electronics of the payload must be secured and covered so that no water can get in and short the circuits
- The terrain must not have any deep holes that would submerge more than 20% of the payload
- Ensure all members abstain from drinking the test water
- Ensure acid rain is not used to saturate the terrain

6.1.2.1.5.4 PROCEDURE

1. Place Rover on the ground on water saturated terrain 1
2. Move 10 feet away from the rover.
3. Activate the rover to move at least 10 feet and collect a 10 ml sample of soil
4. Measure distance and soil sample.

6.1.2.1.6 RESULTS

The wet conditions terrain drive tests were successful. The payload was able to move more than 10 feet in a water saturated terrain.

6.1.2.2 PAYLOAD ROUGH TERRAIN TEST

6.1.2.2.1 TEST OBJECTIVE

The objective of this test is to determine which wheels and soil collection method is necessary for the payload to be able to operate in rough terrain. Rough terrain being defined as grassy, coarse, uneven, and bumpy terrain. This will be done through testing.

6.1.2.2.2 TESTED ITEMS

- The type of wheels on the payload
- The type of soil collector

6.1.2.2.3 MOTIVATIONS

- To ensure the payload may deploy in rough terrain
- To ensure the payload is able to traverse the rough terrain.
- The success of this test will verify the choice in wheel type and soil collection method

- The failure of this test will notify the payload team to change the wheel type and/or the soil collection method

6.1.2.2.4 SUCCESS CRITERIA

Table 39: PT2 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results
PT2	The payload will drive 10 feet over 5 different rough terrain conditions and collect 10 ml of soil	Pass: The payload is able to move 10 feet in the rough terrain and collect the 10ml of soil. Fail: If the pass criteria is not met	Completed February 23, 2019

6.1.2.2.5 TESTING PROCEDURES

6.1.2.2.5.1 EQUIPMENT

The equipment needed for this is the payload rover, dirt and and the laptop which will activate the signal.

6.1.2.2.5.2 SETUP

The payload team will create (or locate) 3 different rough terrains each with different levels of difficulty. Assemble rover so it is fully functional. Ensure the batteries on the rover are charged. Ensure the receiver is connected and functional.

6.1.2.2.5.3 SAFETY NOTES

- Ensure all members do NOT eat any of the dirt
- All personnel are to watch their step so as to not trip over the almost 6” tall rover
- It is advised that all members wear gloves before handling any dirt

6.1.2.2.5.4 PROCEDURE

1. Place Rover on the ground on rough terrain 1
2. Move at least 10 feet away from the rover.
3. Activate the rover to move at least 10 feet and collect a 10 ml sample of soil.
4. Repeat steps 1-3 for the next 2 rough terrain fields

6.1.2.2.6 RESULTS

The rough terrain drive tests were successful. The payload was able to move more than 10 feet on the three different terrains. However, the payload moved better on the terrain with less grass than the grassy terrain and would sometimes stall so the team adjusted the wheel shape to compensate. The modified wheels removed the flat faces from the wheels texture so that the wheels have a spiked perimeter and grip the ground better.

Figure 73: Drive test on grass using ground system control, better clearance than grass.

Figure 74: Drive test on grass using ground system control, less clearance as dirt above.

6.1.2.3 PAYLOAD BATTERY TEST

6.1.2.3.1 TEST OBJECTIVE

The objective of this test is to determine how long the battery can last in the payload once it has been turned on. This will be done through demonstration.

6.1.2.3.2 TESTED ITEMS

- The duration of the batteries

6.1.2.3.3 MOTIVATIONS

- To ensure that the batteries will be able to function properly even after extended hours of delay
- The success of this test will verify the batteries chosen are durable and can withstand the necessary time delays.
- The failure of this test will result in the payload team looking into batteries that will last longer.

6.1.2.3.4 SUCCESS CRITERIA

Table 40: PT3 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results
PT3	The batteries will be turned on and after 2 hours of delay the payload will be activated and be able to drive for 20 minutes.	Pass: 1. The batteries will last at least 2 hours after being turned on and kept on standby. 2. The batteries will be able to continuously work for at least 5 minutes while the payload is actively moving around and collecting soil samples. 3. The batteries will not leak more than .001oz of battery acid and will remain intact and undamaged while the rover is on. Fail: If the pass criteria is not met	Completed February 23, 2019.

6.1.2.3.5 TESTING PROCEDURES

6.1.2.3.5.1 EQUIPMENT

The equipment needed for this is the payload rover, voltmeter, timer and the laptop which will activate the signal.

6.1.2.3.5.2 SETUP

Charge or replace all batteries on the payload so that all batteries are fully charged.

6.1.2.3.5.3 SAFETY NOTES

- Ensure appropriate handling of batteries.
- If batteries break, wear gloves before handling and clean up the discharged fluid or oxidation using the appropriate method
- Ensure all personnel do NOT drink battery acid
- Dispose of dead/broken batteries according to US federal guidelines

6.1.2.3.5.4 PROCEDURE

1. Ensure the batteries are full using the voltmeter.
2. Activate the rover so that it is prepared to move whenever the signal is given.
3. Signal the payload to move at least 10 feet over dirt and collect soil samples for at least 5 minutes.
4. Put the payload on standby, set a timer and wait at least 2 hours.
5. Measure the charge left in the batteries.

6.1.2.3.6 RESULTS

At the February launch, a battery test was completed, which consisted of a 20 minute driving test in which Nautilus was remote-controlled all around the launch site, left plugged in and idling for 7 hours, including checking the battery life with a test drive every hour. At the end of the day, the LiPo batteries still had around 20% charge left. This test far exceeded anything Nautilus will be asked to do on competition day, and we are confident the batteries will be more than enough to complete the mission.

6.1.2.4 SIGNAL STRENGTH TEST

6.1.2.4.1 TEST OBJECTIVE

The objective of this test is to determine how far the signal strength of the payload rover goes. This will be done through demonstration.

6.1.2.4.2 TESTED ITEMS

- The signal receiver on the payload

6.1.2.4.3 MOTIVATIONS

- To ensure the rover can be remotely activated

- The success of this test will verify that the signal receiver and signal transmitter are adequate for starting the payload deployment process.
- The failure of this test will result in the payload team looking for another signal receiver or transmitter.

6.1.2.4.4 SUCCESS CRITERIA

Table 41: PT4 Success Criteria

Unique ID	Description	Pass/Fail Criteria	Results
PT4	Personnel will stand 1000 feet away from the payload and activated the deployment process	Pass: The payload has a signal strength of at least 1000 ft and from 1000 ft it can start the payload deployment process. Fail: If the pass criteria is not met	Completed February 23, 2019.

6.1.2.4.5 TESTING PROCEDURES

6.1.2.4.5.1 EQUIPMENT

The equipment needed for this is the payload rover, tape measure and the laptop which will activate the signal.

6.1.2.4.5.2 SETUP

Assemble rover so it is fully functional. Ensure the batteries on the rover are charged. Ensure the receiver is connected and functional.

6.1.2.4.5.3 SAFETY NOTES

- Don't trip moving backwards
- Ensure the grounds the rover is being tested on is not in a radioactive zone, war zone, near land mines, close to the edge of a clift, inhabited by dangerous animals, a phosphate manufacturer's dump zone or on private property.

6.1.2.4.5.4 PROCEDURE

1. Place Rover on the ground in a soil rich area.
2. Using a tape measuring, move 1000 feet away from the rover.
3. Activate the rover to move at least 10 feet and collect a 10 ml sample of soil.

6.1.2.4.6 RESULTS

Using the Xbee S3b radio modules, wireless range has been tested up to ~1100 ft. At this range, packet loss is still minimal, but competition requirements will require a more consistent signal at longer ranges. This range will be significantly increased over the following week with the addition of an external antenna to amplify the signal.

6.2 REQUIREMENTS COMPLIANCE

6.2.1 NASA REQUIREMENT VERIFICATION

Review and update the verification plan. Describe how each handbook requirement was verified using testing, analysis, demonstration, or inspection.

6.2.1.1 GENERAL

Table 42: General Requirements and Verification.

Req. No.	**Requirement**	**Method**	**Verification**	**Verification Status**
1.1	*Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation except for assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor).*	Demonstration	USF SOAR is a student-only organization. Team leads will monitor all operations and construction of the rocket and payload to ensure all work is done by the student members. Safety Officer will monitor that all handling of explosive items, electric matches or igniters, and motor assembly are conducted by the team mentor.	Verified with submission of FRR. {REFERENCE: contributors, construction photos}

1.2	*The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.*	Demonstration	Team leader and project manager will work with sub- team leaders to construct a project timeline that includes project milestones. Safety officer will build checklists, as well as risk/mitigation charts. Outreach coordinator will find and handle outreach events.	Verified with submission of FRR. {REFERENCE: Project Plan, Safety Checklists, Educational Engagement}
1.3	*Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during certain activities.*	Documentation	SOAR will submit information on foreign national students no later than submission of the PDR. A team roster is being kept with information on all Foreign Nationals, this data will be sent to the correct personal no later than the due date of the PDR.	Verified 10/29/18 when email confirmation was received that Frederick Kepner and Zachary Koch received the list of Foreign Nationals.
1.4	*The team must identify all team members attending launch week activities by the Critical Design Review (CDR).*	Documentation	SOAR will submit information on team member attendees no later than submission of the CDR.	Verified with submission of CDR.
1.4.1	*Students actively engaged in the project throughout the entire year.*	Documentation	A team roster is being kept with information regarding each member's activity level.	Verified with submission of CDR.

1.4.2	*One mentor (see requirement 1.13).*	Documentation	SOAR has a designated mentor who meets the requirements of Section 1.13 of the NASA Student Launch 2019 Handbook. The mentor has agreed to travel with the team during launch week.	Verified with project proposal. {REFERENCE: Team Mentor}
1.4.3	*No more than two adult educators.*	Documentation	SOAR will identify no more then two adult educators who will be attending launch week.	Verified with submission CDR.
1.5	*The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement Activity Report, by FRR. An educational engagement activity report will be completed and submitted within two weeks after completion of an event.*	Demonstration	SOAR has designated an Outreach Coordinator to organize and handle all outreach events. Multiple outreach events are scheduled and the Operations Manager has been designated to schedule further events.	Verified with submission of CDR as the team has reached over 400 students. {REFERENCE: STEM Engagement count}
1.6	*The team will establish a social media presence to inform the public about team activities.*	Demonstration	SOAR has established social media accounts on Facebook, Twitter, Instagram, and LinkedIn. The NSL team will utilize these established accounts to inform the public about team activities. The Team Lead has access to all of these accounts which she will keep updated with NSL material.	Verified with submission of social media handles to Ryan Connelly on 10/9/18.

1.7	*Teams will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, inclusion of a link to download the file will be sufficient.*	Demonstration	The NSL Team Leader will be responsible to send the documentation to NASA project management for each milestone. In addition, each report will be posted on our website to the following page: http://www.usfsoar.com/projects/nsl-2018-2019/	Verified with submission of FRR.
1.8	*All deliverables must be in PDF format.*	Inspection	One team member has been designated to format and proofread all documents before submission. They will inspect that each deliverable will be in PDF format.	Verified with submission of FRR.
1.9	*In every report, teams will provide a table of contents including major sections and their respective sub-sections.*	Inspection	One team member has been designated to format and proofread all documents before submission. They will inspect that each report contains a table of contents.	Verified with submission of FRR.
1.10	*In every report, the team will include the page number at the bottom of the page.*	Inspection	One team member has been designated to format and proofread all documents before submission. They will inspect that each report has a page number at the bottom of the page.	Verified with submission of FRR.

1.11	*The team will provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a broadband Internet connection. Cellular phones can be used for speakerphone capability only as a last resort.*	Demonstration	The SOAR team has access to computers, speaker phones, Wi-Fi connection, and a video camera for teleconference purposes. The Team Lead is responsible for booking an adequate conference room and renting all necessary equipment for the presentation.	Verified with submission of FRR.
1.12	*All teams will be required to use the launch pads provided by Student Launch's launch service provider. No custom pads will be permitted on the launch field. Launch services will have 8 ft. 1010 rails, and 8 and 12 ft. 1515 rails available for use.*	Demonstration	The Launch vehicle will be designed to utilize the standard rails made available on the NSL launch site. Full-scale launches will be conducted in a similar way in order to mimic launch day conditions.	Verified with submission of FRR.
1.13	*Each team must identify a "mentor."*	Documentation	SOAR's NSL Team has identified a mentor who meets the qualifications specified in the NASA Student Launch 2019 Handbook.	Verified with submission of project proposal. {REFERENCE ,Team Mentor, NAR/TRA Number and Certification

				Level, Team Members }

6.2.1.2 VEHICLE

Table 43: Vehicle Requirements and Verification

Req. No.	Requirement	Method	Verification	Verification Status
2.1	*The vehicle will deliver the payload to an apogee altitude between 4,000 and 5,500 feet above ground level (AGL). Teams flying below 3,500 feet or above 6,000 feet on Launch Day will be disqualified and receive zero altitude points towards their overall project score.*	Demonstration	The team have identified a target apogee of 5,000 feet.	Will be verified on Launch Day for Full-Scale Vehicle.
2.2	*Teams shall identify their target altitude goal at the PDR milestone. The declared target altitude will be used to determine the team's altitude score during Launch Week.*	Documentation	The target goal will be determined using OpenRocket simulation following any changes to the rocket prior to PDR submission.	Verified with submission of PDR.
2.3	*The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining*	Demonstration	The vehicle will feature five altimeters in two separate avionic bays, capable of deploying charges and recording the flight apogee.	Verified with submission of PDR.

	the altitude award winner.			
2.4	*Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.*	Inspection	Each altimeter will have an arming switch via a keyed electronic rotary switch. There will be two switches in the transition bay of the main avionics bay, and two switches in the payload avionics bay. All switches will be visible and physically accessible when the rocket is on the rail.	Verified with submission of FRR.
2.5	*Each altimeter will have a dedicated power supply.*	Demonstration	One 9V LiPo battery will be installed for each altimeter.	Verified with submission of FRR.
2.6	*Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).*	Inspection	There are two settings to the electronic rotary switch. The switch itself has mechanical components that force it to remain in its set position.	Verified with submission of FRR.
2.7	*The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.*	Testing/ Inspection	The launch vehicle will contain parachutes on every separate or tethered part of the rocket that will be deployed with sufficient time to slow the rocket adequately. After each launch the Safety Officer will inspect the vehicle to identify	Verified with submission of FRR.

			it as recoverable and reusable.	
2.8	*The launch vehicle shall have a maximum of four (4) independent sections.*	Demonstration	The launch vehicle will consist four sections: the nose cone, rover compartment, main avionics bay, and the booster section. The nose cone and rover compartment will be tethered together, as will the avionics bay and booster, thus resulting in two independent sections.	Verified with submission of FRR.
2.8.1	*Coupler/ airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length.*	Demonstration	The coupler connecting the upper and lower sections will extend at least 6" into the airframes.	Verified with submission of FRR.
2.8.2	*Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.*	Demonstration	The nose cone shoulder will extend 5" into the upper airframe.	Verified with submission of FRR.
2.9	*The launch vehicle shall be limited to a single stage.*	Demonstration	Launch vehicle will contain only one motor to light and start the flight.	Verified with submission of FRR.
2.10	*The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the Federal Aviation Administration flight waiver opens.*	Testing	There will be Final Assembly and Launch Procedure Checklist before the test flights of the subscale rocket and the full-scale rocket that will be timed to ensure we complete the list safely and within the time of 2 hours.	Verified with submission of FRR.

