USLI

WORCESTER POLYTECHNIC INSTITUTE

G.O.A.T.S

USLI PROJECT Critical Design Review 2018 - 2019

January 11, 2019

Table of Contents

Acronym Dictionary

The Critical Design Review (CDR) uses a variety of acronyms. All of them are defined within this section.

- 3D – Three Dimensional
- A – Amps
- ABS – Acrylonitrile Butadiene Styrene
- AGL – Above Ground Level
- AIAA – American Institute of Aeronautics and Astronautics
- APCP – Ammonium Perchlorate Composite Propellant
- CCW – Counterclockwise
- CDR – Critical Design Review
- CG – Center of Gravity
- COM – Center of Mass
- CP – Center of Pressure
- CTI – Cesaroni Technology Incorporated
- CW – Clockwise
- DC – Direct Current
- E-Bay – Electronics Bay
- FAA – Federal Aviation Administration
- FEA – Future Excursion Area
- FMEA – Failure Modes and Effects Analysis
- FRR – Flight Readiness Review
- ft – Feet
- G.O.A.T.S. – Get Our Apogee to Space
- GPS – Global Positioning System
- GSSS – Garden State Spacemodeling Society
- IMU – Inertial Measurement Unit
- in – Inch
- KV – RPM per Volt
- lbf-ft – Pound Foot (torque)
- lb – Pounds
- LiPo – Lithium Polymer
- mAh – Milliamp Hours
- MMMSC – Maine Missile Math and Science Club
- MPU – Micro Processing Unit
- MSDS – Material Safety Data Sheets
- mW – Milliwatt
- N/A – Not Applicable
- NAR – National Association of Rocketry
- NASA – National Aeronautics and Space Administration
- PDR – Preliminary Design Review
- PLA – Poly Lactic Acid

- PPE – Personal Protective Equipment
- PWM – Pulse Width Modulation
- RDO – Range Deployment Officer
- RPM – Rotations per Minute
- RSO – Range Safety Officer
- SGA – Student Government Association
- s – Second
- STEM – Science, Technology, Engineering and Mathematics
- TRA – Tripoli Rocketry Association
- UAV – Unmanned Aerial Vehicle
- USLI – University Student Launch Initiative
- V – Volt
- WPI – Worcester Polytechnic Institute

Section 1. Summary

Section 1.1. Team Summary

Section 1.1.1. Adult Educators

Robert Dehate: Team Mentor
President AMW/ProX
NAR L3CC 75918 TRA 9956
robert@amwprox.com
(603) 566-2904

Section 1.2. Launch Vehicle Summary

The final Launch Vehicle design has a diameter of 6in, a length of 125in and a theoretical mass plus motors of approximately g. The vehicle, named Batman, has been designed to reach an apogee of approximately 4683ft. The Launch Vehicle will split into four main sections over the course of its decent that will each contain its own global positioning system (GPS) tracker. These consists of the upper airframe, the lower airframe, the payload retention system and the nose cone. Housed within the upper airframe will be the payload retention system made of airframe tubing dedicated to housing the selected payload for the duration of its flight. The vehicle will have three parachutes, a nose cone parachute, drogue parachute and main parachute. The launch vehicle's flight data will be recorded using a Raven 3 Altimeter that will be housed in the electronics bay.

Section 1.3. Payload Summary

Our selected payload is the deployable UAV beacon delivery system which our team has named Robin. The purpose of the payload system is to deliver a beacon to a Future Excursion Area. This task will be completed using a quadcopter which will be housed within an active retention system contained in the airframe of the launch vehicle during flight with its arms folded. To separate this retention section of the airframe from the main airframe a parachute will deploy after the activation of black powder charges at the appropriate altitude and pull it out. The housing will consist of bluetube cut into four separate pieces to allow it to unfold upon landing and orient itself to deploy the UAV to takeoff. Once the launch vehicle is visually confirmed to have landed and having received permission, it will power on and fly to a Future Excursion Area to deliver the beacon. The beacon will be a 3D printed small cube and will be secured to the bottom of the UAV with small linear servo used to drop it when the UAV reaches the Future Exertion Area.

Section 2. Changes Made Since PDR

Section 2.1 Launch Vehicle Changes

In terms of the launch vehicle there has only been a few change since the design proposed in the PDR. The change that was made falls into the recovery system of the launch vehicle. Originally, in order to accommodate the forces experienced by the main parachute and main parachute shock cord upon deployment, we had proposed a design that included an intermediate shock absorption system. This consisted of a section of bungee cord with aluminum links at each end. One link would have been connected to shock cord connecting the upper airframe and payload to a quick link attached to the bulkhead of the electronics bay. The other link would have been connected to the main parachute. Instead, we have now moved to a more reliable design that takes the shock cord and folds it over itself in a fashion known as. This will be secured using tape such that it easily comes apart upon parachute ejection from the airframe.

The other main change has to do with the Mission Performance Predictions. After acquiring the data for the subscale flight, which can be viewed in more detail in section 3.3.2., we found that the additional weight added to the subscale due to epoxy, nuts, bolts, u-bolts, nomex blankets, parachutes, etc. had a significant impact on its during flight apogee. The added additional weight was approximately 550g. Therefore, we took this additional weight and added it to the full scale vehicle simulations to have a better grasp on our predicted apogee value. In doing this, we now aim to shoot for an apogee of approximately 4,500ft AGL as the simulation with the theoretically added weight places the full scale value at an apogee of 4683ft AGL. Due to this for the purpose of this document we will address the launch vehicle in two different fashions: weighted and unweighted. In other words simulations and values have been given for both the weighted and unweighted depictions of the launch vehicle.

Additionally other issues that needed to be addressed dealt with the calculations for the PDR Flysheet. In a few places a wrong unit was entered and that has now been fixed. Furthermore, the team originally had interpreted calculating the kinetic energy for each independent section as only two sections, the tethered main rocket body and the nose cone. Instead it is now fixed such that the kinetic energy for the four subsections separated during flight are calculated tethered to the main rocket body or not. Therefore, the flysheet now represents data for the kinetic energy of the upper airframe, lower airframe, nose cone, and tethered airframe retention system.

It was determined through field tests that the NRF24L01 transceiver modules were insufficient for the ranges required for successful communication between the launch vehicle, payload, and ground station. As a result, the Adafruit RFM95W LoRa transceivers were selected as our new radio communication system for their known range capabilities and good performance when tested.

Section 2.2. Payload Changes

In terms of Payload changes the UAV will no longer be human controlled. The team has now decided to use autonomous flight to pilot the UAV due to the fact that the autonomous capabilities and telemetry of the Pixhawk Mini is reliable enough that a human pilot is unnecessary. The UAV will thus be piloted via commands from the ground station with specific GPS locations. This also eliminates the necessity of the FPV camera as there's no need for a human pilot to view live feed from the UAV.

Section 2.3. Project Plan Changes

In terms of project plan changes, the team's officer board convened to include the Team Derived Requirements and Verification Plans. Additionally, due to budget cuts, the budget has changed and WPI's AIAA chapter will currently only be covering funding for parts and necessary materials and tools for the construction of the Launch Vehicle and Payload. All other expenses such as travel will be covered by corporate sponsorship. The new budget can be viewed in more detail in section 6.3. The Gantt chart as also been reorganized to better fit the progression of this year.

Section 3. Vehicle Criteria

Section 3.1. Mission Statement, and Mission Success Criteria

Section 3.1.1. Mission Statement

Our mission is to successfully fly our Launch Vehicle design on an L level motor to a goal apogee of 4500ft AGL. It is our goal to then successfully ensure the Launch Vehicle's safe descent as well as the protection of the payload housed within it. Upon reaching apogee, the drogue parachute will be ejected from the lower airframe via black powder charge. This will aid in the Launch Vehicle's initial descent. Then, upon reaching 700ft AGL the Launch Vehicle will deploy a larger main parachute via another black powder charge. Connected to the main parachute and upper airframe by shock cord, the payload retention system will then be ejected from the upper airframe via another black powder charge. This retention system is composed of its own piece of airframe. Additionally, this charge will separate the nose cone from the upper airframe. The nose cone will then continue its own descent separate from the rest of the launch vehicle with its own parachute. Through test flights, calculations, simulations, and collaborative team brainstorming we have come up with a design we feel best meets the criteria of the mission while also solidifying our team with the best chances of success.

Section 3.1.2. Mission Success Criteria

1. All materials and components necessary to the success of the launch vehicle are working and accounted for before attending a test launch or traveling to competition.
2. All components are placed correctly within the Launch Vehicle when assembling it for launch.
3. Raven 3 Altimeter is programmed and oriented correctly as well as safely housed within the electronics bay such that flight data can be received and analyzed after launch.

4. Every section of the launch vehicle along with the payload is equipped with a GPS tracking device that is checked to be successfully transmitting data such that each piece can be easily found after launch.
5. Nomex blankets are placed such that black powder charges will cause no damage to parachutes or other devices within the Launch Vehicle
6. Launch vehicle then must be set up on the launch pad. This will only be done by a member or mentor that holds at least a level 2 certification. They will switch on the altimeter and check for continuity of charges. They will then proceed to clear the launch pad.
7. Reach an apogee of at least 4500ft AGL.
8. Upon reaching apogee a black powder charge will deploy the drogue parachute separating the upper and lower airframes
9. At 700ft AGL a second black powder charge will deploy the main parachute, payload retention system and nose cone.
10. The nose cone will continue its own descent with its own parachute separate from the rest of the launch vehicle which will continue to descend via the main parachute and drogue parachute.
11. Safely descend such that there is negligible damage to the Launch Vehicle upon impact with the ground ensuring its ability to be flown more than once.
12. After confirming all sections of the launch vehicle have safely landed on the ground and receiving permission to activate it, the payload retention system will unfold to release the UAV
13. The UAV will be remotely piloted to fly to a Future Excursion Area
14. Once appropriately positioned, the UAV will release the beacon to drop it onto the Future Excursion Area
15. The UAV will safely fly away, land, and power down

Section 3.2. Design and Verification of Launch Vehicle

Section 3.2.1. Introduction

In this section we go into the finalized design and materials for the Launch Vehicle and all of its components. We will focus on the overarching airframe and then discuss in depth the five main sections crucial to the Launch Vehicle's success: the nose cone, upper airframe, lower airframe, electronics bay, and payload retention system.

Figure 3.2.1.1 Full Scale Assembly

Section 3.2.2. Airframe

The launch vehicle airframe will be constructed out of 6in x 0.074in Blue Tube 2.0. Manufactured by Always Ready Rocketry, Blue Tube is defined as a vulcanized cardboard laminate and is known for its high density and strength. The Blue Tube 2.0 is also heat resistant.

Blue Tube was selected for the finalized design because it is highly resistant to abrasion, cracking, shattering and other forms of damage. This is essential in order for the launch vehicle to be recoverable and flown on multiple occasions, ruling out other alternatives such as phenolic for its lack of strength and durability.

In terms of weight and price point carbon fiber was the lightest but most expensive reliable option, Blue Tube being next with a heavier weight than carbon fiber but still light enough with a cheaper price point. Finally, fiberglass was the heaviest and most expensive option making it an easy alternative to discard. It was important to choose a material that was not too heavy in order to come as close as possible to the goal of an apogee between 4000ft AGL and 5500ft AGL for competition. Carbon fiber is a conductive material. This means devices that must transmit to the ground station from within the airframe could be blocked completely and unreliable in competition. This problem is eliminated with the reinforced paper tube that is Blue Tube. Therefore Blue Tube proved to be the best airframe option and WPI’s final airframe material selection for the final launch vehicle design as it is light, durable, at a good price point, and not a conductive material, meaning little to no interference with on-board devices. This should ultimately ensure a successful launch, execution of all required tasks and recovery.

In terms of the airframe layout, the upper and lower airframes will be connected by a blue tube tube coupler that will house the altimeter and electronics bay of the launch vehicle. The tube coupler serves not only as a form of extra protection for the instruments contained inside but also as a simpler way to access the launch vehicle’s electrical components. The coupler is referred to as the electronics bay and houses two Raven 3 altimeters that will act as the primary and secondary flight computers for the launch vehicle.

The height of the launch vehicle was determined due to the stability in correspondence with the moment arm of the vehicle. A taller rocket increased the stability therefore putting the current height of the vehicle at 10’ 5” or 125in tall. This height is adequate to house the payload retention system, the payload, the recovery system (including the electronics bay) and the payload without any crowding around devices, parachutes, nomex blankets, or energetics that may cause damage or interference to the packed or electrical components contained within the airframe. Figures 3.2.2.1. and 3.2.2.2. show an OpenRocket depiction of the finalized launch vehicle design in a side and 3D finished view.

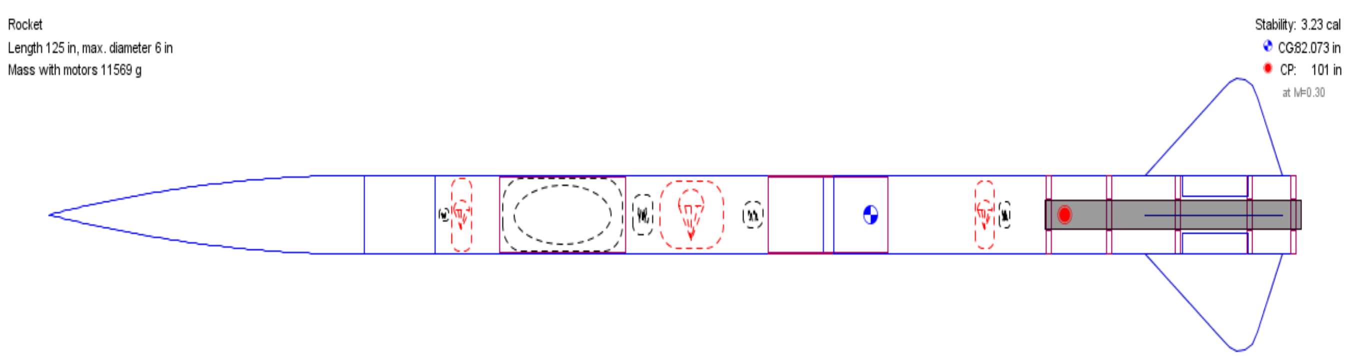


Figure 3.2.2.1. full scale OpenRocket Side View

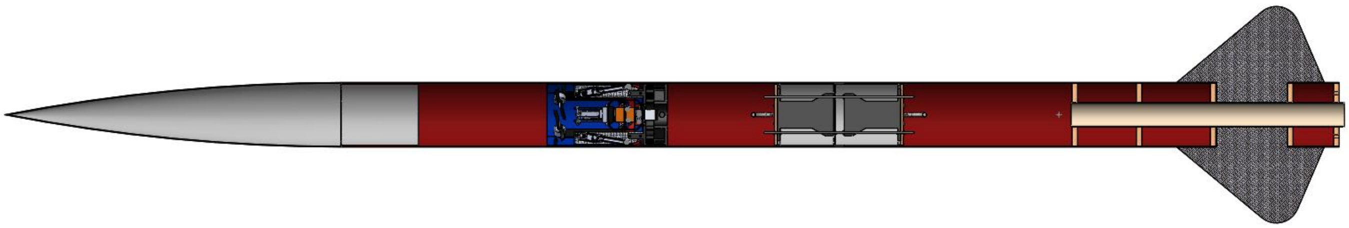


Figure 3.2.2.2. Full Scale Assembly Section View

Section 3.2.3. Nose Cone

The final nose cone selection has a length of 31.5in, a diameter of 6in, and wall thickness of 0.079in. The team settled upon an ogive shape that is made of fiberglass and weighted with a metal tip. Figure 3.2.3 shows the model of the nose cone.

The team considered multiple other nose cone options throughout the design process with the original launch vehicle design including a fiberglass conical nose cone. This decision was made to move to an ogive shape because of the positive aerodynamic properties compared to conical nose cones. Due to this, the team found this change was necessary in order to reduce the drag experienced by the launch vehicle.

Other options for nose cone shapes consist of parabolic, elliptical, biconic, and spherical blunted. For transonic speeds, the conical and ogive nose shapes are preferred. In cases of supersonic speed, shapes such as parabolic, spherical blunted, and biconic nose types are preferred. The launch vehicle will not be traveling at supersonic speeds, so a conical or ogive nose cone is a better fit in terms of design. Based on these options for the predicted speeds the launch vehicle will experience, the team felt it best to choose the more aerodynamic option of the two. When ultimately choosing between a fiberglass conical and fiberglass ogive nose cone, the team felt that the material and overall aerodynamic properties of the ogive nose cone made it the best decision for our final launch vehicle.

Specifically, the metal tipped ogive nose cone was chosen to counteract the weight of the launch vehicle's carbon fiber fins. With the original conical nose cone in place, the carbon fiber fins caused the launch vehicles stability to drop significantly due to the added weight. By choosing a metal tipped nose cone we were able to restabilize the launch vehicle as the metal balanced out the gained weight due to the carbon fiber.

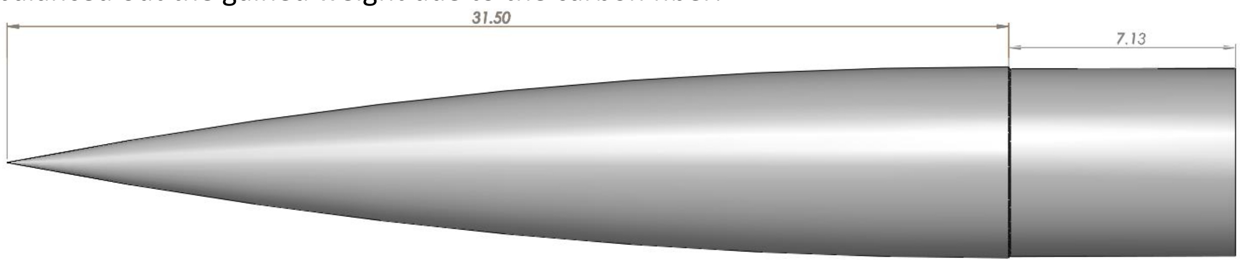


Figure 3.2.3.1. Nose Cone

Section 3.2.4. Upper Airframe

The upper airframe of the finalized launch vehicle design houses the selected payload, payload retention system/airframe, the nose cone parachute, and main rocket body parachute. Figure 3.2.4.1. displays the 3D finished layout of the upper airframe as displayed by Open Rocket with numbers assigned to the individual components. The component name for each number can be found below in table 3.2.4.2. This section focuses on finalized payload and payload retention system design. Parachute parameters and recovery design can be found in section 3.4.

The upper airframe contains a section of airframe inner tube approximately 12.5in in length that will act as the UAV's active retention system, made of blue tube, a material we continue to use due to its durability and utility. It is pushed out at 700ft AGL with the nose cone, nose cone parachute, and main parachute. The retention system is further detailed in Section 5.

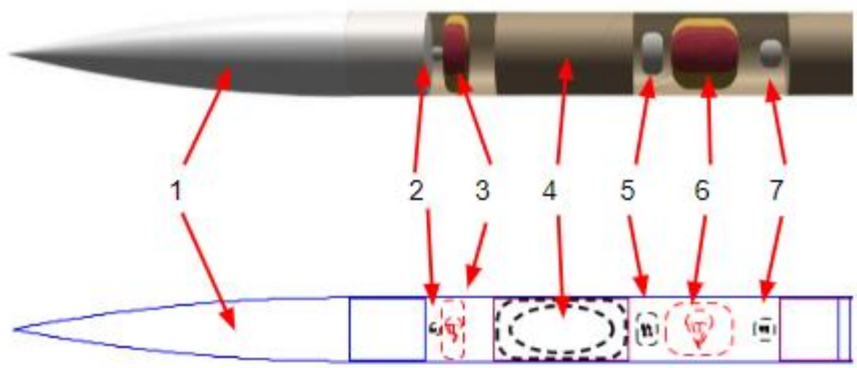


Figure 3.2.4.1. Upper Airframe

Component Number	Component Name
1	Nose Cone
2	Nose Cone Shock Cord
3	Nose Cone Parachute
4	Payload
5	Shock Cord
6	Main Parachute
7	Main Shock Cord

Table 3.2.4.1 Upper Airframe Component List

Section 3.2.5. Lower Airframe

For this section of the launch vehicle the main concerns centered around the finalized fin shape and material, motor selection and motor tube, and number of centering rings. Nothing within the lower airframe was changed between the PDR and the CDR. Figure 3.2.5 displays the 3D finished layout of the lower airframe as displayed by Open Rocket with numbers assigned to the individual components. The component name for each number can be found below in table 3.2.5.2.

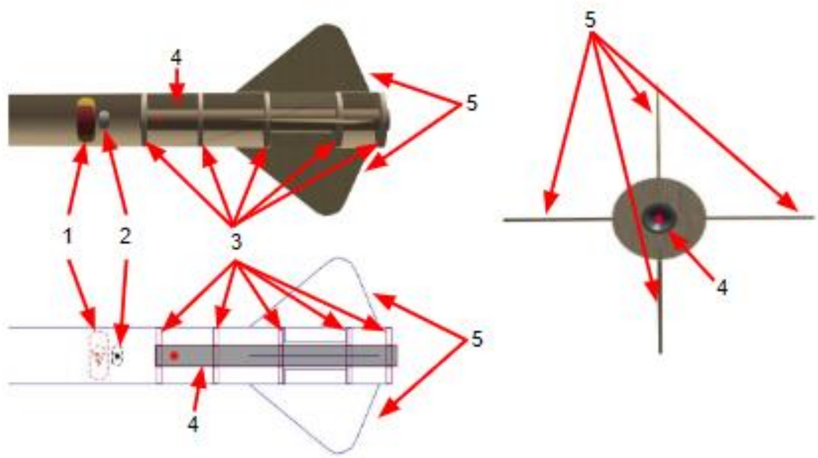


Figure 3.2.5.1. Lower Airframe

Component number	Component name
1	Drogue Parachute
2	Drogue Shock Cord
3	Centering Rings
4	Motor Tube
5	Fins

Table 3.2.5.2. Lower Airframe Component List

Section 3.2.6. Fins

The chosen fin material for the final launch vehicle has been decided to be quarter inch thick carbon fiber. The original design of the launch vehicle included four fins that were going to be made of plywood. The team had originally chosen to work with plywood as it was the chosen material for most fins made by our American Institute of Aeronautics and Astronautics (AIAA) chapter. We quickly realized, however, that with the greater competition USLI offers and with the growing size of the launch vehicle, that the impact speed it would experience upon hitting the ground would be around 26.7ft/s which is a high impact speed for a material like plywood to withstand due to its low durability.

When comparing the weight of carbon fiber to other materials considered for fin design the team found that carbon fiber is lighter than materials such as fiberglass. This was a good sign as we knew with this material being heavier than plywood that changing the fins to this material could have a negative effect on the stability of the launch vehicle. We found that carbon fiber was very strong and could withstand the speed of our ground hit velocity, and that it is a more rigid material, allowing the rocket to experience minimal flex patterns. Due to the fact that at high speeds highly flexible fins can be prone to fluttering we felt that carbon fiber would be a more reliable material in regards to rigidity. In regards to toughness we found that the shape of carbon fiber will not change when a consistent and constant force is applied to it. Although materials like fiberglass can withstand higher forces for longer amounts of time than carbon fiber due to its flexibility, rigidness was valued more for the following reason. We felt it was important to consider thermal characteristics and the effect weather might have on this material due to our specific location. Since we are located in New England most of our test launches will occur during the colder months. We needed a material that wouldn't deform too much in the cold as we prepared for competition. Ultimately we found that carbon fiber has a negative coefficient of thermal expansion, meaning carbon fiber will shrink or expand less than other comparable materials when exposed to extreme weather conditions. Although carbon fiber is a more expensive material due to its difficulty to manufacture, we felt that the overall benefits it had in regards to thermal characteristics, strength, rigidity, and weight outweighed the negatives of expense and toughness making it our choice of fin material for the final launch vehicle design.

Additionally, The final shape of the fins will remain the more rounded triangular shape rather than the jagged trapezoidal shape considered in our original design. This was in order to benefit the launch vehicle aerodynamically in terms of drag. Therefore, the curvature of these fins allows for there to be less drag during liftoff. The final fin dimensions can be seen below in figure 3.2.6.1

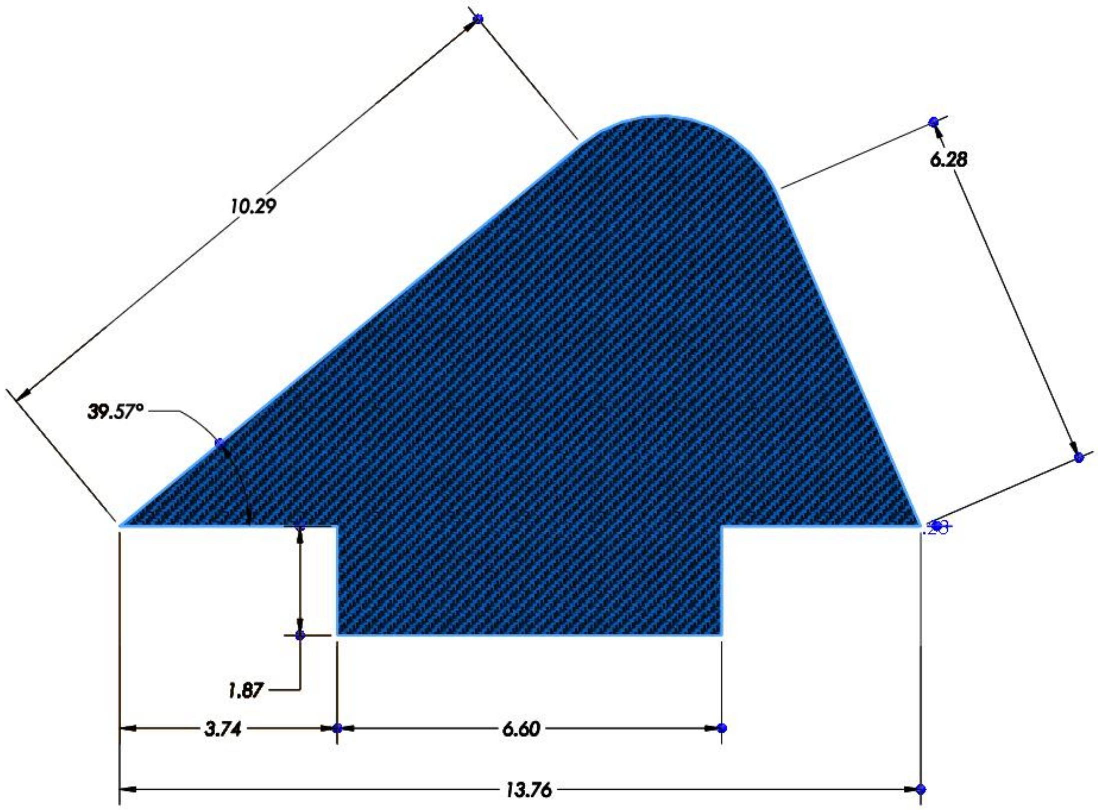


Figure 3.2.6.1. Carbon Fiber Fins

Section 3.2.7. Motor and Motor Tubing

In this section we will perform a dimensional analysis of the motor and its tubing in the lower airframe. The chosen primary motor selection for the final launch vehicle design is the L730-0 with the secondary motor selection being the L1030. The L730-0, manufactured by Cesaroni Technologies proved to be the best option for the team in order to reach our goal apogee while also complying with the 90 second decent time limit set by NASA. More about the selection process for the primary and secondary motors can be found in section 3.5. Mission Performance Predictions. The motor tubing will be made from blue tube like the outer airframe of the launch vehicle.

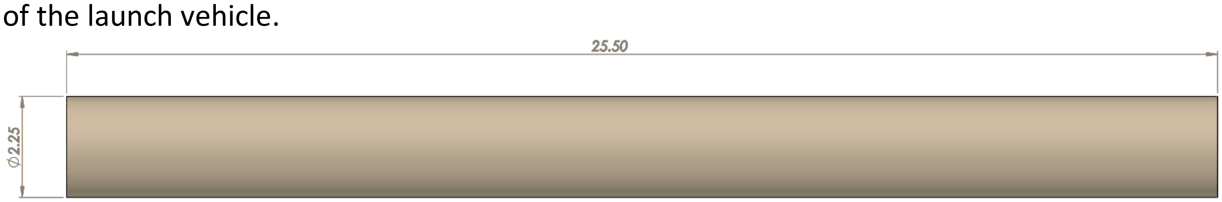


Figure 3.2.5.2.1

Section 3.2.8. Centering Rings

The amount of centering rings located on the motor mount within the lower airframe is five. the centering rings act to help with stability of the motor tube and ensuring its rigidity within the launch vehicle. Centering rings will be laser cut from quarter inch plywood and attached to the motor tubing using epoxy. The bottomost centering ring will have two holes drilled into it for installing the motor retention. The selection motor retention will consist of nuts, bolts, washers, and Z-clips. The upper most centering ring will additionally contain two holes drilled into it for the U-bolt that will connect the shock cord in the lower airframe.

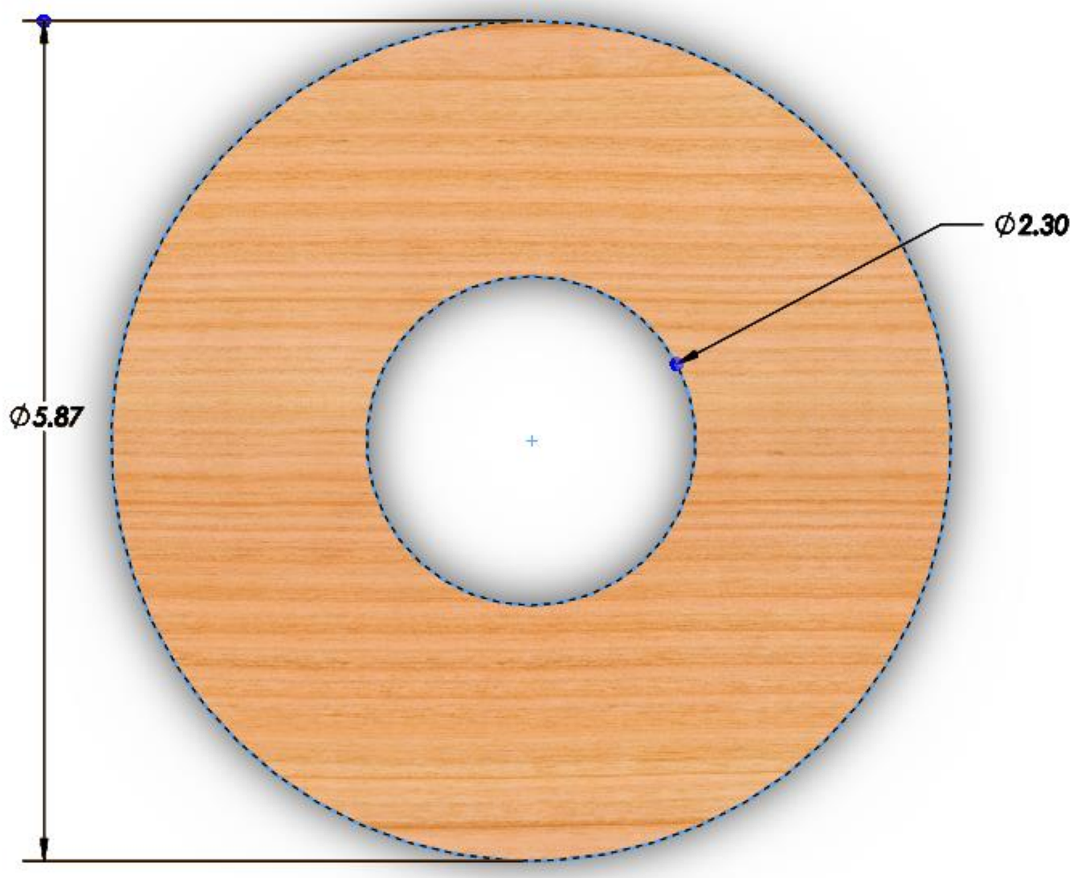


Figure 3.2.8.1. CAD of Centering Rings

Section 3.2.9. Electronics Bay Coupler

The final electronics bay design will be made of an inner tube coupler. The coupler will be composed of bluetube with a 1in ring of the outer airframe tubing epoxied in the middle. This is so that the upper airframe and the lower airframe can slide into place and be held together by screws and shear pins. The upper airframe will be bolted to the electronics bay coupler with screws so that when the black powder charge associated with an altitude of 700ft goes off, the coupler will not be pushed out with the parachutes and shock cord.

The lower airframe will be connected to the coupler using shear pins allowing the lower airframe to separate from the rest of the airframe by shearing the shear pins when the apogee black powder charge goes off. However, the lower airframe will still be connected to the rest of the launch vehicle via shock cord. The coupler will have two bulkheads made of 0.25in plywood supported by small rings of bluetube. The bulkheads will have two threaded aluminum rods that run through each side. There will be 2 nuts on each side (8 total) of the bulkhead on both rods to secure them. Each bulkhead will have a U-bolt to connect the shock cord. There will be an access point on the main body of the launch vehicle with a toggle switch to turn the Raven 3 altimeter on/off. Charges will also be wired to the outside of the electronics bay so that they are easily replaceable or fixable.