2.11	*The launch vehicle will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components.*	Testing	The launch vehicle and the electronic components within will be properly connected and sealed to prevent anything from causing it to disconnect or be damaged. The batteries will have a life long enough to be at the launch pad for an hour without losing any power.	Verified with submission of FRR.
2.12	*The launch vehicle shall be capable of being launched by a standard 12-volt direct current firing system.*	Demonstration	The ignitor used in the rocket will be able to fire with a standard 12-volt DC firing system.	Verified with submission of FRR.
2.13	*The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch.*	Demonstration	The only required external circuitry will be the 12-volt direct current firing system that is compatible with the ignitor in the launch vehicle.	Verified with submission of FRR.
2.14	*The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).*	Demonstration	The selected motor is a commercially available certified standard APCP solid-fuel motor.	Verified with submission of FRR.

2.14.1	*Final motor choices will be declared by the Critical Design Review (CDR) milestone.*	Documentation	Preliminary motor has been selected; any changes will be noted and justified in CDR.	Verified by submission of CDR.
2.14.2	*Any motor change after CDR must be approved by the NASA Range Safety Officer (RSO) and will only be approved if the change is for the sole purpose of increasing the safety margin. A penalty against the team's overall score will be incurred when a motor change is made after the CDR milestone, regardless of the reason.*	Documentation	No motor change is expected after the CDR Report is submitted.	Verified by submission of CDR. Note: a change in motors had to be made for safety reasons after CDR submission which was approved.
2.15	*Pressure vessels on the vehicle shall be approved by the RSO and shall meet the following criteria.*	Documentation	Our design does not contain a pressure vessel.	Verified with submission of Project Proposal.
2.15.1	*The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.*	Documentation	Our design does not contain a pressure vessel.	Verified with submission of Project Proposal.
2.15.2	*Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.*	Documentation	Our design does not contain a pressure vessel.	Verified with submission of Project Proposal.

2.15.3	*Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.*	Documentation	Our design does not contain a pressure vessel.	Verified with submission of Project Proposal.
2.16	*The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newton-seconds (L-class).*	Analysis	The motor chosen is not bigger than an L class motor.	Verified with submission of CDR.
2.17	*The launch vehicle shall have a minimum static stability margin of 2.0 at the point of rail exit.*	Analysis	The rocket has been simulated in OpenRocket to have a loaded static stability margin greater than 2.0. Will be further verified with physical balance tests after fabrication.	Re-verified for full scale rocket with submission of FRR.
2.18	*The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit.*	Analysis	The motor that was chosen for the rocket will allow the rocket to achieve a minimum of 52 fps at rail exit..	Re-verified for full scale rocket with submission of FRR.
2.19	*All teams shall successfully launch and recover a subscale model of their rocket prior to CDR.*	Testing	Our team successfully launched and recovered a subscale vehicle on December 15th 2018. The subscale information will be documented in the CDR.	Verified with submission of CDR.

2.19.1	*The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model.*	Demon-stration	The subscale model was constructed to resemble the full-scale model as ac-curately as possible given finances and fabrication techniques.	Verified with submission of CDR.
2.19.2.	*The subscale model will carry an altimeter capable of recording the model's apogee altitude.*	Demon-stration	The avionics bay on the subscale rocket will include an altimeter that will record the subscales apogee.	Verified with submission of CDR.
2.19.3	*The subscale rocket must be a newly constructed rocket, designed and built specifically for this year's project.*	Demon-stration	The subscale rocket will be newly constructed rocket, designed and build at a scale unique to the full-scale rocket.	Verified with submission of CDR.
2.19.4	*Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.*	Docu-menta-tion	An altimeter will be at-tached to the subscale rocket so that altimeter data can be used to prove a successful launch.	Verified with submission of CDR.
2.20	*All teams will complete demonstration flights as outlined below.*			

2.20.1	*All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day.*	Testing	The full-scale rocket will be built and launched as well as recovered prior to the FRR and it will be the same rocket flown on launch day.	Verified with submission of FRR.
2.20.1.1	*The vehicle and recovery system will have functioned as designed.*	Inspection	The vehicle and recovery system will be observed during and after full-scale launch to ensure it functions as designed. During our February launch the Booster section recovery did not function as designed thus we will be launching in March to test the funcatility.	Verified with submission of FRR.
2.20.1.2	*The full-scale rocket must be a newly constructed rocket, designed and built specifically for this year's project.*	Demonstration	The full-scale rocket will be newly constructed rocket, designed and build at a scale unique to the full-scale rocket.	Verified with submission of FRR.
2.20.1.3	*The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:*			

2.20.1.3.1	*If the payload is not flown, mass simulators will be used to simulate the payload mass.*	Demonstration	A payload prototype (complete with electronics and motors) was flown on February 23 2019. This is not the final rover as some 3D printed parts will be re printed but the weight and configuration resembles the final configuration.	Verified with submission of FRR.
2.20.1.3.2	*The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.*	Inspection	No mass simulators were flown.	Verified with submission of FRR.
2.20.1.4	*If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale demonstration flight.*	Documentation	The PDLS will be active during the full-scale demonstration flight.	Verified with submission of FRR.
2.20.1.5	*Teams shall fly the launch day motor for the Vehicle Demonstration Flight. The RSO may approve use of an alternative motor if the home launch field cannot support the full impulse of the launch day motor or in other extenuating circumstances.*	Testing	The launch day motor, Aerotech L2200, was flown in the vehicle demonstration flight and will be flown in any other flight that is conducted.	Verified with submission of FRR.

2.20.1.6	*The vehicle must be flown in its fully ballasted configuration during the full-scale test flight.*	Inspection	The fully ballasted configuration will be used in the full-scale demonstration flight.	Verified with submission of FRR.
2.20.1.7	*After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer (RSO).*	Documentation	After completing the full-scale demonstration flight, no components will be changed.	Verified with submission of FRR.
2.20.1.8	*Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement.*	Documentation	Complete flight analysis and altimeter data will be included in the FRR report to prove successful flight apogee have been achieved.	Verified with submission of FRR.
2.20.1.9	*Vehicle Demonstration flights must be completed by the FRR submission deadline. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. This extension is only valid for re-flights, not first-time flights. Teams completing a required re-flight must submit an FRR Addendum by the FRR Addendum deadline.*	Demonstration	Full-scale vehicle demonstration flight was completed on February 23 2019. See verification reference for details.	Verified with submission of FRR.

2.20.2	*Payload Demonstration Flight - All teams will successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The following criteria must be met during the Payload Demonstration Flight:*			
2.20.2.1	*The payload must be fully retained throughout the entirety of the flight, all retention mechanisms must function as designed, and the retention mechanism must not sustain damage requiring repair.*	Documentation	The payload is designed to be fully retained with a solenoid system. The solenoids will be attached to the payload. The solenoids will be set to a locked position, only unlocking if power is supplied. This prevents any failure of the rover exiting the launch vehicle prematurely. The solenoids held the rover in during the Payload Demonstration Flight on February 23 2019, see verification reference for details.	Verified with submission of FRR.
2.20.2.2	*The payload flown must be the final, active version.*	Demonstration	The payload was flown in its final active version. The payload did land in water so some 3D printed parts and electronics have to be replaced but no major designs will occur.	Verified with submission of FRR.

2.20.2.3	*If the above criteria is met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.*	Demonstration	If the above criteria is met during the Vehicle Demonstration Flight then we will submit no other information and will detail results in FRR.	Verified with submission of FRR.
2.20.2.4	*Payload Demonstration Flights must be completed by the FRR Addendum deadline. No extensions will be granted.*	Demonstration	The Payload Demonstration Flight was completed for the first time on 2/23/19 and again on 3/3/19.	Verified with submission of FRR. {REFERENCE: Payload Criteria}
2.21	*An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report.*	Documentation	SOAR will submit an FRR addendum if a payload demonstration flight is not completed by the payload demonstration flight deadline.	Will be verified if needed.
2.22	*Any structural protuberance on the rocket will be located aft of the burnout center of gravity.*	Inspection	Designs place all protrusions aft of the center of gravity. Further verification will be performed at the full sale balance test.	Verified with submission of FRR.

2.23	*The team's name and launch day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe.*	Inspection	The launch vehicle team will apply this information to each individual section, as well as the payload.	Verified with submission of FRR.
2.24	*Vehicle Prohibitions*			
2.24.1	*The launch vehicle will not utilize forward canards. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.*	Documentation	Our design does not utilize forward canards.	Verified with submission of Launch Vehicle Design in PDR.
2.24.2	*The launch vehicle will not utilize forward firing motors.*	Documentation	Our design does not utilize forward motors.	Verified with submission of Launch Vehicle Design in PDR.
2.24.3	*The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)*	Documentation	Our design does not utilize motors that expel titanium sponges.	Verified with submission of CDR.
2.24.4	*The launch vehicle will not utilize hybrid motors.*	Documentation	Our design utilizes a single solid-fuel commercial off-the-shelf standard motor.	Verified with submission of Launch Vehicle Design in CDR.

2.24.5	*The launch vehicle will not utilize a cluster of motors.*	Documentation	Our design utilizes a single solid-fuel commercial off-the-shelf standard motor.	Verified with submission of Launch Vehicle Design in CDR.
2.24.6	*The launch vehicle will not utilize friction fitting for motors.*	Documentation	Our design utilizes a standard Cesaroni motor casing with rear closure and motor retainer.	Verified with submission of Launch Vehicle Design in CDR.
2.24.7	*The launch vehicle will not exceed Mach 1 at any point during flight.*	Documentation	Our design does not exceed Mach 1 at any point in flight.	Verified with submission of FRR.
2.24.8	*Vehicle ballast will not exceed 10% of the total unballasted weight of the rocket as it would sit on the pad (i.e. a rocket with and unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).*	Documentation	Any vehicle ballast will not exceed 10% of the total unballasted weight of the rocket.	Verified with submission of FRR.
2.24.9	*Transmissions from onboard transmitters will not exceed 250 mW of power.*	Documentation	Transmission from onboard transmitters do not exceed 250 mW of power.	Re-verified with submission of FRR.

2.24.10	*Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.*	Documentation	The vehicle design will not use excessive or dense metal.	Verified with submission of FRR.

6.2.1.3 RECOVERY

Table 44: Recovery Requirements and Verification

Req. No.	Requirement	Method	Verification	Verification Status
3.1	*The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude.*	Demonstration	Design Parameters: The launch vehicle is designed to deploy the drogue parachute at apogee (nominally 5,000 ft) using no delay. The main parachutes will deploy at 750 and 725 ft.	Verified with submission of Launch Vehicle Design in PDR.
3.1.1	*The main parachute shall be deployed no lower than 500 feet.*	Demonstration	The lower section main parachute will deploy at 750 ft, while the upper section main parachute will deploy at 725 ft.	Verified with submission of Launch Vehicle Design in PDR.
3.1.2	*The apogee event may contain a delay of no more than 2 seconds.*	Demonstration	The primary apogee event contains no delay; the backup apogee event contains a 1.0-second delay.	Verified with submission of Launch Vehicle Design in PDR.