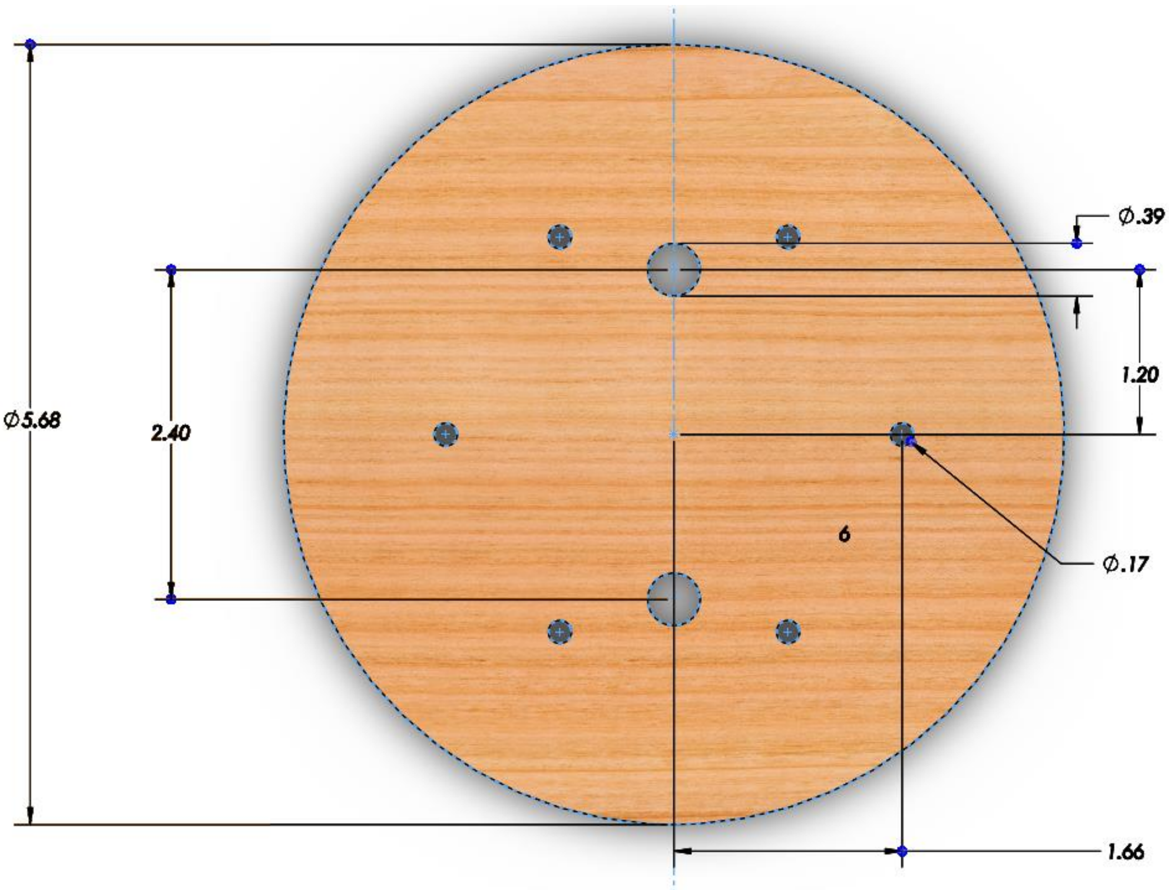


Figure 3.2.9.1. Bulkhead

Inside the inner tube, a 3D printed Poly Lactic Acid (PLA) sled will house two Raven 3 altimeters, a NEO-6M, a 9V battery, and wires. The sled will be attached to the two aluminum rods. One Raven 3 altimeter will be used for backup charges in case of a failure in the primary altimeter. We will be using the barometer feature of the Raven 3 because it is accurate in detecting the altitude of apogee and dual deployment during flight. It also has an accelerometer feature, but that assumes a vertical path which will throw the altitude value off over time. To counteract this we will be using a discrete Inertial Measurement Unit (IMU) to measure acceleration.

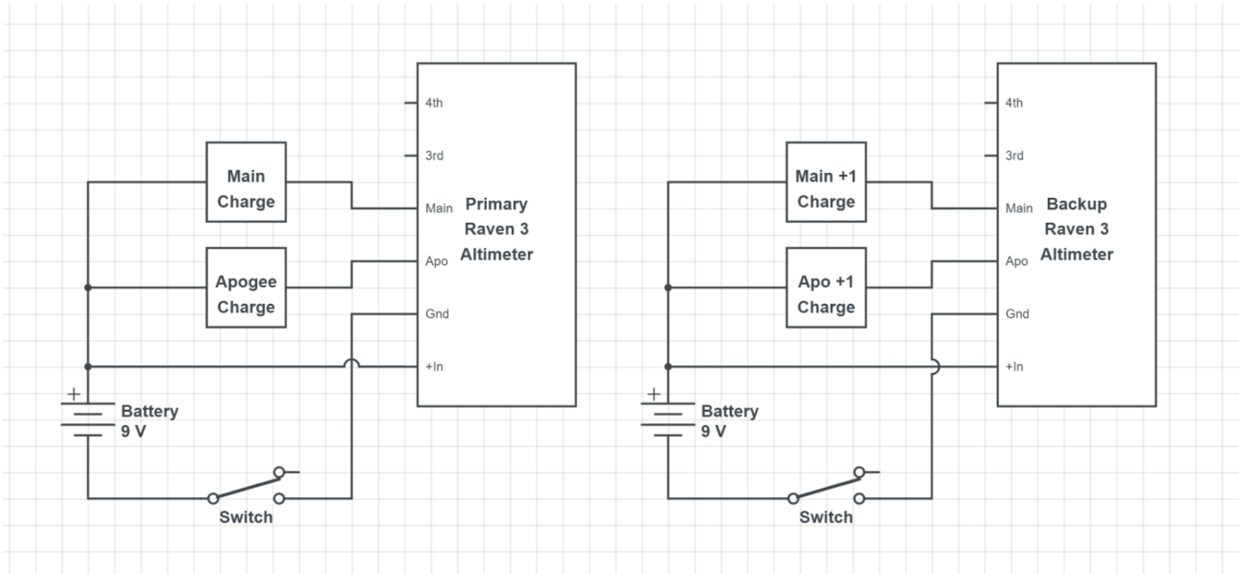


Figure 3.2.9.2. E-Bay Circuit Diagrams

Multiple methods were considered in terms of charges used in ejecting systems of the launch vehicle. We could have used a method with CO_2 or black powder. However, CO_2 is more expensive, heavier, larger, and still required us to use a small amount of black powder. We initially considered using CO_2 because it is more reliable at higher altitudes, but the launch vehicle will not get to a height that will cause this to have a significant effect.

When deciding how the electronics bay would be laid out we had the option of fixing a sled to the inside or attaching a wooden block to the center of the inner tube. The sled quickly became the more logical route because it would be hard to support the battery on a flat plane. Screwing components to the wood could cause splits and keeping components vertical would be difficult without physical blocking.

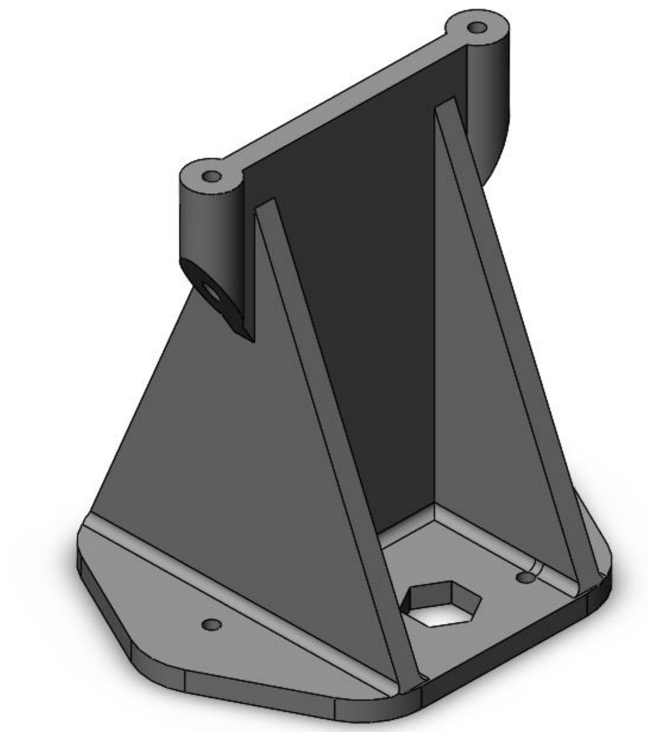


Figure 3.2.9.3 E-Bay Sled

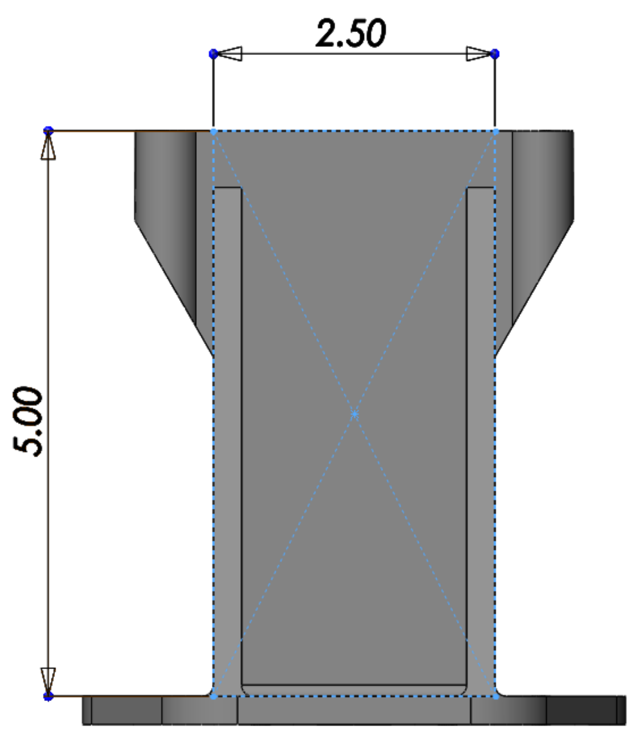


Figure 3.2.9.4. E-Bay Mount Bottom View

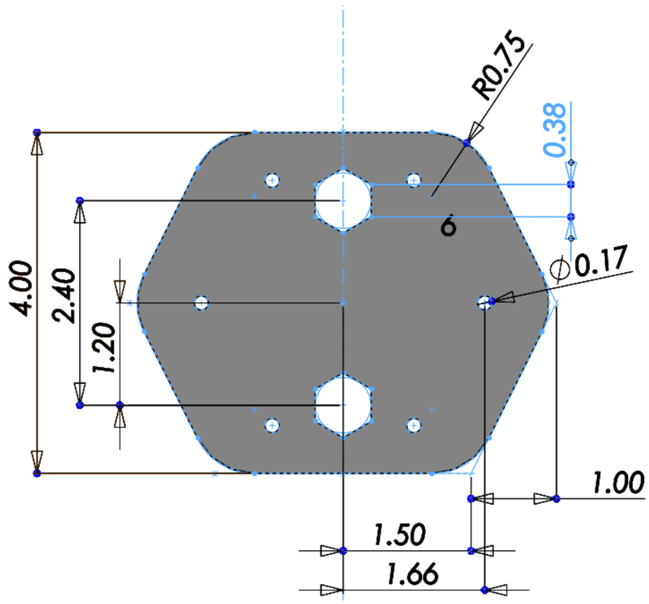


Figure 3.2.9.5. E-Bay Sled Bottom View

The chosen switch for the final launch vehicle is a toggle switch because our team was familiar with the device as it has been used in prior years by our AIAA chapter. We considered using a magnetic reed switch because it would be more aerodynamic and if we could use it we would not necessarily need a hole in the side of the airframe for the switch. After we looked into it more we found that reed switches are used more for a temporary state of on/off and we were looking for something that would stay on after triggered in order to comply with the rules set by NASA. This made the rotary toggle switch the most reliable and efficient option for competition.

Figure 3.2.9.6. Arming Switch

We also considered using Acrylonitrile Butadiene Styrene (ABS) instead of PLA for the construction of the sled. ABS is an oil based thermoplastic which has a higher melting point but can warp upon cooling. PLA is made from organic material so it is safer to use but it is weaker than ABS. We went with PLA because melting point was not a concern in this project and PLA is capable of a higher level of detail and is less prone to errors.

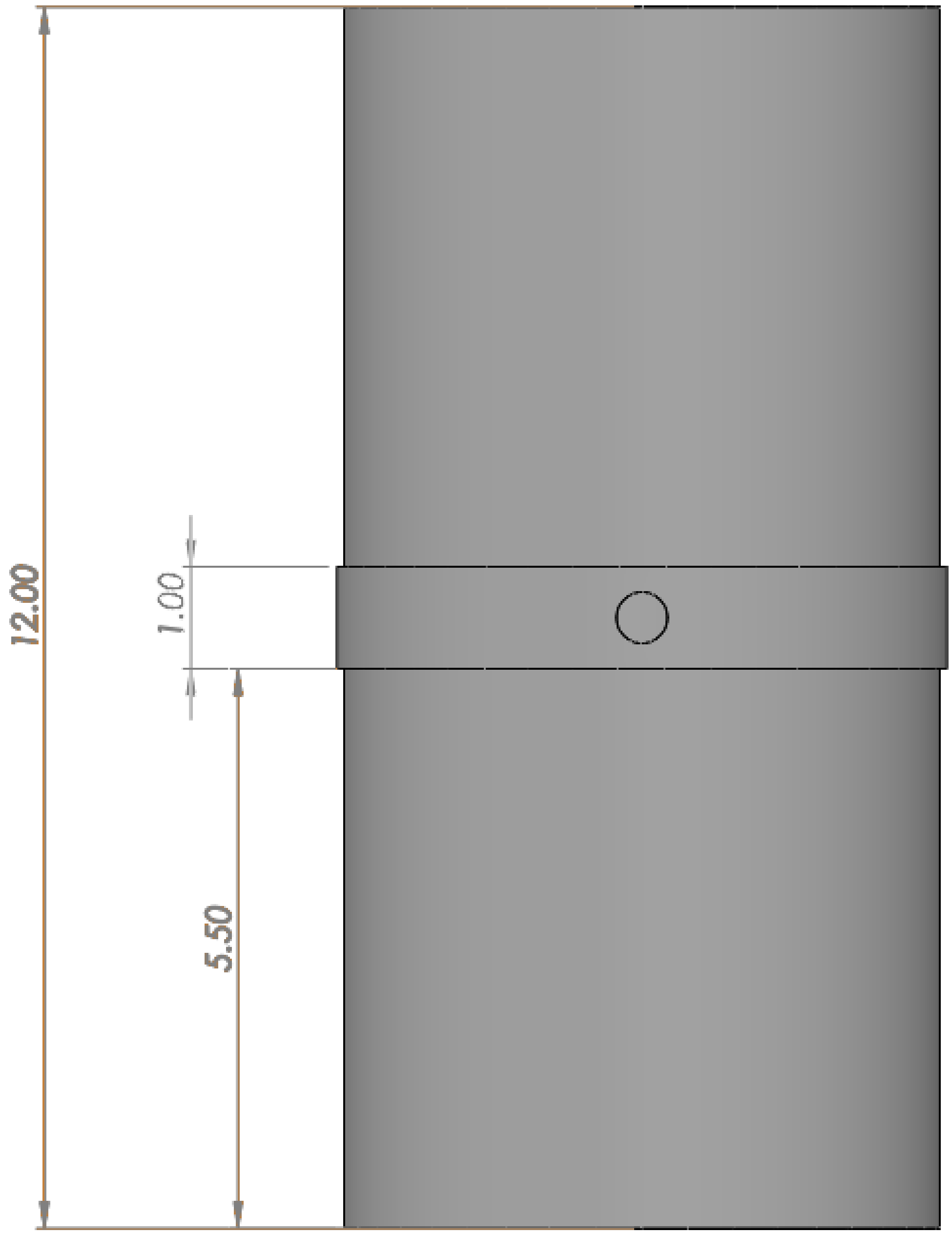


Figure 3.2.9.7. Electronics Bay Exterior

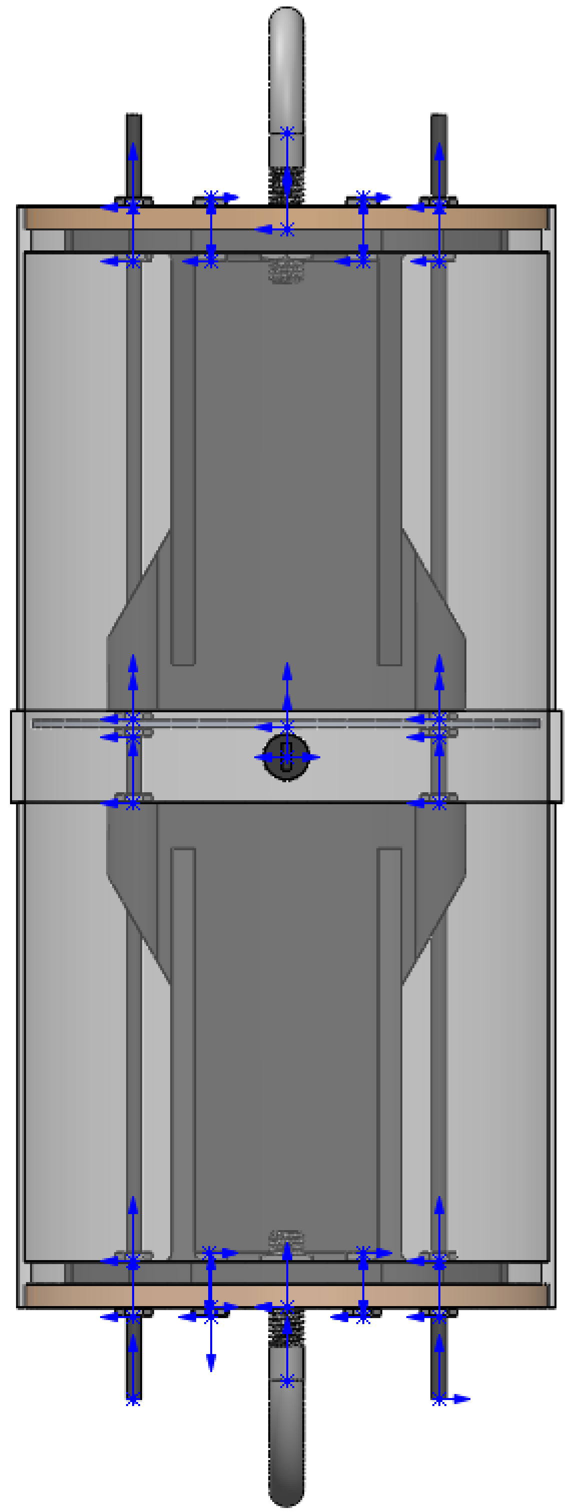


Figure 3.2.9.8. Electronics Bay Assembly

Section 3.2.10. Integrity
The centering rings within the lower airframe offer further stability and structure to the launch vehicle. Due to the length of the vehicle, five centering rings were chosen to offer the needed support to the motor tube and vehicle itself.

The inner tube's two plywood bulkheads are being supported by a small ring of bluetube along with threaded aluminum metal rods that run through the middle. There will also be an added support of two nuts on each side, 8 total. Each bulkhead will also have a U-bolt for the purpose of connecting the shock cords to the different sections of the launch vehicle. When the shock cord pulls the bulkhead the aluminum rod pulls the other bulkhead, which is stuck in place by the bluetube ring blocking its movement. The bolts prevent the aluminum rods from sliding through the plywood. The integrity of the bulkheads themselves are sound due to the metal rods, supporting bluetube rings and the nuts securing them in place.

The rocket will have a primary and secondary motor, the L730-0 and L1030-RL, respectively. These motors are capable of getting the rocket to the maximum allowed altitude and keep within the 90 second decent limit.

The launch vehicle's fins are made of carbon fiber in order to reduce the likeliness of damage during a landing at our vehicle's anticipated ground hit velocity. Carbon fiber is also a very rigid material, while at high speed some materials are susceptible to flex while carbon fiber is less so, making it a much more reliable material. This material also has a low sensitivity to heat and cold, making the temperature during launch a non-issue. A rounded triangular shape was chosen as the final fin shape because of its ability to reduce drag during liftoff, benefitting the overall aerodynamics of the vehicle. Along with the fins, the fin tabs were made smaller to accommodate the weight of the carbon fiber in the fins and ensure the vehicle is as light as functionally possible.

When coming to our final design we thought about the total weight of the launch vehicle and all its sub-systems. It was important for us to keep the weight down when choosing materials so that we can include everything that we need without making the rocket too heavy.

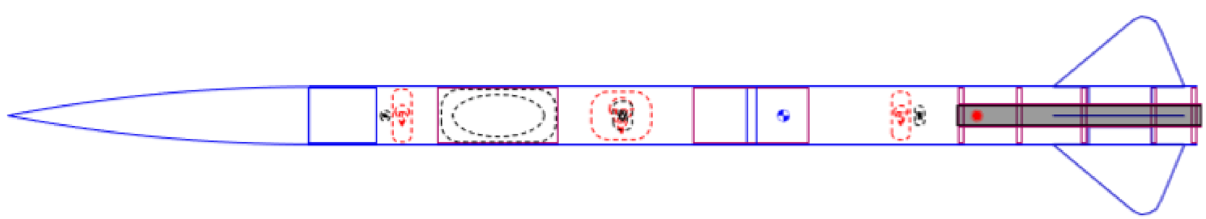
Launch Vehicle Masses

Nose Cone	435g
Upper Airframe	1346g
Innertube	300g
Main Parachute	243g
Payload	1056g
Nose Cone Parachute	47.2g

Nose Cone Shock Cord	11.6g
2 Shock Cords	456g (228g each)
Electronics Bay	29.3g
Tube Coupler	200g
Lower Airframe	1354g
5 Centering Rings	29.3g
Fin Set	1750g
Drogue Parachute	47.2
Innertube	232g
Total Mass	11.506kg

Table 3.2.10.1 Estimated Final Mass Breakdown Unweighted

Rocket Design



Rocket
Stages: 1
Mass (with motor): 11687 g
Stability: 3.38 cal
CG: 81.19 in
CP: 101 in

L1030-RL-0

Altitude	4646 ft
Flight Time	109 s
Time to Apogee	16.4 s
Optimum Delay	13.8 s
Velocity off Pad	43.2 ft/s
Max Velocity	663 ft/s
Velocity at Deployment	60.5 ft/s
Landing Velocity	23.6 ft/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
L1030-RL	1038 N	2.68 s	1539 N	2781 Ns	8.99:1	1520 g	2.13/25.6 in

L730-0

Altitude	4659 ft
Flight Time	110 s
Time to Apogee	16.8 s
Optimum Delay	13 s
Velocity off Pad	43.7 ft/s
Max Velocity	603 ft/s
Velocity at Deployment	60.8 ft/s
Landing Velocity	23.7 ft/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
L730	738 N	3.74 s	1217 N	2764 Ns	6.44:1	1351 g	2.13/25.6 in

Parts Detail

Sustainer

	Nose cone	Fiberglass ($1.85\ g/cm^3$)	Ogive	Len: 31.5 in	Mass: 1435 g
	Upper Airframe	Blue tube ($1.3\ g/cm^3$)	Dia_{in} 5.852 in Dia_{out} 6 in	Len: 45.85 in	Mass: 1855 g
	Main Parachute	Ripstop nylon ($67\ g/m^2$)	Dia_{out} 84 in	Len: 6.3 in	Mass: 243 g
	Shroud Lines	Elastic cord (round 2 mm, 1/16 in) ($1.8\ g/m$)	Lines: 6	Len: 11.811 in	
	Inner Tube	Cardboard ($0.68\ g/cm^3$)	Dia_{in} 5.781 in Dia_{out} 5.811 in	Len: 12.567 in	Mass: 300 g
	Payload		Dia_{out} 5.5 in		Mass: 1056 g
	Nose Cone Parachute	Ripstop nylon ($67\ g/m^2$)	Dia_{out} 36 in	Len: 1.984 in	Mass: 47.2 g
	Shroud Lines	Elastic cord (round 2 mm, 1/16 in) ($1.8\ g/m$)	Lines: 6	Len: 11.811 in	
	Nose Cone Shock cord	Tubular nylon (25 mm, 1 in) ($29\ g/m$)		Len: 50 in	Mass: 36.8 g
	Shock cord	Tubular nylon (25 mm, 1 in) ($29\ g/m$)		Len: 184 in	Mass: 135 g
	E-Bay.com	Blue tube ($1.3\ g/cm^3$)	Dia_{in} 5.852 in Dia_{out} 6 in	Len: 1 in	Mass: 29.3 g
	Tube coupler	Blue tube ($1.3\ g/cm^3$)	Dia_{in} 5.704 in Dia_{out} 5.852 in	Len: 12 in	Mass: 200 g
	Lower Airframe	Blue tube ($1.3\ g/cm^3$)	Dia_{in} 5.852 in Dia_{out} 6 in	Len: 46.15 in	Mass: 1354 g
	Centering ring	Plywood (birch) ($0.63\ g/cm^3$)	Dia_{in} 2.3 in Dia_{out} 5.852 in	Len: 0.5 in	Mass: 117 g
	Centering ring	Plywood (birch) ($0.63\ g/cm^3$)	Dia_{in} 2.3 in Dia_{out} 5.852 in	Len: 0.5 in	Mass: 117 g
	Centering ring	Plywood (birch) ($0.63\ g/cm^3$)	Dia_{in} 2.3 in Dia_{out} 5.852 in	Len: 0.5 in	Mass: 117 g
	Centering ring	Plywood (birch) ($0.63\ g/cm^3$)	Dia_{in} 2.3 in Dia_{out} 5.852 in	Len: 0.5 in	Mass: 117 g
	Centering ring	Plywood (birch) ($0.63\ g/cm^3$)	Dia_{in} 2.3 in Dia_{out} 5.852 in	Len: 0.5 in	Mass: 117 g
	Freeform fin set (4)	Carbon fiber ($1.78\ g/cm^3$)	Thick: 0.225 in		Mass: 1781 g
	Drogue Parachute	Ripstop nylon ($67\ g/m^2$)	Dia_{out} 36 in	Len: 1.87 in	Mass: 47.2 g

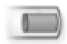
	Shroud Lines	Elastic cord (round 2 mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 11.811 in	
	Inner Tube	Blue tube (1.3 g/cm³)	Dia_{in} 2.126 in Dia_{out} 2.25 in	Len: 25.5 in	Mass: 232 g
	Shock cord	Tubular nylon (25 mm, 1 in) (29 g/m)		Len: 138 in	Mass: 102 g

Figure 3.2.10.2. Estimated Final Mass Breakdown Weighted

Section 3.3. Subscale Construction

The scale of the subscale rocket was 2.15:6 in, which simplifies to a scaling factor of about 0.358. The only components that were not scaled were the electronics, as their size could not be reduced and still have them functioned. The parachutes were scaled down from a 72in main to a 30in main, the 36in drogue scaled down to an 18in drogue, and the 36in nose cone parachute was scaled down to an 18in nose cone parachute. Therefore the main parachute was scaled down to a quarter of its original size and the drogue and nose cone parachutes where scaled down by a half their original size. The parachutes for both the full scale and subscale rocket have a coefficient of drag of approximately .75. This is beneficial towards the integrity of the design as the subscale can represent the full scale design more accurately during the course of its flight.

The construction of the subscale took about a week. In order to save money the team used carbon fiber from AIAA scrap material. The airframe was cut from 2.15in diameter blue tube and a small 2.15in diameter blue tube e-bay coupler.

The subscale was especially important in helping the team to understand the approximate amount of weight that would be added to the final launch vehicle due to smaller components OpenRocket does not take into consideration. This helped us to tune the launch parameters of our full scale design to be more accurate and precise. The final weight of the subscale came to be about 556g heavier than predicted by OpenRocket. This weight was measured on a scale before its launch and accounts for epoxy, u-bolts, nomex blankets, nuts, bolts, etc after complete construction. Therefore we have included both the parts and masses for the unweighted and weighted full scale. When the extra weight was applied to the subscale in OpenRocket, the apogee value came close to matching what was experienced during the actual launch.

In order to determine the theoretical drag coefficient for the full scale based on the subscale launch data we used the Buckingham Pi Theorem and from this, Reynolds number. The formula for Reynolds number is $Re = \varrho vL/\mu$.

Reynolds number is defined in fluid mechanics as the ratio between viscous and inertial force. Through this we found the drag coefficient with the formula, $D = mg$ = 1 2 $\varrho ACDv$ 2.

Theoretically, due to flow similarity within similar geometric shapes. The drag coefficient of the subscale and full scale should be approximately the same. This can be seen in figures 3.3.1. and 3.3.2.

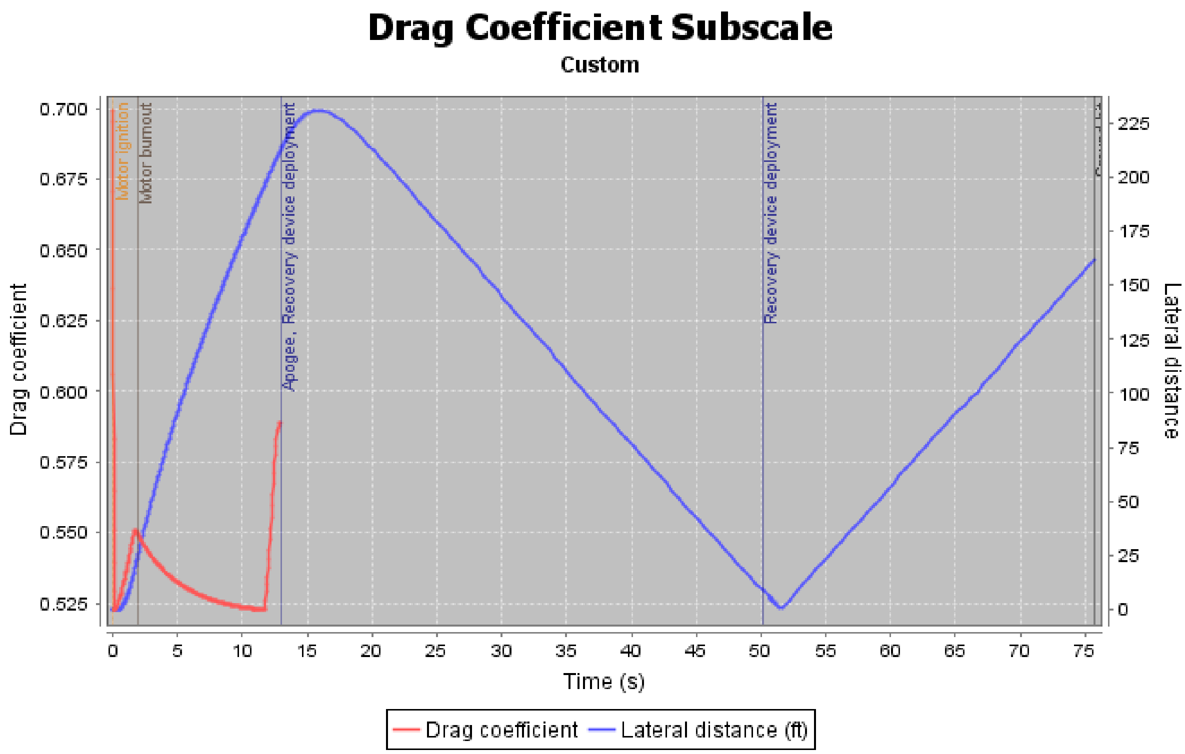


Figure 3.3.1. Subscale Drag Coefficient

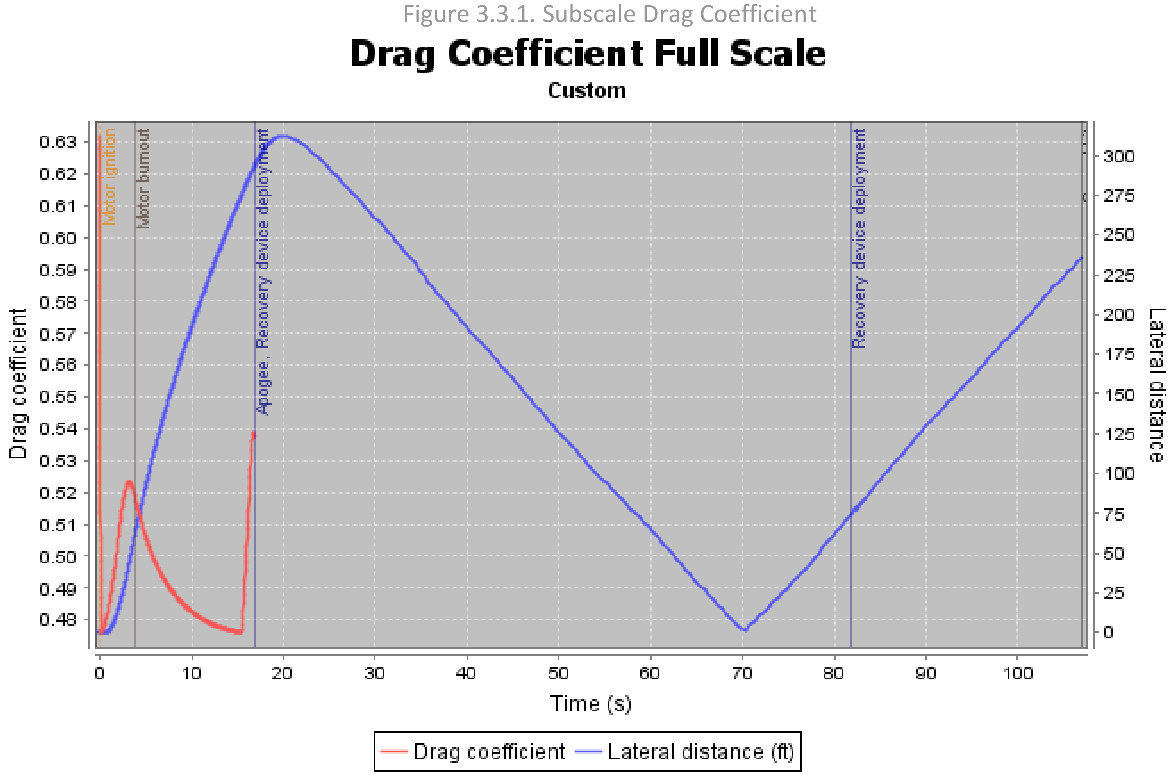
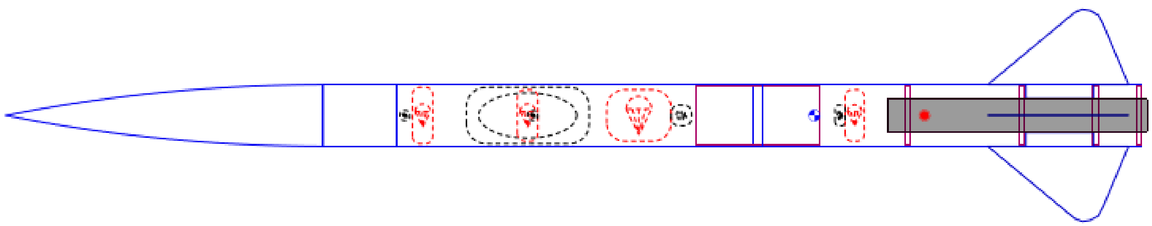


Figure 3.3.2. Full Scale Drag Coefficient

Section 3.3.1 Subscale Parts List/Masses

Figures 3.3.1.1 and 3.3.1.2. show the subscale design unweighted and weighted. The weighted version of the subscale was the weight measured on a scale before its launch that accounts for epoxy, u-bolts, nomex blankets, nuts, bolts, etc. Figure 3.3.1.3. displays the parts list and masses of all the components within the subscale. Additionally it shows the location of the CG and CP and the stability value. The motor information can be seen as well along with parameters in relation to the launch pad.