3.2	*Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.*	Testing	A ground ejection test for the drogue and main parachutes was conducted for the full scale vehicle flight.	Verified with submission of FRR
3.3	*At landing, each independent sections of the launch vehicle shall have a maximum kinetic energy of 75 ft·lbf*	Analysis	The correct and appropriate parachute size will be chosen in order to slow the launch vehicle down enough to ensure a kinetic energy of less than 75 ft·lbf. Multiple tests will be simulated. Calculations in this report detail the descent rate and kinetic energy at impact.	Verified with submission of FRR
3.4	*The recovery system electrical circuits shall be completely independent of any payload electrical circuits.*	Inspection	Recovery electrical system is connected only to the recovery system altimeters. Payload design incorporates a separate power supply. Inspection will be conducted by the safety officer during construction.	Verified with submission of FRR
3.5	*All recovery electronics will be powered by commercially available batteries.*	Inspection	All recovery electronics will be inspected to ensure they are commercially bought batteries.	Verified with submission of FRR

3.6	*The recovery system shall contain redundant, commercially available altimeters.*	Inspection	The current design includes redundant, commercially available altimeters. The rocket will use a total of four altimeters, each powered by a separate battery that will not power any other equipment.	Verified with submission of PDR.
3.7	*Motor ejection is not a permissible form of primary or secondary deployment.*	Inspection	The launch vehicle design does not include motor ejection as means of deployment.	Verified with submission of PDR.
3.8	*Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.*	Inspection	The launch vehicle has been designed with shear pins at each separation point.	Verified with submission of FRR
3.9	*Recovery area will be limited to a 2500 ft. radius from the launch pads.*	Analysis/ Testing	During the first full scale flight the booster section drifted about 1.3 miles due to the main deploying pre-maturely and wind being high. During the second full scale flight the same thing happened but the distance drifted was about half as the first flight.	Will be verified at next launch on 3/16/19
3.10	*Descent time will be limited to 90 seconds (apogee to touch down).*	Analysis/ Testing	During the first full scale flight the booster section drifted about 1.3 miles due to the main deploying pre-maturely and wind being high. During the second full scale flight the same thing happened but the distance drifted was about half as the first flight. Due to these issues descent time was greater than 90 seconds for the booster section.	Will be verified at next launch on 3/16/19

3.11	*An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.*	Inspection	A loud audible beacon transmitter will be included in both altimeters bays separate from the recovery electronics. The beacon will produce a high enough decibel that will allow us to locate the separate sections.	Verified with submission of FRR
3.11.1	*Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device.*	Inspection	A loud audible beacon transmitter will be included in both altimeters bays separate from the recovery electronics. The beacon will produce a high enough decibel that will allow us to locate the separate sections.	Verified with submission of FRR
3.11.2	*The electronic tracking device will be fully functional during the official flight on launch day.*	Inspection	The sounding beacons will be installed within the avionics bays and will be functional on launch day.	Verified with submission of FRR
3.12	*The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).*	Testing	The recovery electronics will be housed in avionics bays which will contain no other onboard electronics. Testing will be done to ensure no other electronics affect the recovery electronics.	Verified with submission of FRR
3.12.1	*The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.*	Inspection	The recovery electronics will be housed in avionics bays which will contain no other onboard electronics.	Verified with submission of FRR

3.12.2	*The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.*	Inspection	The current design includes no other transmitting devices. Safety Officer will monitor updates to design and all payload and launch operations.	Verified with submission of FRR
3.12.3	*The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.*	Inspection	The recovery electronics will be housed in avionics bays which will contain no other onboard electronics. Testing will be done to ensure no other electronics affect the recovery electronics.	Verified with submission of FRR
3.12.4	*The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.*	Inspection	The selected payload electronics systems will not interfere or interact in any way with the recovery subsystem.	Verified with submission of FRR

6.2.1.4 PAYLOAD

Table 45: Payload Requirements and Verification

Req. No.	**Requirement**	**Method**	**Verification**	**Verification Status**
4.3.1	*Teams will design a custom rover that will deploy from the internal structure of the launch vehicle.*	Testing	We have designed the rover to be deployed from the internal structure of the launch vehicle using a specially design deployment system.	Verified with submission of payload design. {REFERENCE: Payload section}

4.3.2	*The rover will be retained within the vehicle utilizing a fail-safe active retention system. The retention system will be robust enough to retain the rover if atypical flight forces are experienced.*	Testing	The design utilizes solenoids to secure the deployment system into the rocket in a fail safe position. The system was tested at our full scale launch and kept the rover in the rocket the entire flight.	Verified at Full Scale flight 1 on 2/23/19 and Full Scale Flight 2 on 3/3/19. {REFERENCE: Deployment Section and Payload Retention Test}
4.3.3	*At landing, and under the supervision of the Remote Deployment Officer, the team will remotely activate a trigger to deploy the rover from the rocket*	Testing	Multiple communication systems are being tested and designed. Multiple wireless communications tests will be conducted. All results will be recorded to effectively choose the best materials to use.	Will be verified on competition day.
4.3.4	*After deployment, the rover will autonomously move at least 10 ft. (in any direction) from the launch vehicle. Once the rover has reached its final destination, it will recover a soil sample.*	Testing	Drove tests have been conducted and the rover can move at least 10 feet using controls but we are still working on getting an automatic test complete. The vacuum system has also not been tested.	REFERENCE: Payload Testing
4.3.5	*The soil sample will be a minimum of 10 milliliters (mL).*	Testing	The compartment for the soil sample will be larger than 10 mL, the rover will continue to retrieve soil until the compartment is full or after a certain time period.	Will be verified when testing is conducted. REFERENCE: Payload Testing

4.3.6	*The soil sample will be contained in an onboard container or compartment. The container or compartment will be closed or sealed to protect the sample after collection.*	Testing	The rover design includes an onboard container in order to protect the soil sample.	Verified with submission of CDR.
4.3.7	*Teams will ensure the rover's batteries are sufficiently protected from impact with the ground.*	Testing	The rover is designed to protect all electrical components. During full scale flights the rover compartment landed in water causing some electronics to corrode. More fulls ca	Verified after full scale launch 1 on 2/23/19 and full scale launch 2 on 3/3/19.
4.3.8	*The batteries powering the rover will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other rover parts.*	Inspection	Proper supplies will be used to ensure that the batteries for the rover are secure, safe for transport, and are distinguishable from other rover components. Shipping guidelines and recommendations from IATA and PHMSA will be considered when marking, labeling, and protecting batteries from impact.	Verified with submission of FRR.

5. Safety

6.2.1.5 SAFETY REQUIREMENTS AND VERIFICATION.

Table 46: Safety Requirements and Verification.

Req. No.	Requirement	Method	Verification	Verification Status
5.1	*Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.*	Demonstration	Team will use launch and safety checklists. Subscale launch lists and checklists will be made. Final checklists will be included in FRR report and used during LRR and all launch day operations.	Verified with submission of FRR. {REFERENCE: Safety checklists}
5.2	*Each team must identify a student safety officer who will be responsible for all items in section 5.3.*	Demonstration	The Safety Officer has been identified and will ensure safety of participants, spectators and other safety procedures as mentioned in the "Launch Safety" section of NSL Student Handbook. All team activities mentioned in section 5.3 will be supervised to meet specific safety requirements	Verified with submission of Project Proposal.
5.3	*The role and responsibilities of each safety officer will include, but are not limited to:*			
5.3.1	*Monitor team activities with an emphasis on Safety during:*			
5.3.1.1	*Design of vehicle and payload*	Demonstration	A safety officer will look over the final designs created by the vehicle and payload teams and confirm the designs before construction begins.	Verified with submission of FRR.

5.3.1.2	*Construction of vehicle and payload*	Demonstration	A safety officer will be present and monitor the team during the construction of the vehicle and payload.	Verified with submission of FRR.
5.3.1.3	*Assembly of vehicle and payload*	Demonstration	A safety officer will be present and monitor the team during the assembly of the vehicle and payload.	Will continue to be verified throughout the projects, especially for launch days.
5.3.1.4	*Ground testing of vehicle and payload*	Demonstration	A safety officer will be present and monitor the team during ground testing of the vehicle and payload.	Will continue to be verified throughout the projects.
5.3.1.5	*Subscale launch test(s)*	Demonstration	A safety officer will be present and monitor the team during the subscale launch test.	Verified during subscale launch on 12/15/19.
5.3.1.6	*Full-scale launch test(s)*	Demonstration	A safety officer will be present and monitor teams during full-scale launch tests.	Verified during full scale launch on 2/23/19 and will continue to be verified with future launches. .
5.3.1.7	*Launch day*	Demonstration	A safety officer will be present and monitor teams during Launch Day.	Will be verified on launch day.
5.3.1.8	*Recovery activities*	Demonstration	A safety officer will be present and monitor teams during all recovery activities.	Verified on subscale and full scale launch. Will continue to be verified for future full scale launches.

5.3.1.9	*STEM Engagement Activities*	Demonstration	A safety officer, or appointed personnel, will be present at all STEM Activity.	Verified with submission of FRR as no further outreach events will take place.
5.3.2	*Implement procedures developed by the team for construction, assembly, launch, and recovery activities.*	Demonstration	The most updated checklist will be completed during every launch. Safety Officer will supervise all operations using the checklist. All SOAR members will abide by the Safety SOP.	Will be verified throughout completion of project milestones. {REFERENCE, Safety checklists}
5.3.3	*Manage and maintain current revisions of the team's hazard analyses, failure modes analysis, procedures, and MSDS/chemical inventory data.*	Demonstration	The Safety Officer will make sure the MSDS/chemical inventory data is up to date and participants are aware of the safety hazards that could occur.	Verified with submission of FRR. {REFERENCE: Corresponding Safety section}
5.3.4	*Assist in the writing and development of the team's hazard analyses, failure modes analysis, and procedures.*	Demonstration	The Safety Officer will assist in the writing and development of these analysis and procedures.	Verified with submission of FRR. {REFERENCE: Corresponding Safety section}

5.4	*During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch Initiative does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.*	Demonstration	Safety Officer or designated team lead will supervise all operations to ensure rules and guidance are followed. Before proceeding to test flights, all requirements will be inspected to make sure teams are working accordingly. Effective communication will be taken so the project can run smoothly.	Will be verified throughout the project.
5.5	*Teams will abide by all rules set forth by the FAA.*	Demonstration	Teams will be knowledgeable of all rules from the FAA. The Safety Officer will ensure these rules are being met throughout the whole timeline of the project. Training records for safety training sessions will be maintained on the SOAR share drive.	Will be verified throughout the project.

6.2.2 TEAM REQUIREMENT VERIFICATION (2 OUT 7 ON CDR)

6.2.2.1 VEHICLE

Table 47: Vehicle Derived Requirements and Verification.

Req. No.	**Requirement**	**Method**	**Verification**	**Verification Status**

Derived Requirement 2.1.1	*The team will design an airbrake system to control the altitude of the rocket to ensure an apogee within 50 feet of the targeted 5,000 feet.*	Demonstration	DAAS has been designed to slow down the velocity of the rocket so that it can within ±50 ft. accuracy in altitude.	Verified with submission of CDR. Note: This requirement is no longer needed as the air brakes had to be removed.
Derived Requirement 2.1.2	*The team will construct and launch the airbrake system prior to FRR to verify systems functionality.*	Demonstration	The team will submit final airbrakes design by CDR and complete construction and testing prior to launch day in February.	Not verified as the air brakes system had to be removed.
Derived Requirement 2.1.3	*The batteries powering the airbrakes subsystem will be brightly colored, clearly marked as a fire hazard, and easily distinguishable.*	Inspection	Airbrakes subsystem batteries will be contained in a bright, fireproof container.	Not verified as the air brakes system had to be removed.
2.5.1 Derived Requirement	*The batteries powering the altimeters will be brightly colored, clearly marked as a fire hazard, and easily distinguishable.*	Inspection	Batteries will be colored in bright red or orange.	Will be verified.
Derived Requirement 2.20.1.1.1	*The vehicle subsystems including the Payload Compartment Leveling System and the Airbrake System will have function as designed.*	Inspection	The Payload Compartment Levelling System worked as designed during the full scale test but the air brakes had to be removed.	Verified on 2/23/19 date of full scale flight 1.

Derived Requirement 2.20.1.3.1.1	*If the airbrake system is not flown, mass simulators will be used to simulate the airbrake system mass.*	Demonstration	The air brakes system has been completely removed from the rocket.	Not verified as the air brakes system had to be removed.

6.2.2.2 RECOVERY

Table 48: Recovery Derived Requirements and Verification.

Req. No.	Requirement	Method	Verification	Verification Status
Derived Requirement 3.1.1	*All launch vehicle recovery subsystem hardware will meet a minimum factor of safety of 3.0.*	Analysis	Manual calculations and finite element analysis was conducted to calculate the factor of safety based on component design and material properties.	Verified with submission of CDR.

6.2.2.3 PAYLOAD

Table 49: Payload Derived Requirements and Verification.

Req. No.	Requirement	Method	Verification	Verification Status
Derived Requirement 4.3.1	The rover will implement a deployment system that will successfully deploy the rover from the launch vehicle.	Testing	The team will develop and test a deployment system that will successfully deploy the rover. The payload team will also work with the vehicle team to ensure the rocket comes down in the best way possible for rover deployment.	Will be verified when testing is conducted.

Derived Requirement 4.3.4	The rover will implement an autonomous control system to maximize efficiency in movement.	Testing	Preliminary prototypes have been made to test electrical and mechanical components to ensure driving and steering capabilities can be achieved.	Will be verified when testing is conducted.
Derived Requirement 4.3.5	The rover will utilize a soil compartment of 20 mL in order to ensure sufficient soil collection capacity.	Testing	Tests will be conducted in order to measure the amount of soil that the rover can collect based on the designs tested.	Verified with construction. {REFERENCE: Payload Criteria}

6.3 BUDGETING AND TIMELINE

6.3.1 BUDGET

The budget has been constructed based on material costs, planned test launches, subscale launches, and prior years expenses. These are projected costs and are subject to change as the need arises. The budget has been adjusted since the PDR to account for new developments.

Table 50: Budget

. **Materials**	**Budgeted Amount** ($)
Launch Vehicle Materials	5,190.00
Competition Launch Motors	250.00
Test Launch Motors	750.00
Subscale Launch Vehicle Materials	1,508.00
Subscale Test Launch Motor	177.00
Payload	1,275.00
Miscellaneous Hardware	250.00
Travel	1,500.00
Total	*10,400.00*

6.3.1.1 LINE ITEM BUDGET

Table 51: Line Item Budget

ITEM NAME	SUPPLIER	PRODUCT #	QUANTITY	TOTAL PRICE	CATEGORY
Copper Tubing for Drinking Water, 2 feet, 1 1/8" OD, Low Pressure	McMaster Carr	5175K136	1.00	$ 9.12	Vehicle Tools
Raspberry Pi 3.0 B+	Amazon		1.00	$ 39.70	Payload Supplies
TB6612 Motor Driver Breakout Board	Amazon		1.00	$ 7.49	Payload Supplies
DROK Voltage Stepdown Converter	Amazon		1.00	$ 11.58	Payload Supplies
Raspberry Pi Case	Amazon		1.00	$ 5.59	Payload Supplies
Grafix R05DC4025 Clear .005 Dura-Lar 40-Inch-by-25-Feet, Roll	Amazon	B004QVIXCG	1.00	$ 32.78	Vehicle Supplies
CROWN Mold Release and Protector 13 oz. Aerosol Can	Huron Industrial Supply	1-125-3470	2.00	$ 11.80	Vehicle Supplies
Scotch Heavy Duty Shipping Packaging Tape, 1.88 inches x 800 inches, 6 Rolls with Dispenser, 1.5 inch Core (142-6)	Amazon	B000J07BRQ	1.00	$ 11.64	Vehicle Supplies
820Resin Gal 824Slow Hardnr 0.2Gal pumps 114.99USD	Soller Composites		1.00	$ 114.99	Vehicle Supplies
FNC4.0-4.5-1-VK-FW-MT	Wildman Rocketry	FNC4.0-4.5-1-VK-FW-MT	1.00	$ 69.00	Subscale Supplies
G12CT-4.0	Wildman Rocketry	G12CT-4.0	24.00	$ 62.40	Subscale Supplies
G12-4.0 / 4 Foot Piece	Wildman Rocketry	G12-4.0	2.00	$ 186.80	Subscale Supplies
Structural Fiberglass Sheet / 24" Wide x 24" Long, 1/8" Thick	McMaster Carr	8537k43	1.00	$ 42.49	Subscale Supplies
U-Bolt / with Mount Plate, Zinc-Plated Steel, 3/8"-16 Thread Size, 1-1/2" ID	McMaster Carr	3043t78	4.00	$ 7.40	Subscale Supplies
Oval Shaped Threaded Connecting Link / Zinc-Plated Steel, 5/16" Thickness, 3/8" Opening, Not for Lifting	McMaster Carr	8947t17	4.00	$ 9.76	Subscale Supplies
RRC2+ Altimeter	Missile Works	RRC2+	2.00	$ 89.90	Subscale Supplies
RRC3 Sport Altimeter	Missile Works	RRC3	2.00	$ 139.90	Subscale Supplies
1/4" Tubular Kevlar Shock Cord	Top Flight Recovery	TUK-1/4"	17.00	$ 42.50	Subscale Supplies
FCP18X18	Wildman Rocketry	FCP18X18	3.00	$ 32.85	Subscale Supplies
541706M	Wildman Rocketry	541706M	1.00	$ 190.00	Subscale Supplies
2-Pole Rotary Switch	Missile Works	SW-2	4.00	$ 19.00	Subscale Supplies
Battery Holder / for 9V Battery, Snap Holder	McMaster Carr	7712K62	4.00	$ 11.44	Subscale Supplies
Adhesive-Mount Nut / Zinc-Plated Steel, 5/16"-18 Thread Size	McMaster Carr	98007A250	1.00	$ 7.46	Subscale Supplies
Thread-Locking Button Head Hex Drive Screws / Alloy Steel, 5/16"-18 Thread, 1/2" Long	McMaster Carr	92360a410	1.00	$ 3.12	Subscale Supplies
RA54	Wildman Rocketry	RA54	1.00	$ 38.00	Subscale Supplies
AeroTech K1103X	Wildman Rocketry	K1103X	1.00	$ 114.99	Subscale Supplies
G12-2.1 / 2 Foot Piece	Wildman Rocketry	G12-2.1	1.00	$ 28.80	Subscale Supplies

18-8 Stainless Steel Countersunk Washer / for 5/16" Screw Size, 0.38" ID, 0.891" OD	McMaster Carr	98466A030	1.00	$ 7.37	Subscale Supplies
Female Threaded Hex Standoff / Zinc-Plated 12L14 Steel, 3/16" Hex, 1/2" Long, 4-40 Thread	McMaster Carr	91920A533	10.00	$ 15.00	Subscale Supplies
High-Strength Steel Nylon-Insert Locknut / Grade 8, 3/8"-16 Thread Size	McMaster Carr	90630A121	1.00	$ 3.20	Subscale Supplies
Cast Wire Rope Clamp - Not for Lifting / Zinc-Plated Iron, for 1/16" Rope Diameter	McMaster Carr	30325T13	4.00	$ 1.48	Vehicle Supplies
18-8 Stainless Steel Wire - Not for Lifting / Extra Flexible, 7x19 Construction, 1/16" Diameter	McMaster Carr	3461T96	1.00	$ 9.70	Vehicle Supplies
TowerPro MG90S Mirco Servo	Amazon		1.00	$ 8.99	Payload Supplies
4 Channel Relay	Amazon		4.00	$ 30.36	Payload Supplies
Battery Charger	Amazon		1.00	$ 31.44	Payload Supplies
1300 mAh Batteries	Amazon		3.00	$ 70.29	Payload Supplies
130 pack jumper wires	Amazon		1.00	$ 7.89	Payload Tools
Alligator clips 10 pack	Amazon		1.00	$ 6.27	Payload Tools
12V DC 250N Electric Lifting Magnet	Amazon		3.00	$ 34.77	Payload Supplies
Hand Vacuum	Amazon		1.00	$ 19.99	Payload Supplies
Pulley,Gear,belt kit	Amazon		1.00	$ 7.99	Payload Supplies
IR Remote Control Kit	Amazon		1.00	$ 5.58	Payload Supplies
L298N Motor Driver 2 pack	Amazon		1.00	$ 9.89	Payload Supplies
IR Proximity Sensor	Amazon		1.00	$ 9.99	Payload Supplies
Collision sensor	Amazon		1.00	$ 5.16	Payload Supplies
PhotoResistors	Amazon		1.00	$ 5.35	Payload Supplies
Smart Electronics 3pin KEYES KY-017 Mercury Switch Module for Arduino diy Starter Kit KY017	Newegg	9SI-ADTU5T50155	1.00	$ 4.48	Payload Supplies
Pressure/Altitude/Temperature Sensor	Amazon		1.00	$ 11.99	Payload Supplies
1 Kg PLA Spool - Gray	Amazon		2.00	$ 39.98	Uncategorized
High Performance Solid Carbide Fiberglass and Composite Cutting AlTiN Coated End Mill Router Bits / 1/8" End Mill	Tools Today	48050-E	1.00	$ 23.50	Vehicle Tools
High Precision Steel Router Collet Reducers / 1/4" - 1/8"	Tools Today	RB-102	1.00	$ 10.85	Vehicle Tools
Cesaroni K570-17A Classic Rocket Motor	Chris' Rocket Supplies		1.00	$ 151.99	Subscale Launch Supplies
20" SkyAngle Classic	Chris' Rocket Supplies		1.00	$ 20.00	Subscale Supplies
Cert-3 Large SkyAngle	Chris' Rocket Supplies		1.00	$ 139.00	Subscale Supplies
51" SkyAngle Classic	Chris' Rocket Supplies		1.00	$ 75.00	Subscale Supplies
VNH5019 Motor Driver Carrier	Pololu	1451	2.00	$ 49.90	Payload Supplies
Sparkfun XBee Explorer Dongle	Amazon		1.00	$ 24.95	Payload Supplies
Fusion Climb Aluminum Figure 8 Descender Rigging Plate Black Heavy Duty	Amazon	B00B1PDPAK	1.00	$ 9.95	Subscale Supplies

Epic Peak Rescue Figure 8 Descender Large Bent-ear, Belaying and Rappelling with Free Decal	Amazon	B01915AOLY	1.00	$ 17.99	Subscale Supplies
6 INCH FILAMENT WOUND 5 TO 1 VON KARMAN NOSECONE WITH METAL TIP	Wildman Rock-etry	FNC6.0-5-1VK-FW-MT	1.00	$ 129.00	Vehicle Tools
Cesaroni 54-5 Grain Case	Chris' Rocket Supplies		1.00	$ 107.99	Subscale Supplies
Cesaroni 54mm Rear Closure	Chris' Rocket Supplies		1.00	$ 47.99	Subscale Supplies
Cesaroni K570-17A Classic Rocket Motor	Tom's Rocket Gear		1.00	$ 176.95	Subscale Launch Supplies
2-Pole Rotary Switch	Missile Works	SW-2	1.00	$ 4.75	Subscale Supplies
RRC2+ Altimeter	Missile Works	RRC2+	1.00	$ 44.95	Subscale Supplies
RTx/RRC3 Bluetooth Master Module	Missile Works	m3-BTMM	2.00	$ 29.90	Subscale Supplies
LCD Terminal	Missile Works	m3-LCDT	1.00	$ 39.95	Vehicle Tools
18-8 Stainless Steel Socket Head Screw 4-40 Thread Size, 1/4" Long	McMaster-Carr	92196A106	1.00	$ 3.92	Subscale Supplies
Female Threaded Hex Standoff Zinc-Plated 12L14 Steel, 3/16" Hex, 1/2" Long, 4-40 Thread	McMaster-Carr	91920A533	10.00	$ 15.00	Subscale Supplies
Flanged Wing Nut 1/4"-20 Thread Size, 1" Wide	McMaster-Carr	92239A175	1.00	$ 9.52	Subscale Supplies
Clear High-Strength UV-Resistant Acrylic 24" x 24" x 1/8"	McMaster-Carr	4615T94	1.00	$ 23.61	Vehicle Supplies
Extreme-Temperature Powder Lubricant 0.21 oz. Tube	McMaster-Carr	1291K51	1.00	$ 2.31	Vehicle Supplies
Rotary Shaft 12L14 Carbon Steel, 1/8" Di-ameter, 3" Long	McMaster-Carr	1327K93	6.00	$ 17.58	Vehicle Supplies
Keyed Rotary Shaft 1045 Carbon Steel, 5/16" Diameter, 12" Long	McMaster-Carr	1497K111	1.00	$ 16.33	Vehicle Supplies
Set Screw Shaft Collar for 1/8" Diameter, Zinc-Plated 1215 Carbon Steel	McMaster-Carr	6432K17	12.00	$ 12.36	Vehicle Supplies
Clamping Shaft Collar for 5/16" Diameter, Black-Oxide 1215 Carbon Steel	McMaster-Carr	6435K52	6.00	$ 13.20	Vehicle Supplies
Battery Holder for 9V Battery, Snap Holder	McMaster-Carr	7712K62	10.00	$ 28.60	Vehicle Supplies
Clear High-Strength UV-Resistant Acrylic 24" x 24" x 5/16"	McMaster-Carr	4615T42	1.00	$ 64.87	Vehicle Supplies
Clear High-Strength UV-Resistant Acrylic 24" x 24" x 1/16"	McMaster-Carr	4615T64	1.00	$ 15.85	Vehicle Supplies
18-8 Stainless Steel Button Head Hex Drive Screw 4-40 Thread, 2" Long	McMaster-Carr	92949A415	1.00	$ 7.44	Vehicle Supplies
18-8 Stainless Steel Hex Nut 4-40 Thread Size	McMaster-Carr	91841A005	1.00	$ 2.91	Subscale Supplies
Nylon Unthreaded Spacers 1/2" OD, 1" Long, Black	McMaster-Carr	90176A168	2.00	$ 10.78	Subscale Supplies
Cesaroni K570-17A Classic Rocket Motor	Tom's Rocket Gear		1.00	$ 176.95	Subscale Launch Supplies
G12-3.0 / 4 Foot Piece	Wildman Rock-etry	G12-3.0	1.00	$ 82.04	Vehicle Supplies
G12CT-6	Wildman Rock-etry	G12CT-6	22.00	$ 107.58	Vehicle Supplies
G12-6.0 / 4 Foot Piece	Wildman Rock-etry	G12-6.0	1.00	$ 185.00	Vehicle Supplies
G12-6.0 / 5 Foot Piece	Wildman Rock-etry	G12-6.0	1.00	$ 231.25	Vehicle Supplies