Rocket Design



Rocket
Stages: 1
Mass (with motor): 778 g
Stability: 1.79 cal
CG: 28.31 in
CP: 32.159 in

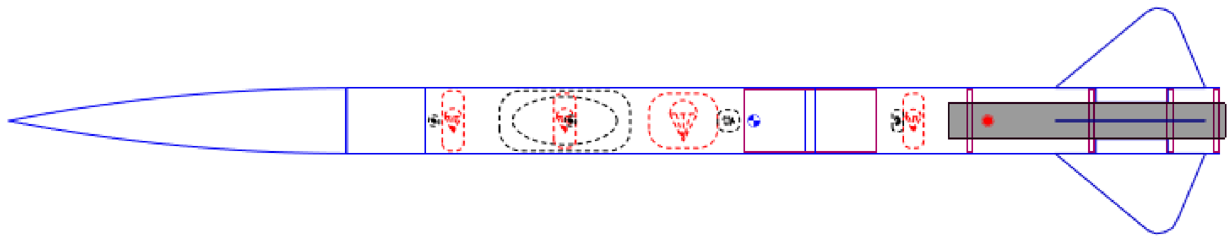
H118-CL-9

Altitude	3659 ft
Flight Time	117 s
Time to Apogee	13.1 s
Optimum Delay	11.3 s
Velocity off Pad	69.5 ft/s
Max Velocity	756 ft/s
Velocity at Deployment	43.1 ft/s
Landing Velocity	19.1 ft/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
H118-CL	118 N	1.82 s	183 N	216 Ns	15.52:1	111 g	1.14/9.09 in

Figure 3.3.1.1. Estimated Final Subscale Design Unweighted

Rocket Design



Rocket
Stages: 1
Mass (with motor): 1287 g
Stability: 3.57 cal
CG: 24.481 in
CP: 32.159 in

H118-CL-9

Altitude	2762 ft
Flight Time	76.1 s
Time to Apogee	12.8 s
Optimum Delay	11 s
Velocity off Pad	53.4 ft/s
Max Velocity	480 ft/s
Velocity at Deployment	57.2 ft/s
Landing Velocity	25.3 ft/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Propellant Wt	Size
H118-CL	118 N	1.82 s	183 N	216 Ns	9.38:1	111 g	1.14/9.09 in

Figure 3.3.1.2. Final Subscale Design weighted

Parts Detail

Sustainer

Nose cone	Polystyrene (1.05 g/cm^3)	Ogive	Len: 11.108 in	Mass: 47.9 g
Upper Airframe	Blue tube (1.3 g/cm^3)	Dia$_{in}$ 2.097 in Dia$_{out}$ 2.15 in	Len: 15.05 in	Mass: 56.7 g
Main Parachute	Ripstop nylon (67 g/m^2)	Dia$_{out}$ 25.8 in	Len: 2.258 in	Mass: 23.8 g
Shroud Lines	Elastic cord (round 2 mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 4.232 in	
Payload		Dia$_{out}$ 1.971 in		Mass: 46 g
UAV Parachute	Ripstop nylon (67 g/m^2)	Dia$_{out}$ 19.35 in	Len: 0.717 in	Mass: 13.9 g
Shroud Lines	Elastic cord (round 2 mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 4.232 in	
Nose Cone Parachute	Ripstop nylon (67 g/m^2)	Dia$_{out}$ 12.9 in	Len: 0.711 in	Mass: 6.81 g
Shroud Lines	Elastic cord (round 2 mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 4.232 in	
Nose Cone Shock cord	Tubular nylon (25 mm, 1 in) (29 g/m)		Len: 5.643 in	Mass: 4.16 g
Shock cord	Tubular nylon (25 mm, 1 in) (29 g/m)		Len: 5.643 in	Mass: 4.16 g
Shock cord	Tubular nylon (25 mm, 1 in) (29 g/m)		Len: 111 in	Mass: 81.8 g
E-Bay.com	Blue tube (1.3 g/cm^3)	Dia$_{in}$ 2.097 in Dia$_{out}$ 2.15 in	Len: 0.358 in	Mass: 1.35 g
Tube coupler	Blue tube (1.3 g/cm^3)	Dia$_{in}$ 2.044 in Dia$_{out}$ 2.097 in	Len: 4.3 in	Mass: 9.2 g
Lower Airframe	Blue tube (1.3 g/cm^3)	Dia$_{in}$ 2.097 in Dia$_{out}$ 2.15 in	Len: 13.258 in	Mass: 50 g
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia$_{in}$ 1.142 in Dia$_{out}$ 2.097 in	Len: 0.179 in	Mass: 4.49 g
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia$_{in}$ 1.142 in Dia$_{out}$ 2.097 in	Len: 0.179 in	Mass: 4.49 g
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia$_{in}$ 1.142 in Dia$_{out}$ 2.097 in	Len: 0.179 in	Mass: 4.49 g
Centering ring	Plywood (birch) (0.63 g/cm^3)	Dia$_{in}$ 1.142 in Dia$_{out}$ 2.097 in	Len: 0.179 in	Mass: 4.49 g

Freeform fin set (4)	Carbon fiber (1.78 g/cm³)	Thick: 0.081 in		Mass: 78.3 g
Drogue Parachute	Ripstop nylon (67 g/m²)	Dia$_{out}$ 12.9 in	Len: 0.67 in	Mass: 6.81 g
Shroud Lines	Elastic cord (round 2 mm, 1/16 in) (1.8 g/m)	Lines: 6	Len: 4.232 in	
Inner Tube	Blue tube (1.3 g/cm³)	Dia$_{in}$ 1.103 in Dia$_{out}$ 1.147 in	Len: 9.094 in	Mass: 15.2 g
Shock cord	Tubular nylon (25 mm, 1 in) (29 g/m)		Len: 111 in	Mass: 81.8 g

Figure 3.3.1.3. Subscale Parts List and Masses

Section 3.3.2 Subscale Flight Results

The subscale launch vehicle was launched in an open field in Berwick Maine on October 20th, 2018. The wind was fairly strong on the day of the launch. The launch vehicle was launched around 1:15 p.m., at which point the external temperature was about 30°F, with wind speeds of about 6 mph from the north. Before flight the final weight of the subscale was taken in order to get an idea of the added weight of epoxy, u-bolts, nomex blankets, nuts, bolts, etc. When applying this data to Open Rocket, we were simulated an expected apogee of approximately 2762ft with a stability of 3.57 cal.

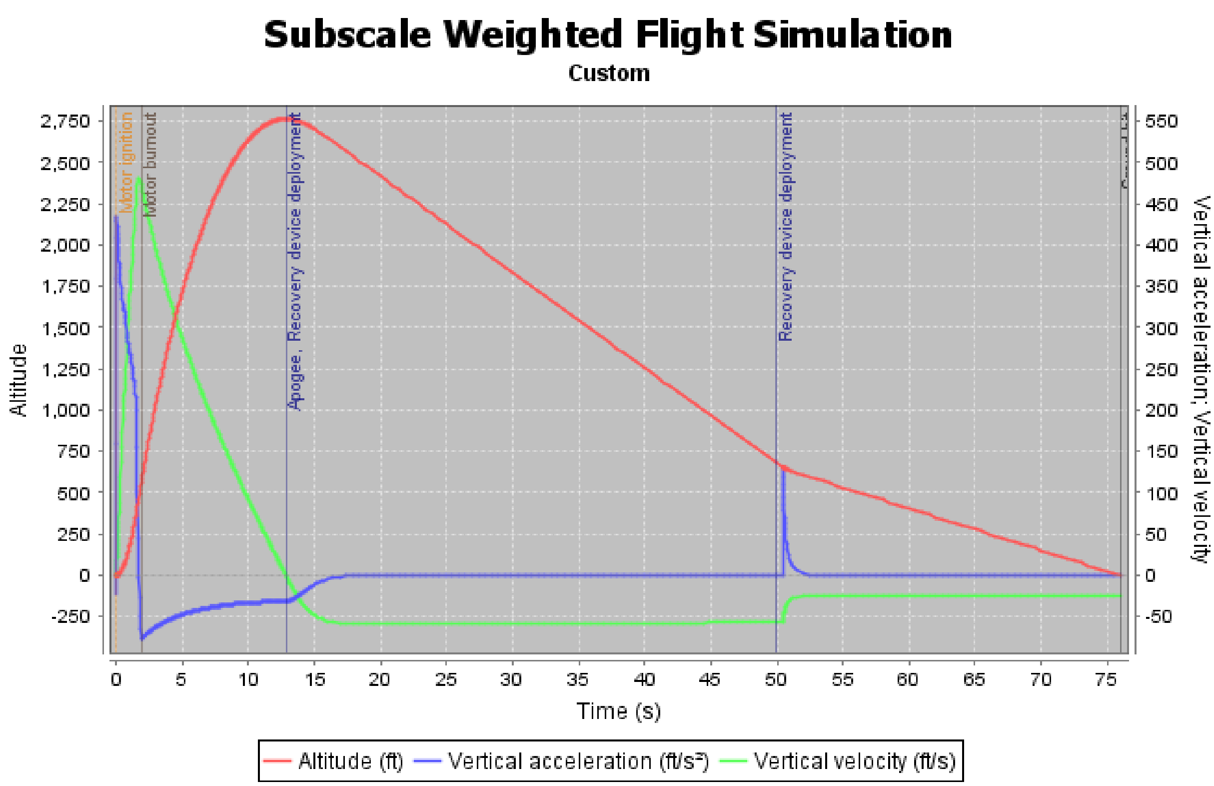


Figure 3.3.2.1. Subscale Flight Simulation

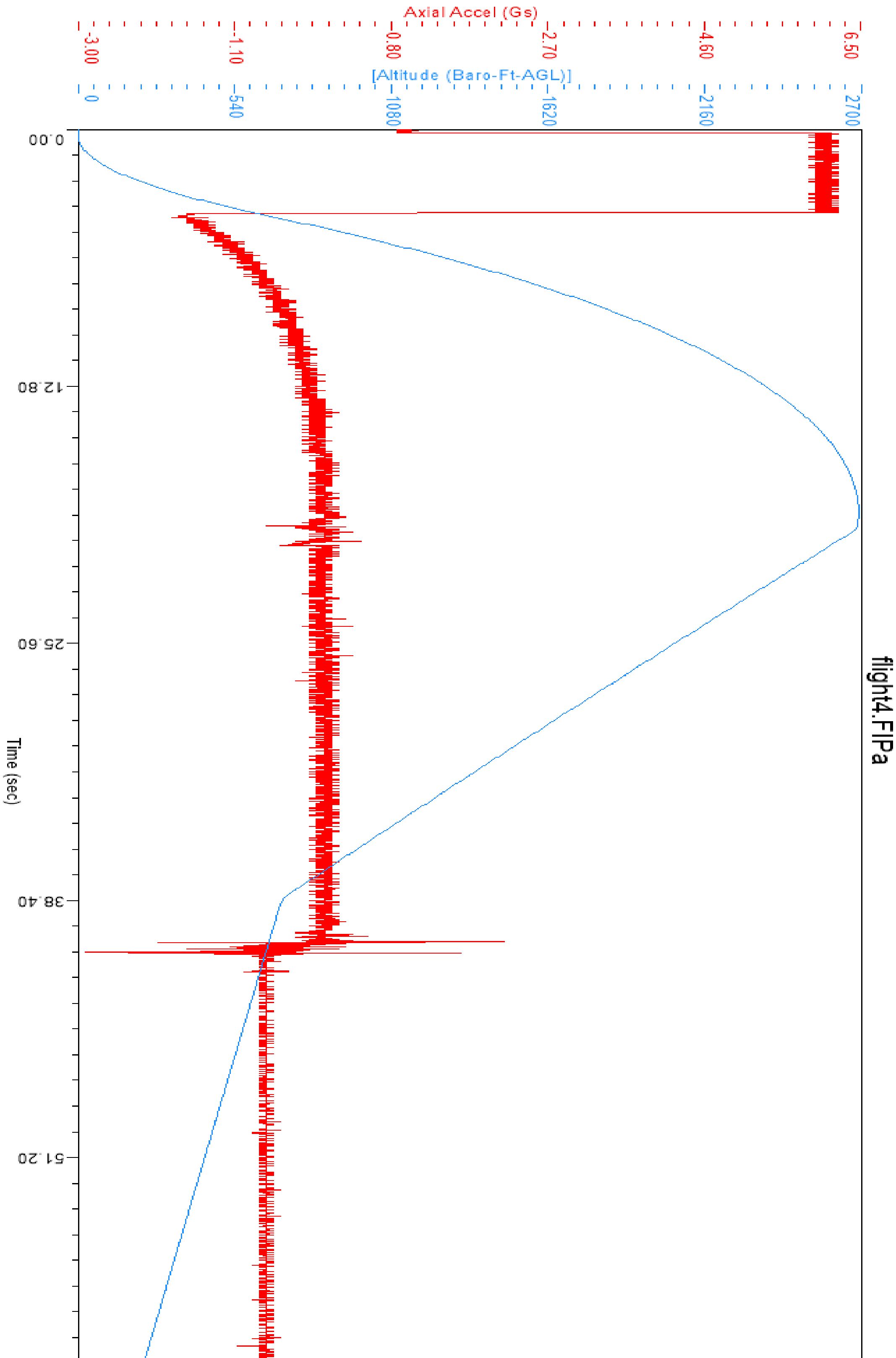

flight4.FIPa
Axial Accel (Gs)
-3.00
-1.10
0.80
2.70
4.60
6.50
[Altitude (Baro-Ft-AGL)]
0
540
1080
1620
2160
2700
0.00
12.80
25.60
38.40
51.20
Time (sec)

Figure 3.3.2.2. Subscale Raven Flight Data

The data from the weighted simulation came very close to the launch day results being off by approximately 62ft. The predicted apogee of the simulation came to approximately 2762ft and the altimeter data from the actual launch came to an apogee of 2700ft AGL. This can be seen in figure 3.3.2.1. above. The difference of 62ft can be explained by the fact that our AIAA chapter has found that Open Rocket apogee values are typically slightly higher than the actual resultant values. Looking at the data in figure 3.3.2.2. all parts of the flight were successful. The blue line on the graph represents the altitude of the subscale showing its apogee at 2700ft AGL and that the second charge did indeed deploy at 700ft AGL. The red line shows the axial acceleration of the subscale during its flight which was relatively constant until about 4 seconds into flight. It is at this point that motor burnout occured leaving gravity as the remaining force. The subscale then drifted up to apogee where at 2700ft AGL the drogue parachute was deployed. This can be seen by the small spike in the axial acceleration. The launch vehicle then descended to an altitude of 700ft AGL where the main parachute was deployed accounting for the second and larger spike in axial acceleration. From there the subscale continued to descend at a steady rate until landing safely with no damage.

Section 3.4. Recovery Subsystem

The launch vehicle will take off in one piece with a predicted apogee at 4683ft AGL. The upper and lower airframes are fastened together with shear pins, as are the upper airframe and nose cone. The electronics bay is fastened to the upper airframe with stainless steel screws. It will utilize a primary altimeter, accompanied by a backup altimeter in the event that the primary fails. At apogee, the primary altimeter will trigger the drogue parachute ejection charge (made of black powder), separating the upper and lower airframes by shearing the shear pins connecting the two sections. The two sections will remain connected with a shock cord after deploying the 36 in drogue parachute. One second later, the backup altimeter will trigger its drogue charge, regardless of whether or not the primary was successful. At this point the launch vehicle will begin its descent.