Super-Corrosion-Resistant 316 Stainless Steel Threaded Rod 5/16"-18 Thread Size, 1 1/2 Feet Long	McMaster-Carr	93250A258	3.00	$ 15.66	Vehicle Supplies
Super-Corrosion-Resistant 316 Stainless Steel Threaded Rod 5/16"-18 Thread Size, 6" Long	McMaster-Carr	90575A605	5.00	$ 15.75	Vehicle Supplies
Super-Corrosion-Resistant 316 Stainless Steel Threaded Rod 5/16"-18 Thread Size, 4" Long	McMaster-Carr	90575A600	4.00	$ 8.88	Vehicle Supplies
Adhesive-Mount Nut 316 Stainless Steel, 5/16"-18 Thread Size	McMaster-Carr	98007A033	3.00	$ 27.57	Vehicle Supplies
316 Stainless Steel Button Head Hex Drive Screw Super-Corrosion-Resistant, 5/16"-18 Thread Size, 1/2" Long	McMaster-Carr	98164A266	2.00	$ 12.66	Vehicle Supplies
316 Stainless Steel Hex Drive Flat Head Screw 82 Degree Countersink Angle, 1/4"-20 Thread Size, 1" Long	McMaster-Carr	90585A542	1.00	$ 5.14	Vehicle Supplies
Adhesive-Mount Nut 316 Stainless Steel, 1/4"-20 Thread Size	McMaster-Carr	98007A029	1.00	$ 8.16	Vehicle Supplies
Super-Corrosion-Resistant 316 Stainless Steel Hex Nut 5/16"-18 Thread Size	McMaster-Carr	94804A030	2.00	$ 12.04	Vehicle Supplies
316 Stainless Steel Washer for 5/16" Screw Size, 0.344" ID, 0.75" OD	McMaster-Carr	90107A030	1.00	$ 10.29	Vehicle Supplies
304 Stainless Steel U-Bolt with Mounting Plate, 5/16"-18 Thread Size, 1-1/2" ID	McMaster-Carr	8896T71	4.00	$ 22.32	Vehicle Supplies
Unthreaded Spacer Stock Gray Polypropylene Plastic, 9/16" OD	McMaster-Carr	92377A300	3.00	$ 15.27	Vehicle Supplies
Off-White Nylon Unthreaded Spacer 3/16" OD, 3/16" Long, for Number 4 Screw Size	McMaster-Carr	94639A704	1.00	$ 8.11	Vehicle Supplies
18-8 Stainless Steel Button Head Hex Drive Screw 4-40 Thread Size, 3/4" Long	McMaster-Carr	92949A113	1.00	$ 4.03	Vehicle Supplies
18-8 Stainless Steel Button Head Hex Drive Screw 4-40 Thread Size, 1/2" Long	McMaster-Carr	92949A110	1.00	$ 3.38	Vehicle Supplies
18-8 Stainless Steel Hex Nut 4-40 Thread Size	McMaster-Carr	91841A005	2.00	$ 6.04	Vehicle Supplies
18-8 Stainless Steel Split Lock Washer for Number 4 Screw Size, 0.12" ID, 0.209" OD	McMaster-Carr	92146A530	2.00	$ 3.04	Vehicle Supplies
18-8 Stainless Steel Cap Nut 4-40 Thread Size	McMaster-Carr	99022A101	3.00	$ 18.24	Vehicle Supplies
Structural Fiberglass Sheet 24" Wide x 24" Long, 3/16" Thick	McMaster-Carr	8537K44	1.00	$ 45.82	Vehicle Supplies
Structural Fiberglass Sheet 24" Wide x 24" Long, 1/8" Thick	McMaster-Carr	8537K43	1.00	$ 42.49	Vehicle Supplies
304 Stainless Steel Sheet 12" x 12", 0.048" Thick	McMaster-Carr	8983K38	1.00	$ 17.09	Vehicle Supplies
LED RED DIFFUSED T-1 3/4 T/H	Digi-Key	754-2139-ND	15.00	$ 7.31	Vehicle Supplies
HOLDER LED PANEL 5MM BLACK NYLON	Digi-Key	67-1332-ND	10.00	$ 2.28	Vehicle Supplies
SWITCH KEYLOCK 2POS SPST 1A 125V	Digi-Key	EG2625-ND	10.00	$ 33.09	Vehicle Supplies
RF ANT 916MHZ WHIP STR RP-SMA ML	Digi-Key	ANT-916-CW-HW-ND	3.00	$ 27.84	Vehicle Supplies
CBL ASSY RP-SMA 11.811"	Digi-Key	602-1066-ND	3.00	$ 45.00	Vehicle Supplies
Aero Pack 54mm Retainer - (Flanged)	Apogee Components	24068	1.00	$ 42.22	Vehicle Supplies
Large Airfoiled Rail Buttons (fits 1.5" Rail - 1515)	Apogee Components	13069	1.00	$ 11.17	Vehicle Supplies

96" Fruity Chutes: Iris Ultra Parachute	Apogee Components	29185	1.00	$ 362.69	Vehicle Supplies
Iris Ultra 84" Standard Parachute - 39lbs @ 20fps	Fruity Chutes	IFC-84	1.00	$ 276.00	Vehicle Supplies
Anodized Aluminum L3 & Larger Recovery Tether, 300lb or more	Fruity Chutes		1.00	$ 129.00	Vehicle Supplies
Recovery Tether Sheath / Sheath Size - Large (for L3 Tether)	Fruity Chutes		1.00	$ 14.00	Vehicle Supplies
5.5" & 6" Deployment Bag / Bag Length (Inches) - 10	Fruity Chutes		1.00	$ 46.00	Vehicle Supplies
Tubular Kevlar, 7200 lb Test	Top Flight Recovery	TUK-1/2	40.00	$ 150.00	Vehicle Supplies
Oval Shaped Threaded Connecting Link Type 316 Stainless Steel, 1/4" Thickness, 9/32" Opening, Not for Lifting	McMaster-Carr	8947T26	1.00	$ 3.46	Vehicle Supplies
20" SkyAngle Classic II	Chris' Rocket Supplies		1.00	$ 22.00	Vehicle Supplies
24" SkyAngle Classic	Chris' Rocket Supplies		1.00	$ 25.00	Vehicle Supplies
Chris' Rocket SuppliesSwivel Barrel 1000#	Chris' Rocket Supplies		3.00	$ 10.50	Vehicle Supplies
18-8 Stainless Steel Corrosion-Resistant Wire Rope Not for Lifting, 7 x 19, 1/16" Diameter, Extra Lubricated, 25 ft. length	McMaster-Carr	3461T96	1.00	$ 24.25	Vehicle Supplies
18-8 Stainless Steel Cast Wire Rope Clamp for 1/16" Rope Diameter - Not for Lifting	McMaster-Carr	31985T19	10.00	$ 9.50	Vehicle Supplies
Light Duty Wire Rope Thimble - Not for Lifting 18-8 Stainless Steel, for 3/64", 1/16", 5/64",& 3/32" Rope Diameter	McMaster-Carr	8914T22	1.00	$ 4.79	Vehicle Supplies
FCP24X24	Wildman Rocketry	FCP24X24	1.00	$ 14.95	Vehicle Supplies
RRC3 Sport Altimeter	Missile Works	RRC3	4.00	$ 279.80	Vehicle Supplies
RRC2+ Altimeter	Missile Works	RRC2+	1.00	$ 44.95	Vehicle Supplies
RTx/GPS Telematics "Navigator" System - Style: RPSMA Jack for external antenna; Rocket Unit GPS Mounting: Flush Mount GPS	Missile Works	RTx	1.00	$ 289.95	Vehicle Supplies
RTx-RRC3 3" Crossover Comm Cable	Missile Works		2.00	$ 7.90	Vehicle Tools
USB IO Dongle	Missile Works		2.00	$ 49.90	Vehicle Tools
RTx/RRC3 Bluetooth Master Module	Missile Works		1.00	$ 14.95	Vehicle Tools
100RPM Speed 6mm Diameter Shaft 2 Terminals Geared Motor DC 12V	Amazon		1.00	$ 10.93	Payload Supplies
Sharpie Permanent Paint Marker, Fine Point, White	Amazon	B00584Q1O2	5.41	$ 5.41	Vehicle Tools
Gunpla PVC Pipe and Plastic Tubing Cutter for Cutting up to 1-5/8inch/42mm OD Tubing	Amazon	B079FGP4CB	1.00	$ 12.95	Vehicle Tools
UL Listed Pwr 6 Ft Mickey Mouse Plug Ac Power Supply Cord AC Adapter Laptop Notebook Computer Charger Cable: IEC-60320 IEC320 C5 to NEMA 5-15P	Amazon	B002V9U7WY	1.00	$ 6.65	Vehicle Tools
2" in x 60yd Dark Green Masking Tape Extra Sticky PRO Grade High Stick Special Project Painters Tape Painting Trim Arts Crafts School Home Office 21 Days 48MM x 55M 1.88 inch	Amazon	B07C5N83T2	1.00	$ 10.95	Vehicle Supplies

Avery Heavy-Duty Binder with 1 Inch One Touch EZD Ring, Green, 1 Binder (79789)	Amazon	B001B0EFXG	2.00	$ 22.26	Vehicle Tools
General Purpose Tap for Through-Hole Threading, 2-56 Thread Size	McMaster-Carr	26955A21	1.00	$ 11.00	Vehicle Tools
General Purpose Tap for Through-Hole Threading, 4-40 Thread Size	McMaster-Carr	26955A24	1.00	$ 6.94	Vehicle Tools
Tap Wrench with Fixed T-Handle, 2-3/4" Long	McMaster-Carr	2546A23	1.00	$ 17.88	Vehicle Tools
Striveday™ 20 AWG Flexible 1007 Wire Electric wire 20 gauge Coper Hook Up Wire 300V Cables electronic stranded wire cable electrics DIY BOX-1	Amazon	B01LH1FV0Y	1.00	$ 16.19	Vehicle Supplies
Battery Charger	Amazon		1.00	$ 31.44	Payload Supplies
1300 mAh Batteries	Amazon		3.00	$ 70.29	Payload Supplies
Solu ® Xbee Bluetooth USB to Serial Port Arduino Bee Adapter	Amazon		1.00	$ 6.99	Payload Supplies
ainSmart Xbee Shield Module for Arduino UNO	Amazon		2.00	$ 23.98	Payload Supplies
Herdio Waterproof Marine Radio Antenna	Amazon		1.00	$ 8.99	Payload Supplies
AeroPack 75mm Retainer - (Flanged)	Apogee Components	24069	1.00	$ 55.56	Vehicle Supplies
K650 Smoky Sam 54mm Motor	Tom's Rocket Gear		2.00	$ 314.39	Subscale Launch Supplies
Steel Pan Head Phillips Screws 5-40, 5/8"	McMaster-Carr	90272A129	1.00	$ 8.83	Vehicle Supplies
Low-Strength Steel Hex Nut, 5-40	McMaster-Carr	90480A006	1.00	$ 1.76	Vehicle Supplies
Stainless Steel Ball Bearing	McMaster-Carr	57155K382	6.00	$ 44.34	Vehicle Supplies
Brass washer .133" diameter	McMaster-Carr	92916A322	1.00	$ 3.75	Vehicle Supplies
Barometric Pressure & Altitude Sensor - Assembled	Adafruit	4059	2.00	$ 23.90	Vehicle Supplies
DC Motor Driver Breakout Board	Adafruit	3190	2.00	$ 15.00	Vehicle Supplies
Arduino Uno R3	Amazon	B007R9TUJE	1.00	$ 21.54	Vehicle Supplies
Aluminum Mounting Hub for 5mm Shaft, #4-40 Holes	Pololu	1203	1.00	$ 21.44	Vehicle Supplies
Half Bridge Body Load Cell Electronic Scale Weighing Sensor 50Kg	Amazon	B00Z8O3NAW	2.00	$ 11.98	Vehicle Supplies
RTx/GPS Telematics Extra/Secondary Rocket Unit Transmitter / Rocket Unit Antenna Style: RPSMA Jack for external antenna; Rocket Unit GPS Mounting: Flush Mount GPS	Missile Works	RTx-RT	1.00	$ 144.95	Vehicle Supplies
PR75-4G-WT	Wildman Rocketry	PR75-4G-WT	2.00	$ 713.98	Vehicle Launch Supplies
37mm diameter DC Geared Motor Mounting Bracket Holder	Amazon		6.00	$ 21.54	Payload Supplies
16 Gauge Primary Remote Wire 4 Color Combo	Amazon		1.00	$ 20.95	Payload Supplies
USB Data Sync Cable for Arduino UNO	Amazon		1.00	$ 9.99	Payload Tools
Solid Carbide Downcut Fish Tail Spiral Bit - 1/32" Downcut Fish Tail Carving Bit	Inventables	30667-01	3.00	$ 47.17	Vehicle Tools
Solid Carbide Downcut Fish Tail Spiral Bit - 1/16" Downcut Fish Tail Carving Bit	Inventables	30667-02	3.00	$ 25.47	Vehicle Tools
AUSTOR 100 Pcs PCB Board Kit Including 30 Pcs Double Sided Prototype Boards	Amazon	B07CK3RCKS	1.00	$ 15.99	Vehicle Supplies

and 30 Pcs 40 Pin 2.54mm Male and Female Header Connector(Bonus: 10 Pcs 2P&3P Screw Terminal Blocks and 30 Pcs Jumper Caps)					
Launch Fee	TTRA		1.00	$ 15.00	Subscale Launch Supplies
Battery Holder for 9V Battery, Snap Holder	McMaster-Carr	7712K62	10.00	$ 28.60	Vehicle Supplies
9V Alkaline Disposable Batteries	McMaster-Carr	71455K68	1.00	$ 20.77	Vehicle Launch Supplies
316 Stainless Steel Button Head Hex Drive Screw Super-Corrosion-Resistant, 4-40 Thread Size, 7/16" Long	McMaster-Carr	98164A431	1.00	$ 3.57	Vehicle Supplies
316 Stainless Steel Washer for Number 4 Screw Size, 0.125" ID, 0.312" OD	McMaster-Carr	90107a005	1.00	$ 3.23	Vehicle Supplies
Turnigy Graphene Panther 950mAh 1S 75C Battery Pack w/JST-SYP-2P	HobbyKing	9067000406-0	4.00	$ 45.26	Vehicle Supplies
JST Male 2 Pin Connector Set (10pcs/set)	HobbyKing	AM-1024Bx10	1.00	$ 1.17	Vehicle Supplies
JST Female 2 Pin Connector Set (10pcs/set)	HobbyKing	AM-1024Ax10	1.00	$ 1.33	Vehicle Supplies
4mm Banana Plug with 6 x JST Plug Charging Harness	HobbyKing	MINIJSTCCPX6	1.00	$ 2.87	Vehicle Supplies
Banana Plugs (non-gold) (10pairs/set)	HobbyKing	AM-1020x10	1.00	$ 3.71	Vehicle Supplies
Cesaroni L2375 White Thunder Rocket Motor	Chris' Rocket Supplies		2.00	$ 713.98	Vehicle Launch Supplies
Adafruit ADXL345 - Triple-Axis Accelerometer	Amazon		2.00	$ 35.98	Payload Supplies
STEPPERONLINE Stepper Motor	Amazon		1.00	$ 12.99	Payload Supplies
SparkFun EasyDriver Stepper Motor Driver	Amazon		1.00	$ 12.99	Payload Supplies
SHKTL Kevlar Trip Line	Amazon		1.00	$ 8.36	Payload Supplies
The Shooting Star of the Rocket City	VRBO	1306956	4.00	$ 1,091.00	Travel
37mm DC Gear Motors Mounting Bracket	Amazon		4.00	$ 27.96	Payload Supplies
37mm Bore Bottom Tapped Clamping Mount	Servo City	555116	4.00	$ 34.95	Payload Supplies
5.5" & 6" Deployment Bag / Bag Length (Inches) - 10	Fruity Chutes		1.00	$ 46.00	Vehicle Supplies
Mini 12V DC 66 RPM 13N.cm Gear Box Electric Motor	Amazon		4.00	$ 59.92	Payload Supplies
Double Sided PCB Board Prototype Kit	Amazon		1.00	$ 11.99	Payload Supplies
40-Watt Soldering Station	Amazon		1.00	$ 39.97	Payload Tools
60-40 Tin Lead Rosin Core Solder Wire	Amazon		2.00	$ 17.18	Payload Tools
Rosin Paste Flux #135 in a 2 oz Jar	Amazon		1.00	$ 7.99	Payload Tools
Helping Hands Soldering Aid	Amazon		1.00	$ 7.01	Payload Tools
ARDUINO MEGA 2560	Amazon		1.00	$ 27.70	Payload Supplies
3/8" Acrylic Sheet 24"x12"	Amazon		2.00	$ 74.54	Payload Supplies
1/4" Acrylic Sheet 12"x12"	Amazon		2.00	$ 25.98	Payload Supplies
Breadboard Jumper Wires Ribbon Cables Kit	Amazon		1.00	$ 6.98	Payload Supplies
Aerotech L2200 Mojave Green Rocket Motor	Chris' Rocket Supplies	1067	4.00	$ 1,219.96	Vehicle Launch Supplies

Xbee Pro S3B Modules	Amazon		2.00	$ 129.98	Payload Supplies
2Packs L298N Motor Drive Controller Board	Amazon		1.00	$ 9.89	Payload Supplies
RTx/GPS Telematics "Navigator" System	Missile Works		2.00	$ 579.90	Vehicle Supplies
uxcell Mini 12V DC 66 RPM 13N.cm Gear Box Electric Motor	Amazon		4.00	$ 59.92	Payload Supplies
Adafruit ADXL345 - Triple-Axis Accel-erometer	Amazon		2.00	$ 35.98	Payload Supplies
STEPPERONLINE Stepper Motor	Amazon		1.00	$ 12.99	Payload Supplies
SparkFun EasyDriver Stepper Motor Driver	Amazon		1.00	$ 12.99	Payload Supplies
SHKTL Kevlar Trip Line	Amazon		1.00	$ 8.36	Payload Supplies
3/8" Acrylic Sheet 24"x12"	Amazon		2.00	$ 74.54	Payload Supplies
1/4" Acrylic Sheet 12"x12"	Amazon		2.00	$ 25.98	Payload Supplies
Breadboard Jumper Wires Ribbon Cables Kit	Amazon		1.00	$ 6.98	Payload Supplies
37mm DC Gear Motors Mounting Bracket	Amazon		4.00	$ 27.96	Payload Supplies
37mm Bore Bottom Tapped Clamping Mount	Servo City	555116	4.00	$ 34.95	Payload Supplies
Xbee Pro S3B Modules	Amazon		2.00	$ 129.98	Payload Supplies
2Packs L298N Motor Drive Controller Board	Amazon		1.00	$ 9.89	Payload Supplies
HOLDER LED PANEL 5MM BLACK NYLON	Digi-Key	67-1332-ND	10.00	$ 2.28	Vehicle Supplies
SWITCH KEYLOCK 2POS SPST 1A 125V	Digi-Key	EG2625-ND	10.00	$ 33.09	Vehicle Supplies
RF ANT 916MHZ WHIP STR RP-SMA ML	Digi-Key	ANT-916-CW-HW-ND	3.00	$ 27.84	Vehicle Supplies
CBL ASSY RP-SMA 11.811"	Digi-Key	602-1066-ND	3.00	$ 45.00	Vehicle Supplies
Oval Shaped Threaded Connecting Link Type 316 Stainless Steel, 1/4" Thickness, 9/32" Opening, Not for Lifting	McMaster-Carr	8947T26	10.00	$ 34.60	Vehicle Supplies
18-8 Stainless Steel Corrosion-Resistant Wire Rope Not for Lifting, 7 x 19, 1/16" Di-ameter, Extra Lubricated, 25 ft. length	McMaster-Carr	3461T96	1.00	$ 24.25	Vehicle Supplies
18-8 Stainless Steel Cast Wire Rope Clamp for 1/16" Rope Diameter - Not for Lifting	McMaster-Carr	31985T19	10.00	$ 9.50	Vehicle Supplies
Light Duty Wire Rope Thimble - Not for Lifting 18-8 Stainless Steel, for 3/64", 1/16", 5/64",& 3/32" Rope Diameter	McMaster-Carr	8914T22	1.00	$ 4.79	Vehicle Supplies
Turnigy Graphene Panther 950mAh 1S 75C Battery Pack w/JST-SYP-2P	HobbyKing	9067000406-0	4.00	$ 45.26	Vehicle Supplies
JST Male 2 Pin Connector Set (10pcs/set)	HobbyKing	AM-1024Bx10	1.00	$ 1.17	Vehicle Supplies
JST Female 2 Pin Connector Set (10pcs/set)	HobbyKing	AM-1024Ax10	1.00	$ 1.33	Vehicle Supplies
4mm Banana Plug with 6 x JST Plug Charging Harness	HobbyKing	MINIJSTCCPX6	1.00	$ 2.87	Vehicle Supplies
Banana Plugs (non-gold) (10pairs/set)	HobbyKing	AM-1020x10	1.00	$ 3.71	Vehicle Supplies
165 RPM HD Premium Planetary Gear Mo-tor w/Encoder	Servo City	638326	1.00	$ 66.98	Payload Supplies
18-8 Stainless Steel Flat-Tip Set Screws, 2-56 Thread, 1/8" Long	McMaster-Carr	94355A080	1.00	$ 7.70	Payload Supplies
Steel Pan Head Phillips Screws, 5-40 Thread, 3/4" Long	McMaster-Carr	90272A130	1.00	$ 10.34	Vehicle Supplies

Dupont Teflon® Penetrating Lubricant, Dry-Film, 14 oz. Aerosol Can	McMaster-Carr	8710T44	1.00	$ 8.98	Vehicle Supplies
Steel Phillips Flat Head Screws, M3 x 0.5 mm Thread, 10 mm Long	McMaster-Carr	91420A120	1.00	$ 2.81	Vehicle Supplies
4 in. x 4 in. x 6 ft. #2 Pine Pressure-Treated Lumber	Home Depot		4.00	$ 22.68	Rocket Fair Display
2 in. x 4 in. x 8 ft. #2 Ground Contact Pressure-Treated LumberHome - Depot	Home Depot		12.00	$ 34.56	Rocket Fair Display
Hardboard Tempered Panel (Common: 1/8 in. 4 ft. x 8 ft.; Actual: 0.115 in. x 47.7 in. x 95.7 in.)	Home Depot		4.00	$ 31.68	Rocket Fair Display
1/2 in. x 48 in. Wood Round Dowel	Home Depot		1.00	$ 1.72	Rocket Fair Display
#8 x 2 in. Phillips Bugle-Head Coarse Thread Sharp Point Polymer Coated Exterior Screws (1 lb.-Pack)	Home Depot		1.00	$ 8.97	Rocket Fair Display
11 oz. All Surface Aged Metallic Weathered Steel Spray Paint and Primer in One (6-Pack)	Home Depot		1.00	$ 46.56	Rocket Fair Display
50 lb. All-Purpose Sand	Home Depot		1.00	$ 4.50	Rocket Fair Display
Putty Knife Set	Amazon		1.00	$ 2.99	Rocket Fair Display
1-1/4 in. O.D. x 7/8 in. I.D. x 2 ft. PVC Washer Discharge Hose	Home Depot		1.00	$ 4.98	Rocket Fair Display
Duracell - CopperTop AA Alkaline Batteries - long lasting, all-purpose Double A battery for household and business - 10 count	Amazon		3.00	$ 35.97	Rocket Fair Display
SAKRETE OF NORTH AMERICA 112447 47 LB Portland Cement, Type 1	Amazon		1.00	$ 35.12	Rocket Fair Display
HIKENRI Battery Powered LED Strip Lights, 17-Keys Remote Controlled, DIY Indoor and Outdoor Decoration, 6.56ft Waterproof	Amazon		3.00	$ 20.97	Rocket Fair Display
Beadsmith Illusion Monofilament Bead Cord .010 In 6 lb 164ft	Amazon		1.00	$ 5.11	Rocket Fair Display
Fairfield the Original Poly-Fil Premium 100% Polyester Fiber Fill Box, 6.5 Pounds, White	Amazon		1.00	$ 25.24	Rocket Fair Display
6061 Aluminum 5/16" Thick, 6" x 12"	McMaster-Carr	9246K464	2.00	$ 43.34	Vehicle Supplies
Clear Cast Acrylic Sheet 12" x 12" x 1/2"	McMaster-Carr	8560K265	1.00	$ 32.05	Vehicle Supplies
Clear Cast Acrylic Sheet 12" x 12" x 3/16"	McMaster-Carr	8560K211	1.00	$ 10.74	Vehicle Supplies
Clear Cast Acrylic Sheet 12" x 12" x 1/8"	McMaster-Carr	8560K239	1.00	$ 9.15	Vehicle Supplies
6061 Aluminum 3/16" Thick x 4" Wide, 1 Foot Long	McMaster-Carr	8975K421	1.00	$ 7.55	Vehicle Supplies
6061 Aluminum Sheet 1/8" Thick, 6" x 12"	McMaster-Carr	89015K236	1.00	$ 16.63	Vehicle Supplies
6061 Aluminum Sheet 0.09" Thick, 6" x 6"	McMaster-Carr	89015K223	1.00	$ 6.14	Vehicle Supplies
Thomas 3D printed parts for Rover 1.0	AVC		1.00	$ 84.96	Payload Supplies
Team Jackets	Image Depot Express		19.00	$ 668.61	NSL General
Team Polos	Image Depot Express		19.00	$ 706.61	NSL General

Multi Purpose Sand	Home Depot		1.00	$ 5.59	Rocket Fair Display
ARDUINO NANO	Arduino	A000005	2.00	$ 44.00	Payload Supplies
eBoot 6 Pack LM2596 DC to DC Buck Converter 3.0-40V to 1.5-35V Power Supply Step Down Module	Amazon	B01GJ0SC2C	1.00	$ 10.65	Payload Supplies
Stackable 0.100" Female Header Set for Arduino Shields	Pololu	1035	10.00	$ 17.60	Payload Supplies
Adafruit 9-DOF Absolute Orientation IMU Fusion Breakout - BNO055	Amazon		1.00	$ 38.03	Payload Supplies
DROK 5pcs Mini Voltage Reducer DC 4.5-24V 12V 24V Step Down to 5V	Amazon		1.00	$ 8.99	Payload Supplies
2 Channel DC 5V Relay Module with Optocoupler	Amazon		1.00	$ 6.79	Payload Supplies
ARDUINO UNO R3	Amazon		2.00	$ 46.00	Payload Supplies
SainSmart Xbee Shield Module for Arduino UNO	Amazon		3.00	$ 35.97	Payload Supplies
Adafruit DRV8871 DC Motor Driver Breakout Board	Amazon		3.00	$ 32.40	Payload Supplies
Launch Fee	TTRA		1.00	$ 7.50	Vehicle Launch Supplies
WYCTIN Diameter 0.6mm 100g 60/40 Active Solder Wire	Amazon		1.00	$ 9.99	Payload Supplies
Striveday™Flexible Silicone Wire 22awg Electric wire 22 gauge Coper Hook Up Wire	Amazon		1.00	$ 15.99	Payload Supplies
RRC3 Sport Altimeter	Missile Works	RRC3	3.00	$ 209.85	Vehicle Supplies
LCD Terminal	Missile Works	m3-LCDT	2.00	$ 79.90	Vehicle Supplies
Nylon Decorative Round Head Slotted Screws Black, 4-40 Thread, 1/2" Long	McMaster-Carr	97263A717	1.00	$ 6.12	Vehicle Supplies
Nylon Decorative Round Head Slotted Screws Black, 2-56 Thread, 1/2" Long	McMaster-Carr	97263A709	1.00	$ 6.12	Vehicle Supplies
3” Wood Screws	McMaster-Carr	90294A257	10.00	$ 58.80	Rocket Fair Display
2” Diameter Hole Saw	McMaster-Carr	4066A35	1.00	$ 7.42	Rocket Fair Display
Arbor with Pilot Drill for Hole Saw	McMaster-Carr	4066A79	1.00	$ 14.05	Rocket Fair Display
2” Diameter Wood Dowel	McMaster-Carr	9683K67	1.00	$ 33.21	Rocket Fair Display
4-piece Wood Chisel Set	McMaster-Carr	3590A32	1.00	$ 35.33	Rocket Fair Display

6.3.1.2 FUNDING

Provide an updated funding plan describing sources of funding, allocation of funds, and a material acquisition plan for any items that have not yet been obtained.