Upon reaching an altitude of 700 ft AGL, the primary altimeter will detonate the primary main parachute ejection charge (also made of black powder). This will separate the upper airframe and nose cone. The nose cone has its own parachute and is not connected to the upper airframe with shock cord. This parachute as well as the main parachute (72in) will deploy with this primary charge. As with the drogue parachute, the backup altimeter will trigger its main charge one second later, regardless of whether or not the primary was successful. At this point, the launch vehicle is descending in two pieces. The first piece consists of the upper airframe (with the electronics bay still fastened), lower airframe, payload, and the drogue and main parachutes (all attached together with shock cord). The second is the nose cone, which descends separately with its own parachute. The two sections will land separately, at which point the payload remains contained in its retention system. In order to comply with the rules

NASA has stated in the handbook, every tethered and untethered piece of the launch vehicle that will land separately will be equipped with a GPS device.

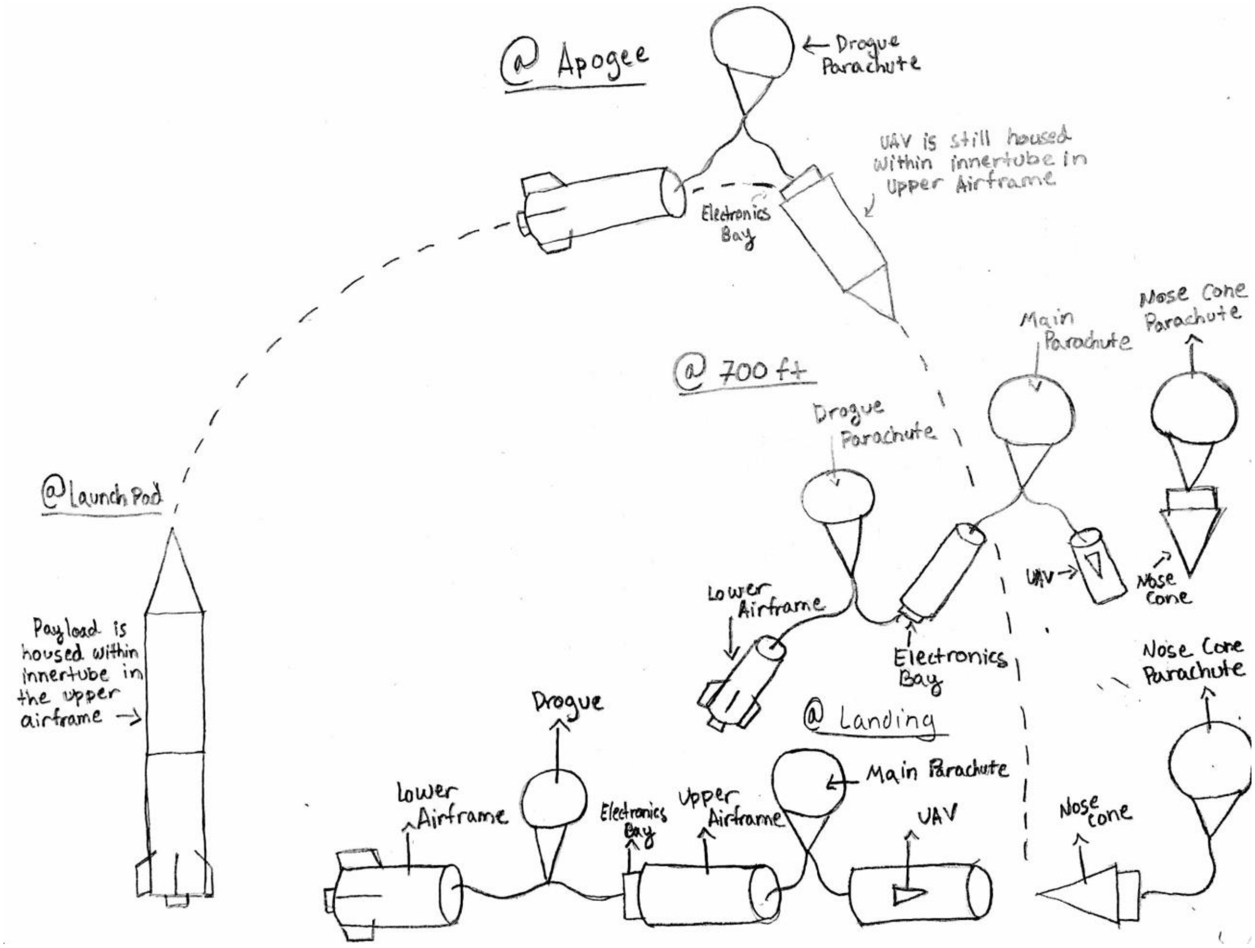


Figure 3.4.1. Flight Plan

In order to reduce the amount of shock inflicted on the parachutes when deployed, a series of layered accordion folds will be made in each of the parachutes' shock cords. The original plan was to use a shock-absorbing system consisting of two buckles with bungee cord in between, however this idea was discarded because it was thought the bungee cord would not be strong enough. By using the accordion folds in the shock cord to further absorb shock, it's guaranteed that the material will be strong enough. All lengths of shock cord are made of 1 in tubular nylon. The shock cord for the drogue parachute will have a length of 138.45 in, and the cord for the main parachute will have a length of 137.55. The bulkheads will be made of 0.25 in plywood and will have a diameter of 5.704 in. All shock cord is attached to the airframe with steel u-bolts.

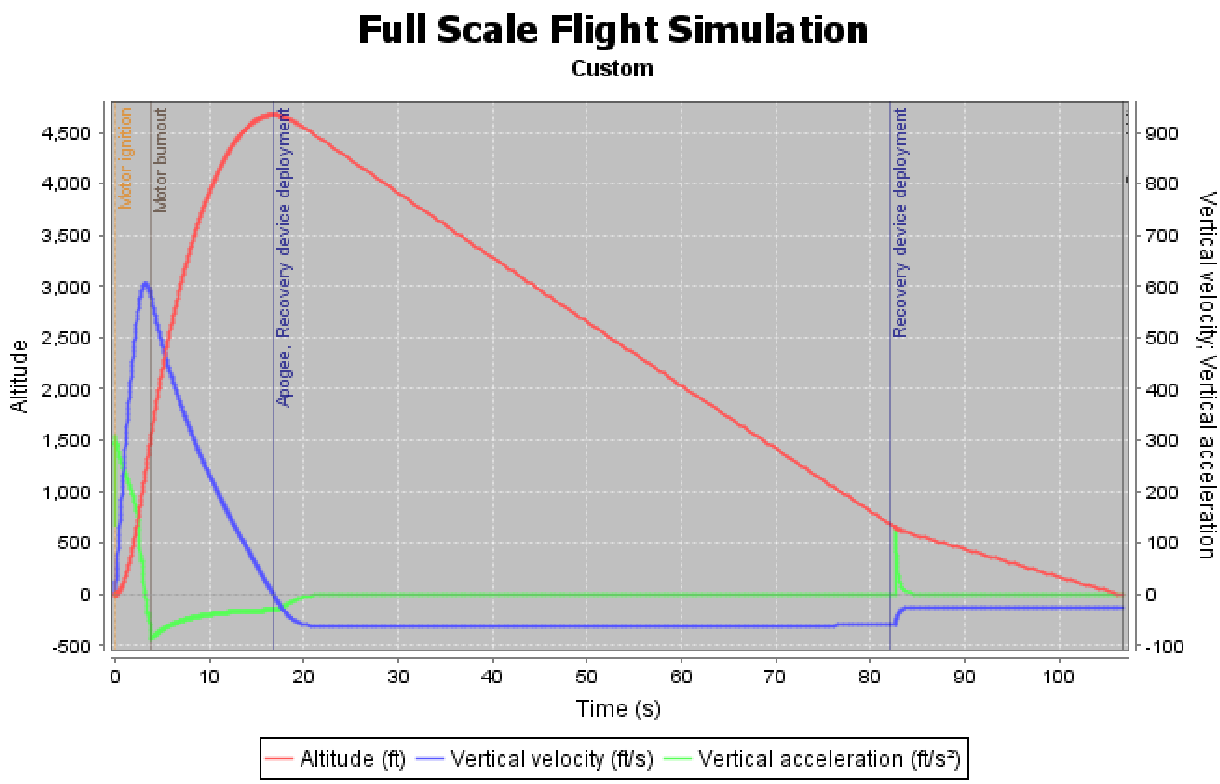


Figure 3.4.2. Flight Simulation Open Rocket

Full Scale Simulation	
Motor Configuration	L730-0
Velocity of Rod	43.2 ft/s
Apogee	4683 ft
Velocity of Deployment	60.6 ft/s
Optimum Delay	13 s
Max Velocity	605 ft/s
Max Acceleration	307 ft/s^2
Flight Time	107 seconds
Decent Time	90.2
Ground Hit Velocity	26.8 ft/s

Table 3.4.1. Flight Plan Simulation Data

Section 3.5. Mission Performance Predictions

Section 3.5.1. Motor Selection

The L730-0 serves as the launch vehicle's main motor. It is 25.6in in length, 2.13in in diameter and has a total impulse of 2763.2100 Ns. The following simulations for this motor were obtained using Open Rocket. The simulation resulted in an apogee of 4704ft AGL and descent time of 92.3 seconds. While this descent time is slightly over the 90 second limit, the simulation does not account for other factors such as the weight of epoxy, quick links, nomex blankets, u-bolts, nuts, bolts, shear pins and screws that will increase the launch vehicle's weight, decreasing the descent time and apogee height. When a theoretical value of this weight was added, the apogee predicted decreased to 4683ft AGL putting our current goal apogee as 4500ft AGL.

Motor Specifications	
Average Thrust	732.9470 N
Class	8% L
Delays	Plugged Seconds
Designation	L730
Diameter	54.0 mm
Igniter	E-Match
Length	6490.0 mm
Letter	L
Manufacturer	CTI
Name	L730
Peak Thrust	1,216.59 N
Propellant	APCP
Propellant Weight	1,351 g
Thrust Duration	3.7700 s
Total Impulse	2763.2100 Ns

Total Weight	2,247.0 g
Type	Reloadable

Table 3.5.1.1. Motor Specifications

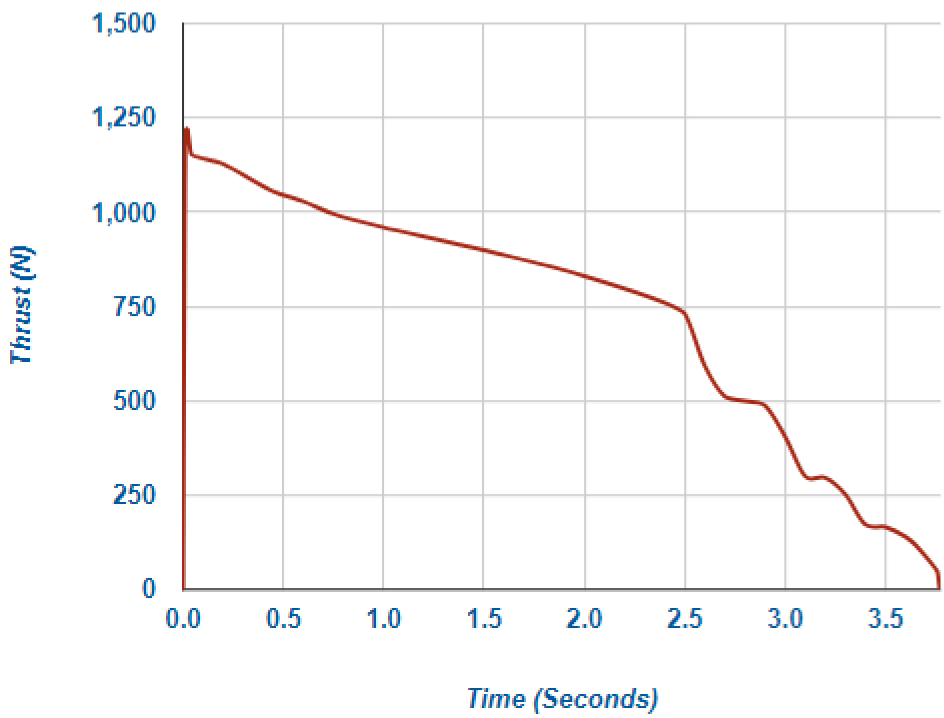


Figure 3.5.1.2. Thrust vs Time

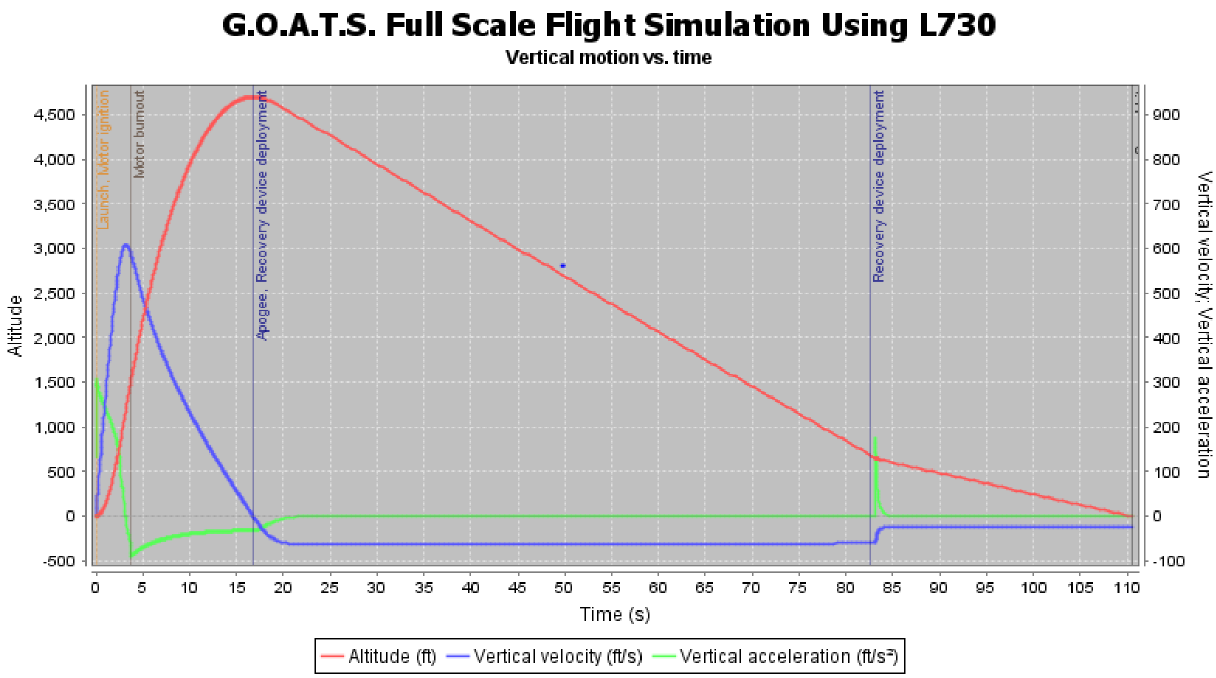


Figure 3.5.1.3. Flight Simulation unweighted

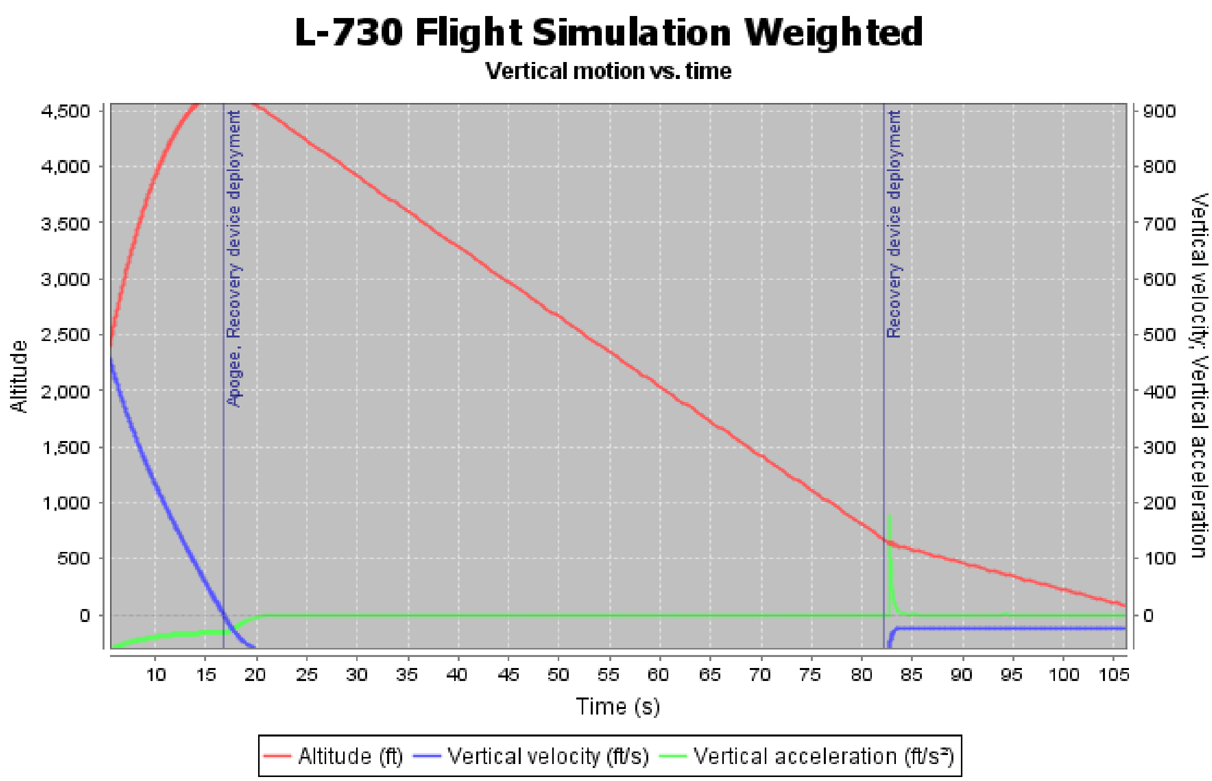


Figure 3.5.1.4. Flight Simulation weighted

The L1030-RL serves as the backup motor. This motor is 25.6in in length, 2.13in in diameter and has a total impulse of 2,781Ns. These values are very similar to the L730-0 motor making it a suitable backup motor. The simulated apogee is 4,679ft AGL with a descent time of 91.5 seconds. While this descent time is slightly over the 90 second limit, the simulation does not account for other factors such as the weight of epoxy, quick links, nomex blankets, u-bolts, nuts, bolts, shear pins and screws that will increase the launch vehicle's weight, decreasing the descent time and apogee height. When a theoretical value of the added weight was added, the apogee predicted decreased to 4669ft AGL.