6.3.2 Timeline

6.3.2.1 GENERAL TIMELINE

Table 52: General Timeline

Date	Item	Status
August 29th, 2018	NSL General Team Meeting	Completed
September 5th, 2018	NSL General Team Meeting	Completed
September 6th, 2018	NSL Handover Meeting	Completed
September 12th, 2018	NSL General Team Meeting	Completed
September 14th, 2018	NSL Proposal Writing Session	Completed
September 19th, 2018	NSL General Team Meeting	Completed
September 19th, 2018	NSL Project Proposal Due	Completed
September 26th, 2018	NSL General Team Meeting	Completed
October 3rd, 2018	NSL General Team Meeting	Completed
October 9th, 2018	Outreach Event: Transfer Day	Completed
October 10th, 2018	NSL General Team Meeting	Completed
October 13th, 2018	Outreach Event: Stampede	Completed
October 17th, 2018	NSL General Team Meeting	Completed
October 24th, 2018	NSL General Team Meeting	Completed
October 31st, 2018	NSL General Team Meeting	Completed
November 2nd, 2018	NSL PDR Due Date	Completed
November 7th, 2018	NSL PDR Presentation	Completed

November 9th, 2018	Outreach Event: Manatee County Engineering Day	Completed
November 10th, 2018	Outreach Event: MOSI Drone Event	Completed
November 13th, 2018	Great American Teach-In Planning Meeting	Completed
November 14th, 2018	Outreach Event: Great American Teach-In Pinellas County	Completed
November 15th, 2018	Outreach Event: Great American Teach-In Hillsborough County	Completed
November 16th, 2018	Outreach Event: Mount Calvary Junior Academy School Visit	Completed
November 17th, 2018	Outreach Event: Bulls Unite Day	Completed
December 14th, 2018	CDR Writing Session 1	Completed
December 17th, 2018	CDR Writing Session 2	Completed
December 28th, 2018	CDR Content due for formatting	Completed
January 1st, 2019	Complete Formatted CDR due to Team Lead	Completed
January 2nd, 2019	Complete CDR Presentation Due to Team Lead	Completed
January 4th, 2019	NSL CDR Due to NASA	Completed
January 5th, 2019	Submit Purchase Order for All Additional Vehicle Full-Scale parts	Completed
January 5th, 2019	Submit Purchase Order for All Additional Payload parts	Completed
January 8th, 2018	Outreach Event: Spring Student Organization Showcase	Completed

January 9th, 2019	Girl Scouts Planning Meeting	Completed
January 17th, 2019	Outreach Event: Pinellas County Engineering Day	Completed
January 22nd, 2019	CDR Presentation Practice	Completed
January 24th, 2019	FRR Q&A	Completed
January 26th, 2019	Outreach Event: Girl Scouts of West Central Florida	Completed
January 27th, 2019	Outreach Event: Girl Scouts of West Central Florida	Completed
January 29th, 2019	CDR Presentation	Completed
February 2nd, 2019	Outreach Event: Bulls Unite Day	Completed
February 3rd, 2019	Outreach Event: Girl Scouts of West Central Florida	Completed
February 8th, 2019	Outreach Event: Git Hub Event	Completed
February 9th, 2019	Outreach Event: Girl Scouts of West Central Florida	Completed
February 15th, 2019	Outreach Event: Engineering Expo	Completed
February 16th, 2019	Outreach Event: Engineering Expo	Completed
February 23nd, 2019	Transmitter Data Sheet due to Fred	Completed
March 4th, 2019	NSL FRR Deliverables & other items Due	Completed
April 3rd, 2019	Team Leaves for Huntsville	Upcoming
April 6th, 2019	Competition Day	Upcoming

April 18th, 2019	PLAR Content due for formatting to Team Lead	Upcoming
April 25th, 2019	Formatted PLAR due to Team Lead	Upcoming
April 26th, 2019	NSL PLAR Due Date	Upcoming

6.3.2.2 VEHICLE TIMELINE

Table 53: Vehicle Timeline.

Date	Item & Description	Status
August 31st, 2018	NSL Vehicle Team Meeting	Completed
September 10th, 2018	X-Winder Training Session	Completed
September 24th, 2018	Order All Materials for Initial Carbon Fiber Testing	Completed
September 27th, 2018	Subscale Design Finalized	Completed
September 30th, 2018	Order Materials and Hardware for Subscale Launch Vehicle	Completed
October 30th, 2018	Order Motors and Parachutes for Subscale Launch Vehicle	Completed
November 18th, 2018	Construction of Subscale Launch Vehicle	Completed
November 20th, 2018	Vehicle Team Meeting	Completed
November 25th, 2018	Construction of Subscale Launch Vehicle	Completed
November 27th, 2018	Vehicle Team Meeting	Completed
November 28th, 2018	Vehicle Team Meeting	Completed
December 2nd, 2018	Construction of Subscale Launch Vehicle	Completed

December 9th, 2018	Construction of Subscale Launch Vehicle	Completed
December 10th, 2018	Construction of Subscale Launch Vehicle	Completed
December 11th, 2018	Construction of Subscale Launch Vehicle/Team Meeting	Completed
December 12th, 2018	Construction of Subscale Launch Vehicle/Team Meeting	Completed
December 13th, 2018	Construction of Subscale Launch Vehicle/Team Meeting	Completed
December 14th, 2018	Subscale Launch Prep	Completed
December 15th, 2018	Subscale Launch Day & Ground Testing	Completed
December 16th, 2018	Subscale Post-Launch Inspection	Completed
December 19th, 2018	Vehicle Subscale build day to clean rocket and conduct post launch analysis	Completed
January 15th, 2019	Vehicle full scale design meeting	Completed
January 17th, 2019	Vehicle full scale design meeting	Completed
January 25th, 2019	Vehicle full scale design meeting	Completed
January 27th, 2019	Vehicle meeting	Completed
January 29th, 2019	Vehicle build day to CNC machine carbon fiber fins	Completed
January 31st, 2019	Vehicle build day to assemble fin can & program altimeters	Completed
February 1st, 2019	Vehicle build day to assemble fin can & nosecone shoulder	Completed

February 2nd, 2019	Vehicle build day to make altimeter bays and assemble fin can	Completed
February 3rd, 2019	Vehicle build day to make altimeter bays and load fin can	Completed
February 4th, 2019	Vehicle build day to start fin filets	Completed
February 7th, 2019	Vehicle build day to continue fin filets	Completed
February 9th, 2019	Vehicle build day to continue fin filets	Completed
February 10th, 2019	Vehicle build day to CNC machine ABS	Completed
February 12th, 2019	Vehicle build day to finish programming and wiring altimeters	Completed
February 14th, 2019	Vehicle build day to finish programming and wiring altimeters	Completed
February 18th, 2019	Vehicle build day to cut and tape shock cord, drill and tap shear pin holes, drill equalization holes for altimeters, sand and ensure couplers slide cleanly.	Completed
February 21st, 2019	Vehicle build day to install PDLS, install PDLS wire and tender descender, cut notch in nose cone shoulder for PDLS. ,	Completed
February 22nd, 2019	Launch Day Prep: test and fold parachutes, pack equipment, and prep for launch.	Completed
February 23rd, 2019	Full-Scale Initial Test Launch & Ground Testing	Completed
February 24th, 2019	Post-Launch Full-Scale Rocket Inspection and cleaning	Completed

February 25th, 2019	Post-Launch Full-Scale Rocket damage assessment for payload compartment that landed in water.	Completed
February 28th, 2019	Vehicle build day to fix damaged altimeters and run post launch simulations.	Completed
March 1st, 2019	Full Scale Launch 2 Prep and packing	Completed
March 3rd, 2019	Full Scale Launch 2 and post launch inspection	Completed
March 5th, 2019	Ground test booster section to determine best shear pin to black powder ratio to ensure main parachute does not deploy at apogee.	Upcoming
March 7th, 2019	Continue ground testing for booster section.	Upcoming
March 9th, 2019	Vehicle build day	Upcoming
March 10th, 2019	Vehicle build day	Upcoming
March 14th, 2019	Vehicle build day	Upcoming
March 15th, 2019	Prepare Full-Scale Rocket for Relaunch	Upcoming
March 16th, 2019	Full-Scale Test Launch 3	Upcoming
March 17th, 2019	If needed: Full-Scale Test Launch 4	Upcoming
March 18th, 2019	Post-Launch Full-Scale Rocket Inspection	Upcoming
March 30th, 2019	Prepare Full-Scale Rocket for Competition Week	Upcoming
April 6th, 2019	Competition Day	Upcoming

6.3.2.3 PAYLOAD TIMELINE

Table 54: Payload Timeline.

Date	Item Due	Status
August 23rd, 2018	NSL Payload Team Meeting	Complete
August 30th, 2018	NSL Payload Team Meeting	Complete
September 6th, 2018	NSL Payload Team Meeting	Complete
September 13th, 2018	NSL Payload Team Meeting	Complete
September 20th, 2018	NSL Payload Team Meeting	Complete
September 20th, 2018	NSL Payload Team Meeting	Complete
October 4th, 2018	NSL Payload Team Meeting	Complete
October 10th, 2018	Wireless Communications tests will be conducted for RF components	Complete
October 25th, 2018	NSL Payload Team Meeting	Complete
November 1st, 2018	NSL Payload Team Meeting	Completed
November 8th, 2018	NSL Payload Team Meeting	Completed
January 3rd, 2019	NSL Payload Team Meeting to review design and test electronics	Completed
January 10th, 2019	NSL Payload Team Meeting to review design and test electronics	Completed
February 7th, 2019	Cut fiberglass for deployment system	Completed
February 10th, 2019	Assemble deployment system and create payload prototype	Completed
February 7th, 2019	Send 3D printed body parts to printer	Completed

February 14th, 2019	Attach vacuum system to body, assemble body to wheels.	Completed
February 16th, 2019	Payload Retention Test and payload drive test on launch field terrain	Cancelled due to rain
February 23rd, 2019	Payload Retention Test and payload drive test on launch field terrain	Completed
February 24th, 2019	Post launch inspection & damage assessment, dry out items that got wet	Completed
February 25th, 2019	Check ability of electronics from water damage and submit order for replacement electronics	Completed
February 28th, 2019	Order new 3D printed body parts	Completed
March 1st, 2019	Payload build day to re configure new electronics	Completed
March 5th, 2019	Install flap on vacuum system to secure soil	Upcoming
March 7th, 2019	Payload build day to finalize and test deployment sequence.	Upcoming
March 8th, 2019	General testing to find any issues.	Upcoming
March 14th, 2019	Payload build day to install finalized XBees and conduct more range testing to make sure they will be sufficient on launch day.	Upcoming
March 16th, 2019	Third payload retention system test, mock launch day to test full deployment and movement sequence.	Upcoming
March 16th, 2019	If needed: Fourth payload retention system test, mock launch day to test full deployment and movement sequence.	Upcoming

March 19th, 2019	Post launch Inspection	Upcoming
March 21st, 2019	Final configuration and prep of Nautilus before competition week.	Upcoming
March 22nd, 2019	Final configuration and prep of Nautilus before competition week.	Upcoming

6.3.2.4 STEM ENGAGEMENT (TABLE AS OF EXPO)

6.3.2.4.1 SUMMARY OF NUMBERS

Table 55: Summary of participants

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect Interactions**	**Direct Interactions**	**Indirect Interactions**
Preschool-4	164		50	50
5-9	528		45	710
10-12	100		30	485
University students	10			80
Educators	11			30
Adult non-students	20	50	75	260

6.3.2.4.2 SUMMARY OF EVENTS

Table 56: Summary of Events

Event	Date	Participants	Description

Stampede	Oct 13, 2018	200	For this event, there was a College Facility Tour with visits to student organization/research tables on the tour. Members of our team set up a booth to talk to local high school students about our organization and the various projects we work on. We brought some of our rockets to display. We explained to students how different disciplines and majors are incorporated into our projects to fill the engineering, business, and administrative aspects of our teams.
Manatee County Engineering Day	Nov 09, 2018	50	For this event, there was college lab tours and demonstrations with visits to student organization/research tables. Members of our team set up a booth to talk to local high school students about our organization and the various projects we work on. We brought some of our larger rockets that were built for specific competitions and one of our Tripoli Level 1 certification rockets. We showed students the parts of the rockets including the parachutes, fins, and nosecones. We discussed the specific design of each rocket and what its function was. We shared with students what possibilities our university and organization can provide for them especially when it comes to valuable hands-on STEM experience. We explained to students how different disciplines and majors are incorporated into our projects to fill the engineering, business, and administrative aspects of our teams.
Museum of Science and Industry Drone Event	Nov 10, 2018	200	Our team was asked to participate at MOSI's drone event and work with some of their students who are a part of their Maker's Club. We had a table and showcased some of our rockets at the Drone Event.
Great American Teach in Pinellas County at Carwise Middle School	Nov 14, 2018	20	For this event, USF SOAR went to Carwise Middle School, a school in Pinellas County, to demonstrate and engage students in a hands-on STEAM activity. We taught the students how to make stomp rockets and launched them.