Motor Specifications	
Average Thrust	1,028.5500 N
Class	9% L
Delays	Plugged Seconds
Designation	L1030-RL
Diameter	54.0 mm
Igniter	E-Match
Length	649.0 mm
Letter	L
Manufacturer	CTI
Name	L1030
Peak Thrust	1,539.44 N
Propellant	APCP
Propellant Weight	1,520 g
Thrust Duration	2.7040 s
Total Impulse	2781.2100 Ns
Total Weight	2,338.0 g
Type	Reloadable

Figure 3.5.1.5. Backup Motor Specifications

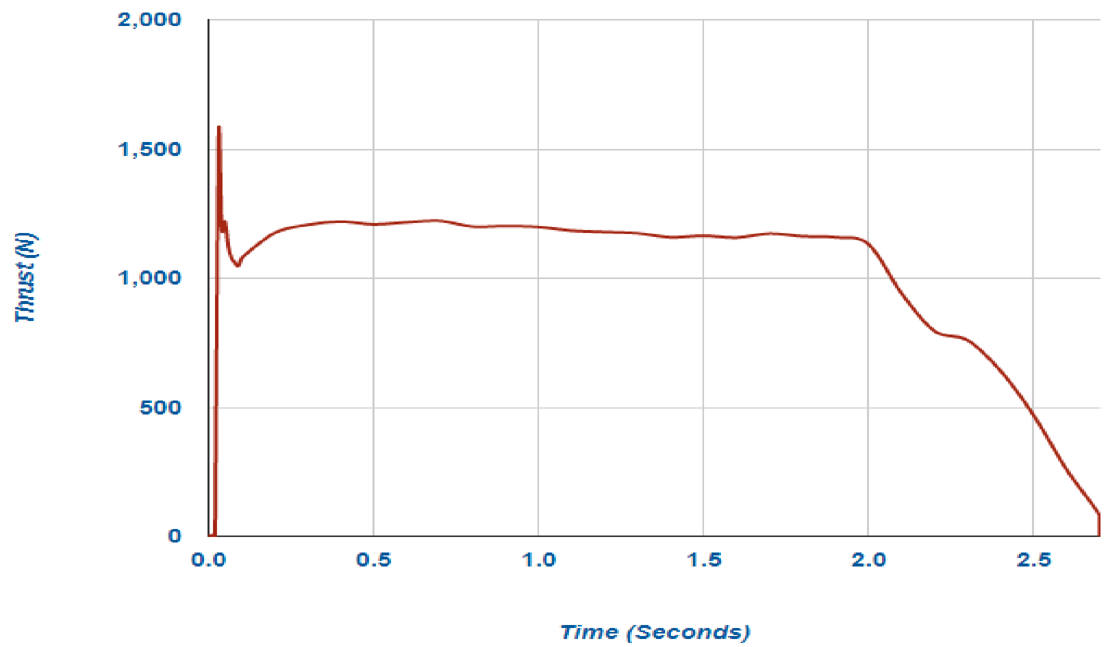


Figure 3.5.1.6. Backup. Thrust vs Time

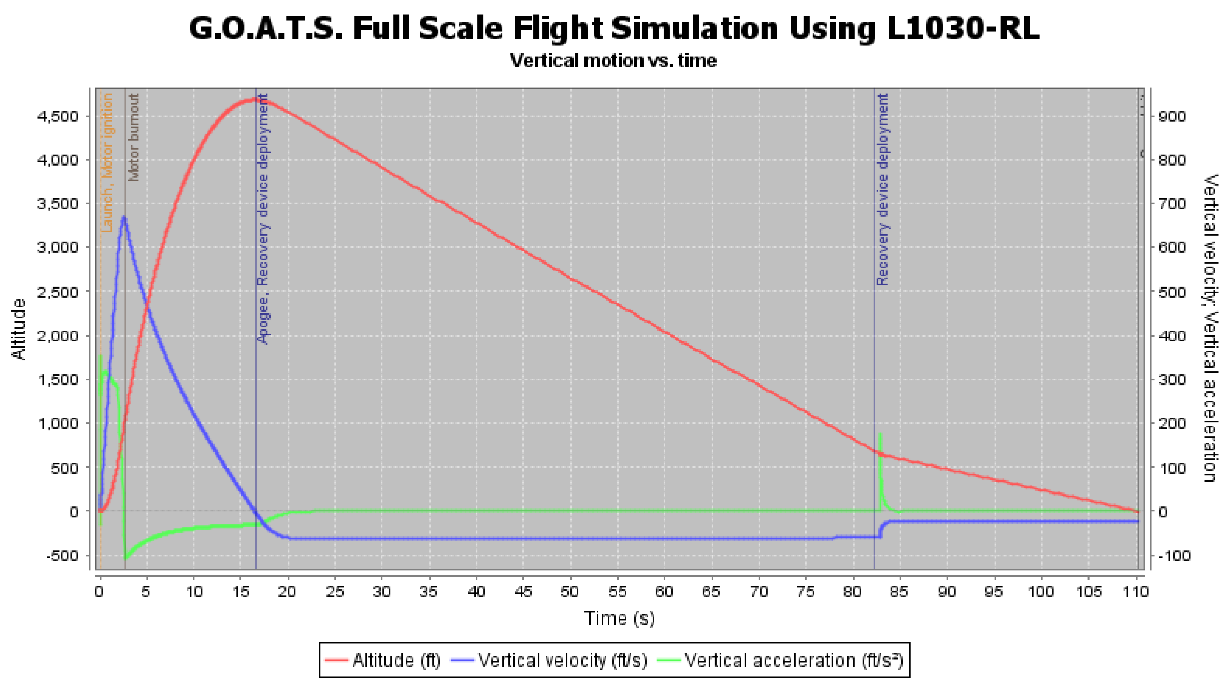


Figure 3.5.1.7. Backup Flight Simulation Unweighted

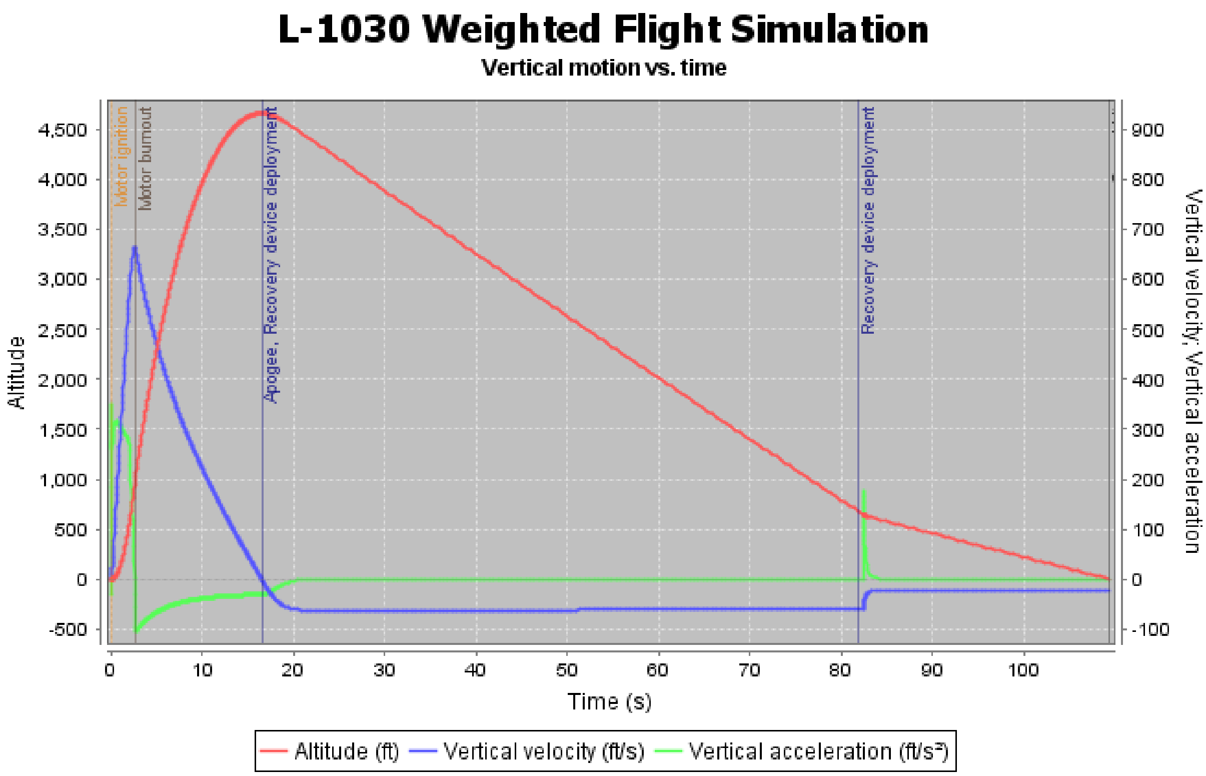


Figure 3.5.1.8. Backup Flight Simulation weighted

Section 3.5.2. Stability Margin and CP/CG Locations

The unweighted launch vehicle's static stability margin on the pad is 3.19 cal. The center of gravity (CG) is located at 82.312 in from the nose cone and the center of pressure (CP) at 101 in from the nose cone. The difference between these two points is 18.828 inches.

The weighted launch vehicle's static stability margin on the pad is 3.52 cal. The center of gravity is located at 80.323 in from the nose cone and the center of pressure at 101 in from the nose cone. The difference between these two points is 20.677 inches.

Note: CG is represented by the blue circle and CP is represented by the red dot in figure 3.5.2.1.

Figure 3.5.2.1. CP and CG location weighted

Section 3.5.3. Matlab Calculations

Recovery Calculations for WPI USLI 2018-19

1) Clear the workspace

```
clear variables; close all; clc;
```

2) Input Constants

```
rho_sl = 0.002377; % Air density at sea level (slug/ft^3)
rho_apo = 0.002067; % Air density at apogee (slug/ft^3)

g = 32.2; % Acceleration due to gravity(ft/s^2)

m1 = 0.07235898; % Section 1 (Payload Rentention) mass (slug)
m2 = 0.1242985; % Section 2 (Nose Cone & Harness) mass (slug)
m3 = 0.291642339; % Section 3 (Lower Airframe) mass (slug)
m4 = 0.219091493; % Section 1 (Upper Airframe) mass (slug)
m5 = m3 + m4;  % Tethered Section (Upper Airframe, Lower Airframe, Payload Retention) mass (slu
m_tot = m1 + m3 + m4;

diameter_drogue = 3; % Drogue chute diameter (ft)
diameter_main = 6; % Main chute diameter (ft)
diammeter_nose = 3; % Nose Cone chute diameter (ft)

Cd = 0.75; % Coefficient of drag for parachutes

apogee_alt = 4574; % Apogee altitude (ft)
main_deploy_alt = 700; % Main chute altitude (ft)

fprintf('Section 1 is the lower airframe, upper aiframe, and payload retainer. Section 2 is the
```

```
Section 1 is the lower airframe, upper aiframe, and payload retainer. Section 2 is the nose cone
```

3) Calculate Descent Times and Velocities

```
% Calculate parachute cross-sectional areas
area_drogue = pi * diameter_drogue^2 / 4; % Drogue chute diameter
area_main = pi * diameter_main^2 / 4; % Main chute diameter
area_nose = pi * diammeter_nose^2 / 4; % Nose cone chute diameter

% Initial descent phase under drogue parachute
v1 = sqrt( (m_tot * g) / (0.5 * rho_apo * Cd * area_drogue) ); % Velocity
t1 = (apogee_alt - main_deploy_alt) / v1; % Flight time

% Second descent phase for main rocket
v2_1 = sqrt( (m5 * g) / (0.5 * rho_sl * Cd * (area_drogue + area_main)) ); % Velocity
t2_1 = (main_deploy_alt) / v2_1; % Flight time

% Second descent phase for nose cone
v2_2 = sqrt( (m2 * g) / (0.5 * rho_sl * Cd * area_nose) ); % Velocity
t2_2 = (main_deploy_alt) / v2_2; % Flight time
```

```
% Calculate total flight time for each section
total_t_1 = t1 + t2_1; % Total flight time for section 1
total_t_2 = t1 + t2_2; % Total flight time for section 2

fprintf('Descent time for Section 1: %0.3f sec\n', total_t_1);
```

```
Descent time for Section 1: 96.816 sec
```

```
fprintf('Descent time for Section 2: %0.3f sec\n', total_t_2);
```

```
Descent time for Section 2: 93.952 sec
```

```
fprintf('Ground hit velocity for Section 1: %0.3f ft/sec\n', v2_1);
```

```
Ground hit velocity for Section 1: 22.848 ft/sec
```

```
fprintf('Ground hit velocity for Section 2: %0.3f ft/sec\n', v2_2);
```

```
Ground hit velocity for Section 2: 25.204 ft/sec
```

4) Calculate Kinetic Energy

```
ke_1 = 0.5 * m1 * v2_1^2; % KE of Section 1
ke_2 = 0.5 * m2 * v2_2^2; % KE of Section 2
ke_3 = 0.5 * m3 * v2_1^2; % KE of Section 3
ke_4 = 0.5 * m4 * v2_1^2; % KE of Section 4

fprintf('Kinetic Energy of Section 1 upon landing: %0.3f lbf*ft\n', ke_1);
```

```
Kinetic Energy of Section 1 upon landing: 18.772 lbf*ft
```

```
fprintf('Kinetic Energy of Section 2 upon landing: %0.3f lbf*ft\n', ke_2);
```

```
Kinetic Energy of Section 2 upon landing: 39.479 lbf*ft
```

```
fprintf('Kinetic Energy of Section 3 upon landing: %0.3f lbf*ft\n', ke_3);
```

```
Kinetic Energy of Section 3 upon landing: 74.857 lbf*ft
```

```
fprintf('Kinetic Energy of Section 4 upon landing: %0.3f lbf*ft\n', ke_4);
```

```
Kinetic Energy of Section 4 upon landing: 56.838 lbf*ft
```

5) Calculate Downrange Drift

```
wind_speeds_mph = [0, 5, 10, 15, 20]; % Wind speeds in mph
wind_speeds = wind_speeds_mph * (5280 / 3600); % Convert to ft/sec

drifts = zeros(3,5); % Set up matrix to hold drift results
```

```
for i = 1:numel(wind_speeds)

    v_wind = wind_speeds(i);

    % Drift = wind speed * descent time
    drift_1 = v_wind * total_t_1;
    drift_2 = v_wind * total_t_2;

    % Put results into results matrix
    drifts(:,i) = [v_wind; drift_1; drift_2];

end
```

6) Plot Downrange drift

```
figure()
plot(wind_speeds_mph,drifts(2,:),wind_speeds_mph,drifts(3,:))
title('Downrange Drift vs Wind Speed');
xlabel('Wind Speed (mph)');
ylabel('Downrange Drift (ft)');
legend('Section 1 (Main Rocket)', 'Section 2 (Nose Cone)');
```