Great American Teach in Hillsborough County at McLane Middle School	Nov 15, 2018	51	For this event, USF SOAR went to McLane Middle School, a school in Pinellas County, to demonstrate and engage students in a hands-on STEAM activity. We taught the students how to make stomp rockets and launched them.
Mount Calvary Junior Academy School Visit	Nov 16, 2018	61	For this event SOAR went to the school Mount Calvary Junior Academy in order to teach them about rocketry and STEM education. We taught the students how to make stomp rockets and launched them.
Bulls Unite Day	Nov 17, 2018	75	For this event, there was a College Facility Tour with visits to student organization/research tables on the tour. Members of our team set up a booth to talk to local high school students about our organization and the various projects we work on.
Patio Tuesday - Student Org Showcase	Jan 11, 2019	30	For this event, various clubs and school organizations showcased themselves to other college students. Members of our team will set up a booth to talk to the university students about our organization and the various projects we work on. We brought some of our rockets. We want to share with students what possibilities the organization can provided for them especially when it comes to valuable hands-on, team and skill building STEM experiences. We explained to students how different disciplines and majors are incorporated into our projects in order to fill the engineering, business, and administrative aspects of our teams.

Pinellas County Engineering Day	Jan 17, 2019	20	This event was hosted by the College of Engineering at USF for Pinellas County schools. This event allowed students from multiple schools in the county to take a tour of the college. This event is a conference style event where the students move around to different stations in order to learn about what the college has to offer. Our purpose was to inform students of what we do and how we are able to teach them things that might not be offered at our University. USF does not have an Aerospace degree, so our organization allows students the opportunity to learn about Rocketry and other aerospace fields despite the University not having a dedicated department to it. This allows more students to be interested in USF event though they do not offer a degree directly related to the aerospace industry. At the event we showcased a couple of our rockets and discussed with the students how we are able to design, construct, and test them for competitions and festivals. We taught students about the functionality and importance of each piece to showcase the ability of our rockets. We talked about the various projects our organization participates in and the skills and benefits that can be gained from being a part of these kinds of projects.
Girl Scouts of West Central Florida	Jan 26, 27,28 2019 Feb 3,9 2019	180	Girl Scout troops of West Central Florida came to USF to build stomp rockets and learn about Rocketry. We started off with a presentation about some basic rocketry concepts, described the events we would be doing, and discussed our organization. We instructed the girls and even some parents how to build the rocket and once they were done, we went outside to launch them. The girls went in groups of four and once they launch, we had someone measure their distance and then record it. Once all the girls were launched, we put them into groups and had them write down what ways they could improve their rocket design and launch. Once finished, the groups went to the front of the room to present their ideas, we had one of our members write down the general concepts from each presentation. After each group was done presenting, we discussed the various different concepts and how they affect their rockets and even ours. We then took the top three rockets who had the farthest distance and reviewed how/why they might have gone the furthest

			based on the discussions we had previously had. After we were done analyzing the results, we gave out surveys to both the students and the parents in order to receive some more feedback. Girl Scouts who were Brownies were able to receive their Fling Flyer Badge other Girl Scouts were able to receive a custom badge or spirit badge depending on what the troop leader chose.
Bulls Unite Day	Feb 02, 2019	60	This event was for Bulls Unite Day. Members of our organization set up a table in the College of Engineering at the University of South Florida where the college was conducting informational tours to prospective students looking to go into STEM fields and to see what the University has to offer. We brought Apis II, our NASA student launch rocket from last year as well as one of our level 1 rockets. We taught participants about the functionality and importance of each piece to showcase the ability of our rockets. We talked about the various projects our organization is currently involved in and the skills and benefits all of them provide. We also explained how these projects allow students to get practical hands on experience with engineering that can be applied in class and in the industry.
Git Hub Event	Feb 08, 2019	11	This was a training session which focused on teaching the fundamentals of Git and GitHub to attendees. Topics included what Git and GitHub are and why they are different, how the tools work, and how they apply in the workplace. Attendees walked through a detailed live demo of the tools, including how to fork, clone, commit, push, pull, submit pull requests, track issues, resolve merge conflicts, and conform to standard industry best-practices. All active participants left with a working understanding of Git and GitHub and how they might implement those tools in current and future projects.
Engineering Expo	Feb 14-15, 2019	1,730	Engineering EXPO is a massive two-day event put on by the College of Engineering at USF. The event has copious participants including student organizations, local companies, and local schools. At our section we had three main components: a corn-hole game, stomp rockets, and a table setup. We had several different stomp rocket

			designs for participants to choose from. We discussed with each group the different nosecones, fin shapes, and overall design in order to teach them about how each component affects the rocket's flight. After the students learned some basic rocketry, they chose a rocket to launch. We kept a record of the longest flight from each group in order to show students how different design and launching techniques affect the distance traveled. We also had a showcase tent where we had our NSL rocket, APIS II, from last year as well as one of our member's Level 1 certification rocket. We discussed with student each component of the rocket and what their intended mission was when building them. For fun, we also had a homemade rocket cornhole game where students could win cool prizes like a space shuttle eraser or glider.

7 APPENDIX: A : CONTRIBUTORS

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8 APPENDIX B: MILESTONE REVIEW FLYSHEET

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(put flysheet ext page)

9 APPENDIX B: DETAILED MASS STATEMENT

Note: Masses are estimated based on component volumes and material densities or reported product masses from manufacturers. Some components are combined to simplify simulations, while some components (the PDLS, DAAS, and Payload) are 'allocated masses;' these subsystems must be less than the allocated masses, and additional mass will be added with ballast to account for any significant differences. This should not be considered a vehicle components breakdown, but rather a parameter of simulations.

Parts Detail

Upper Section

Part	Material	Diameter	Length	Mass
Nose Cone	Fiberglass (1.07 oz/in³)	Haack series	Len: 35 in	Mass: 3.25 lb
Shoulder	Kraft phenolic (0.549 oz/in³)	Dia$_{in}$ 5.74 in Dia$_{out}$ 5.92 in	Len: 9 in	Mass: 1.75 lb
Adjustable Ballast Subsystem (ABS)		Dia$_{out}$ 5.5 in		Mass: 0 lb
Bulkhead	Carbon fiber (1.03 oz/in³)	Dia$_{out}$ 5.74 in	Len: 0.187 in	Mass: 0 lb
Upper Section Shock Cords	Kevlar (9/16 inch & 2000 lb strength) (0.082 oz/ft)		Len: 300 in	Mass: 1.12 lb
Upper Section Main Parachute (FruityChutes Iris Ultra Standard 96")	Ripstop nylon (0.22 oz/ft²)	Dia$_{out}$ 96.063 in	Len: 4 in	Mass: 1.56 lb
Shroud Lines	Braided nylon (2 mm, 1/16 in) (0.011 oz/ft)	Lines: 12	Len: 96 in	
Upper Airframe	Fiberglass (1.07 oz/in³)	Dia$_{in}$ 5.92 in Dia$_{out}$ 6.1 in	Len: 57 in	Mass: 7.12 lb
Payload Descent Leveling Subsystem (PDLS)		Dia$_{out}$ 5.75 in		Mass: 0.312 lb
Upper Section Avionics Bay	Kraft phenolic (0.549 oz/in³)	Dia$_{in}$ 5.74 in Dia$_{out}$ 5.92 in	Len: 6 in	Mass: 2.37 lb
Upper Section Main Deployment Charge A		Dia$_{out}$ 0.984 in		Mass: 0.004 lb
Upper Section Main Deployment Charge B		Dia$_{out}$ 0.984 in		Mass: 0.004 lb
Forward Bulkhead	Carbon fiber (1.03 oz/in³)	Dia$_{out}$ 5.83 in	Len: 0.187 in	Mass: 0 lb
Upper Section Avionics		Dia$_{out}$ 4 in		Mass: 1.25 lb
Rear Bulkhead	Carbon fiber (1.03 oz/in³)	Dia$_{out}$ 5.83 in	Len: 0.187 in	Mass: 0 lb
Rover		Dia$_{out}$ 5.66 in		Mass: 4.1 lb
Deployment System		Dia$_{out}$ 5.92 in		Mass: 3.5 lb

Lower Section

Part	Material	Diameter	Length	Mass
Transition Band	Fiberglass (1.07 oz/in³)	Dia$_{in}$ 5.92 in Dia$_{out}$ 6.1 in	Len: 3 in	Mass: 0 lb
Lower Section Avionics Bay	Fiberglass (1.07 oz/in³)	Dia$_{in}$ 5.74 in Dia$_{out}$ 5.92 in	Len: 15 in	Mass: 4.69 lb

Lower Section Main Parachute (FruityChutes Iris Ultra Standard 84")	Ripstop nylon (0.22 oz/ft²)	Dia_{out} 84 in	Len: 5 in	Mass: 1.31 lb
Shroud Lines	Braided nylon (2 mm, 1/16 in) (0.011 oz/ft)	Lines: 12	Len: 83.858 in	
Lower Section Main Shock Cord	Kevlar (9/16 inch & 2000 lb strength) (0.082 oz/ft)		Len: 300 in	Mass: 0.5 lb
Lower Section Main Deployment Charge A		Dia_{out} 0.984 in		Mass: 0.008 lb
Lower Section Main Deployment Charge B		Dia_{out} 0.984 in		Mass: 0.008 lb
Forward Bulkhead	Carbon fiber (1.03 oz/in³)	Dia_{out} 5.83 in	Len: 0.25 in	Mass: 0 lb
Lower Section Avionics		Dia_{out} 4 in		Mass: 1.25 lb
Dynamic Apogee Adjustment Subsystem (DAAS)		Dia_{out} 5.75 in		Mass: 0 lb
Rear Bulkhead	Carbon fiber (1.03 oz/in³)	Dia_{out} 5.83 in	Len: 0.187 in	Mass: 0 lb
Drogue Deployment Charge A		Dia_{out} 0.984 in		Mass: 0.006 lb
Drogue Deployment Charge B		Dia_{out} 0.984 in		Mass: 0.006 lb
Lower Section Drogue Shock Cord	Kevlar (9/16 inch & 2000 lb strength) (0.082 oz/ft)		Len: 300 in	Mass: 0 lb
SkyAngle Classic 20" (Drogue Parachute)	Ripstop nylon (0.22 oz/ft²)	Dia_{out} 20 in	Len: 1 in	Mass: 0.331 lb
Shroud Lines	Tubular nylon (14 mm, 9/16 in) (0.172 oz/ft)	Lines: 3	Len: 20 in	
Lower Airframe	Fiberglass (1.07 oz/in³)	Dia_{in} 5.92 in Dia_{out} 6.1 in	Len: 43 in	Mass: 11.4 lb
Trapezoidal fin set (3)	Carbon fiber (1.03 oz/in³)	Thick: 0.187 in		Mass: 0 lb
Motor Mount Tube	Fiberglass (1.07 oz/in³)	Dia_{in} 3 in Dia_{out} 3.098 in	Len: 30 in	Mass: 0 lb
Upper Rail Lug	Acrylic (0.688 oz/in³)	Dia_{in} 0.315 in Dia_{out} 0.394 in	Len: 1.181 in	Mass: 0 lb
Lower Rail Lug	Acrylic (0.688 oz/in³)	Dia_{in} 0.315 in Dia_{out} 0.394 in	Len: 1.181 in	Mass: 0 lb
Forward Centering Ring	Carbon fiber (1.03 oz/in³)	Dia_{in} 3.098 in Dia_{out} 5.92 in	Len: 0.187 in	Mass: 0 lb

Middle Centering Ring	Carbon fiber (1.03 oz/in³)	Dia_{in} 3.098 in Dia_{out} 5.92 in	Len: 0.187 in	Mass: 0 lb
Rear Centering Ring	Carbon fiber (1.03 oz/in³)	Dia_{in} 3.098 in Dia_{out} 5.92 in	Len: 0.187 in	Mass: 0 lb

10 APPENDIX C: A ABBREVIATIONS

ABS
Adjustable Ballast Subsystem

AGL
Above Ground Level

APCP
Ammonium Perchlorate Composite Propellant

Apis III
Full-scale launch vehicle

Apis III-S
Subscale launch vehicle

CAD
Computer Aided Design

CAR
Canadian Association of Rocketry

CDR
Critical Design Review

CF
Carbon Fiber

CFR
Code of Federal Regulations

CG or C_G
Center of Gravity

CNC
Computer Numerical Control

CP or C_P
Center of Pressure

DAAS
Dynamic Apogee Adjustment Subsystem

dBi
Decibels-isotropic

deg
Degrees

E-Match
Electronic match

FAR
Federal Aviation Regulations

FEA
Finite Element Analysis

FMEA
Failure Modes and Effects Analysis

FOS
Factor of Safety

fps
Feet per second

FRP
Fiberglass-Reinforced Plastic

FRR
Flight Readiness Review

LiPo
Lithium Polymer

MSDS
Materials Safety Data Sheet

NAR
National Association of Rocketry

NASA
National Aeronautics and Space Administration

NFPA
National Fire Protection Agency

PDLS
Payload Descent Leveling Subsystem

PDLS-S
Payload Descent Leveling Subsystem - Subscale

PDR
Preliminary Design Review

PLAR
Post Launch Assessment Review

PVC
Polyvinyl Chloride

RAC
Risk Assessment Category

Req. No.
Requirement Number

ROAR
Regional Orlando Applied Rocketry

RF
Radiofrequency

RSO
Range Safety Officer

SDS
Safety Data Sheet; equivalent to MSDS

SO
Safety Officer

SOAR
Society of Aeronautics and Rocketry

STP
Standard Temperature and Pressure

TRA
Tripoli Rocketry Association

USF
University of South Florida