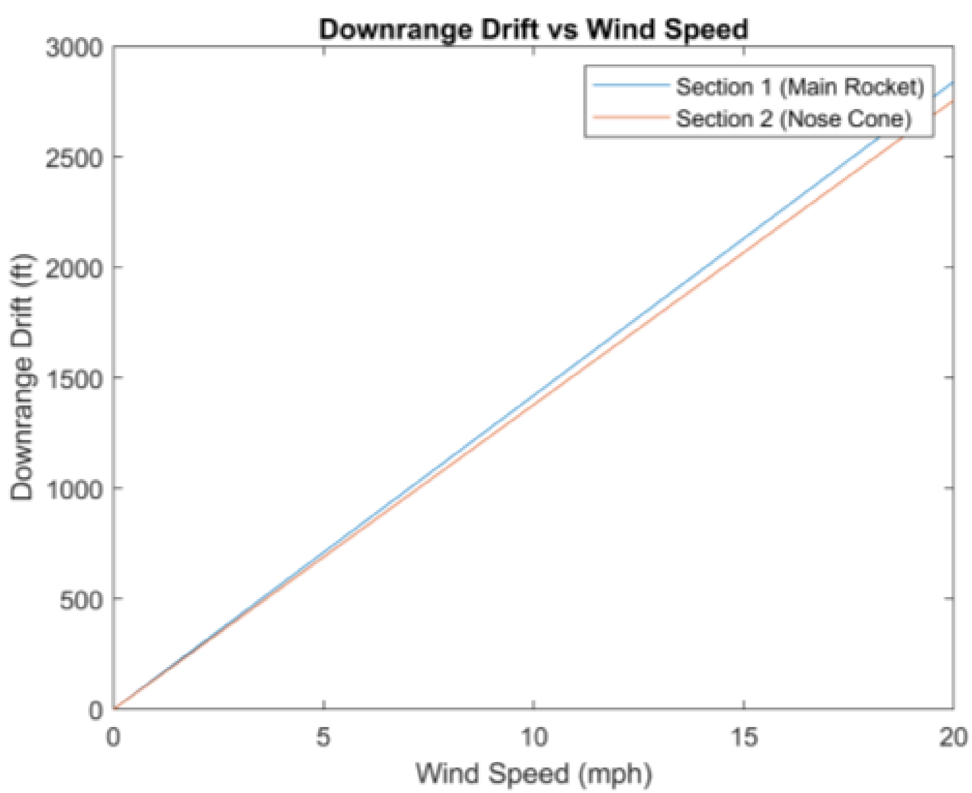


Figure 3.5.3.1. Lateral Drift MatLab

Wind Speed	Section 1 (Main Tethered Section)	Section 2 (Nose cone)
0 mph:	0 ft	0 ft
5 mph:	710 ft	689 ft
10 mph:	1420 ft	1378 ft
15 mph:	2130 ft	2067 ft
20 mph:	2840 ft	2756 ft

Table 3.5.3.1. Drift Parameters

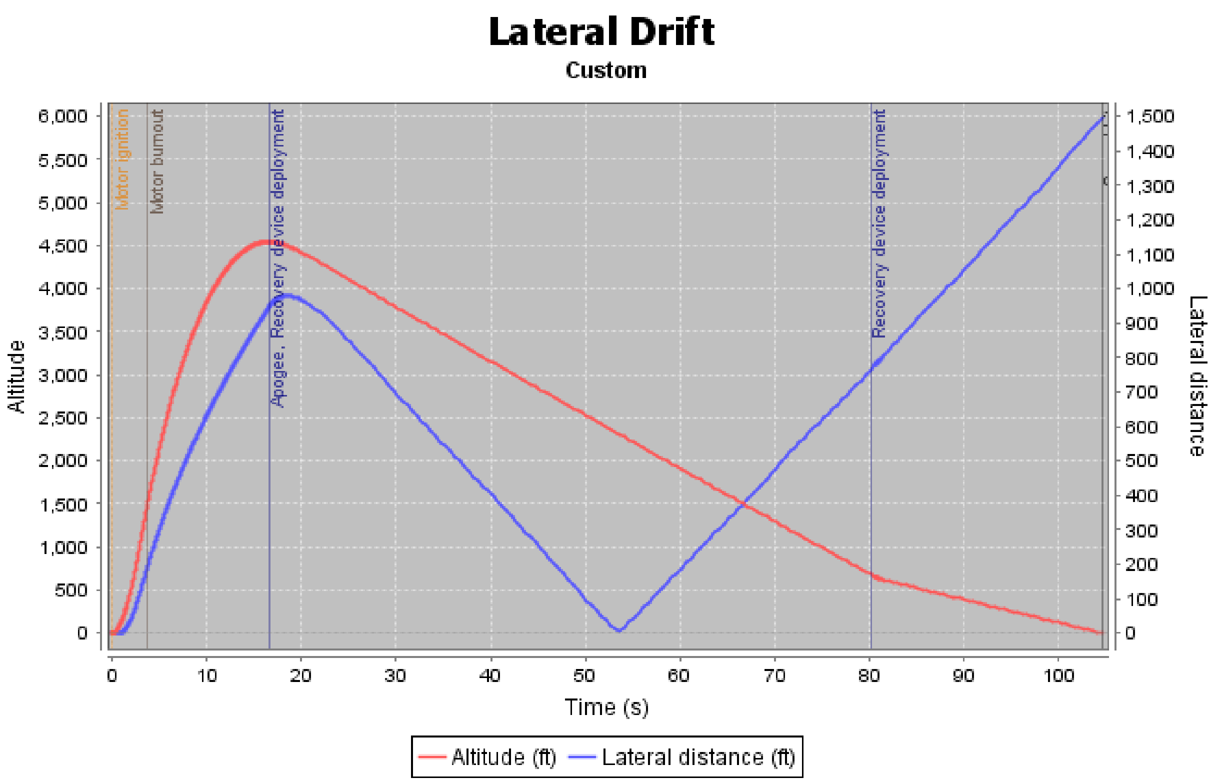
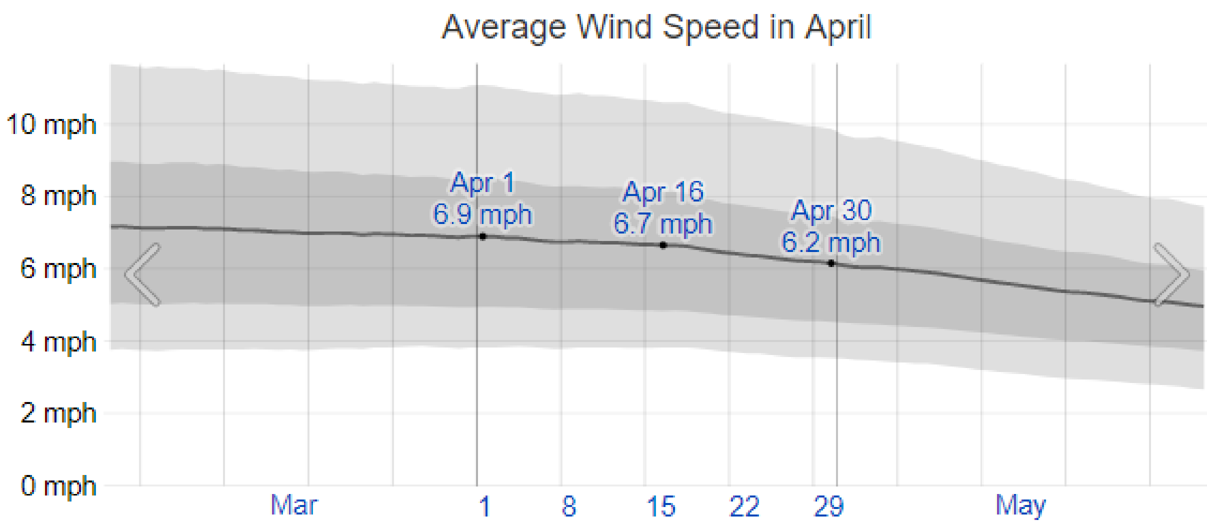


Figure 3.5.3.2. Lateral Drift Open Rocket Graph



Average Wind Speed In April Via WeatherSpark.com
Figure 3.5.3.3. Average Windspeed in Huntsville

Our launch vehicle will not drift outside the range of the recovery area so long as wind speeds remain below 18-20 mph. As shown in the graph above, previous years in Huntsville Alabama average wind speeds during the time period of the competition are well below that. Therefore we believe this will not be an issue.

Section 3.6. Devices for Mission Performance

3.6.1. Component List

Component	Purpose	Picture
Raven 3 Altimeter 9v	Accurately measures altitude, acceleration, and other parameters necessary for proper deployment.	
GPS NEO-6MV2	Required to locate segments of the rocket using a GPS tracker.	

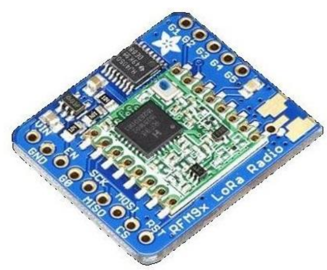
Micro SD card and Breakout Board	Logs gyroscope and accelerometer data.	 
MPU-6050	Senses linear and rotational movement.	
RFM9X LoRa Packet Radio	Transmits and receives GPS data.	
Arduino Nano	Manages the module and makes everything work together.	
Nine Volt Battery	Necessary to power electronics	

Table 3.6.1.1. Devices for Mission Performance

3.6.2. Launch Vehicle Body Tracking System

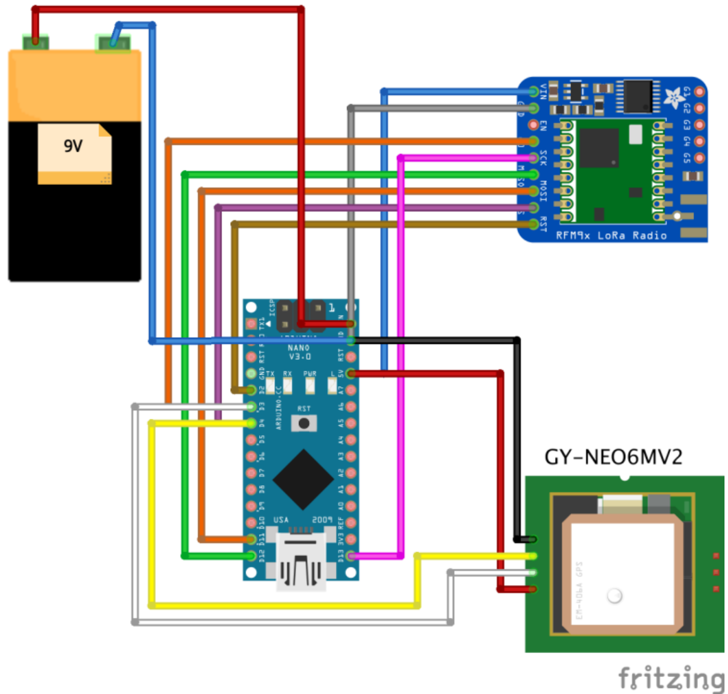


Figure 3.6.2.1. GPS Circuit Diagram

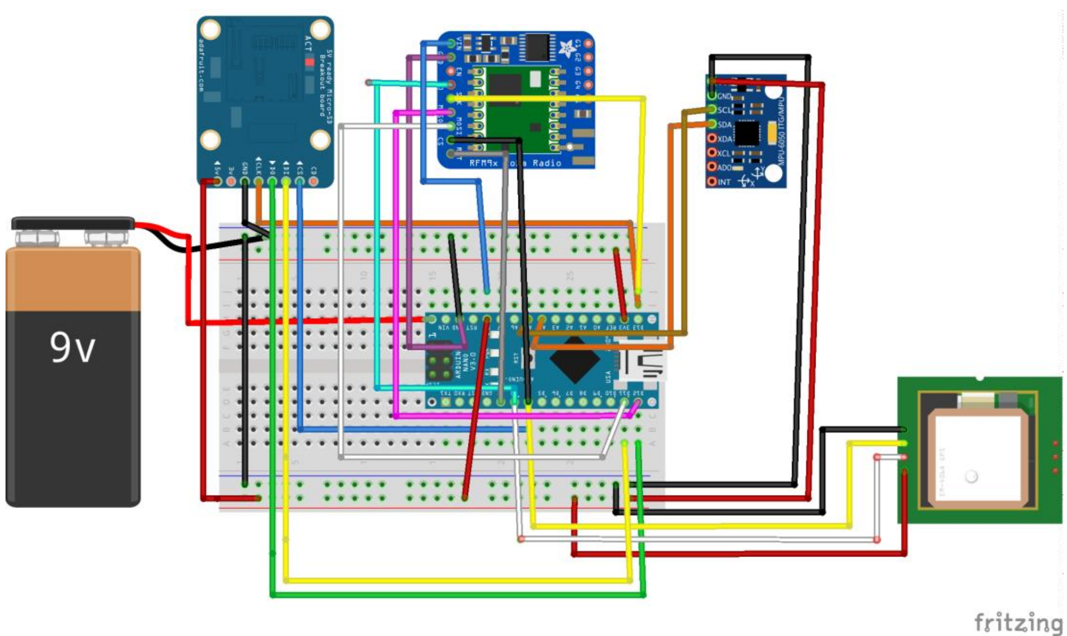


Figure 3.6.2.2. Full GPS Circuit Diagram With E-Bay

The upper airframe, lower airframe, payload, and nose cone will be tracked with the GPS shown in Figure 3.6.2. The UAV will be tracked by the on-board Pixhawk. The upper airframe, in addition to the components in the electronics bay, will include a combined gyroscope and accelerometer chip. These additional components will log data to an sd card.

These tracking modules contain an Arduino Nano, NEO-6MV2, Adafruit RFM95w LoRa radio transceiver, and a 9V battery. The module, contained in a 3D printed shell, will be mounted inside each section of the launch vehicle with epoxy.

All four of the transmissions will be received at the base station by an Adafruit RFM95w LoRa radio transceiver, with the attached antenna. The transceiver is connected to an arduino which outputs data to a laptop.

For the more simplistic module in figure 3.6.2.1, the arduino reads the data from the gps and transmits the longitude and latitude over the transceiver. The arduino is powered by the nine volt battery, the gps and transceiver get power from the arduino's 5V and 3.3V pins respectively. In the upper airframe circuit in figure 3.6.2.2, the same is true with the addition of the the arduino reading the MPU-6050 and writing log data to the sd card. The MPU-6050 and the SD card breakout board are both powered by the arduino 5V pin.

Section 4. Safety

While there are considerations that go into planning the launch of the system, safety is always the team's top priority. This section goes into detail on the procedures and analysis the team is using to minimize risks.

Section 4.1. Launch concerns and operation procedures

When launching such a large vehicle, it is imperative to follow strict procedures to ensure the success and safety of the mission. This section includes multiple checklists that are to be followed in order to launch. With the exception of the Troubleshooting and Post-Flight Inspection Checklists, all checklists must be completed prior to launch. Each list is split into tasks, required personnel for those tasks, and a column for the initials of the officer responsible for verifying the completion of the step.

Section 4.1.1. Payload Checklist

Payload Checklist		
Task	Required Personnel	Initials

Ensure payload has charged batteries. ⚠Setup Hazard: Not using a proper battery charger or creating short circuits may cause combustion.		Payload Lead
Perform an electronics systems check.		Payload Lead
Ensure communications are functional.		Payload Lead
Verify the structural and mechanical components are in working order including the retention system, joints, and the payload deployment system. ⚠Operation Hazard: If the retention system is not structurally sound, it could break upon ejection releasing free falling objects.		Payload Lead
Configure electronics for flight.	Payload Lead	Payload Lead
Pack payload within the retention system. ⚠Operation Hazard: Improperly packing the payload will prevent the main parachute from deploying leaving the vehicle at unsafe speeds.	Payload Lead	Payload Lead

Section 4.1.2. Motor Checklist

Motor Checklist		
Task	**Required Personal**	**Initials**
SAFETY GLASSES REQUIRED Take motor out of package. ⚠Setup Hazard: Motor should not be taken out until it is ready to be used. Keep away from heat sources to prevent premature ignition.	Mentor	Mentor
SAFETY GLASSES REQUIRED Ensure all components are in working condition and has been tampered with. ⚠Operation Hazard: If the motor shows any sign of tampering or damage it may not fire correctly and should not be flown.	Mentor	Mentor

SAFETY GLASSES REQUIRED ⚠ Confirm with the RSO that the motor is safe. The RSO has the final say on the safety of the motor.	Mentor, RSO	Mentor
SAFETY GLASSES REQUIRED Use CTI Delay Drill Bit to adjust motor deployment charge delay time. ⚠ Operation Hazard: An improperly timed delay will cause premature or late deployment from the redundant ejection charge possibly leading damage from aerodynamic forces creating free falling objects.	Mentor	Mentor
SAFETY GLASSES REQUIRED Follow manufacturer instructions to assemble motor ⚠ Operation Hazard: Not following instructions may damage the motor.	Mentor	Mentor
SAFETY GLASSES REQUIRED Mount the motor on the launch vehicle and ensure that it is securely fitted and that the motor retention screws are tightened. ⚠ Operation Hazard: If the motor is not secured, it may be ejected in flight.	Mentor	Mentor

Section 4.1.3. E-Bay Checklist

E-Bay Checklist		
Task	**Required Personal**	**Initials**
Secure the two 9V batteries.		Launch Vehicle Lead
Plug each altimeter into a computer and test that the main altimeter is programmed for dual deployment at apogee and 700 ft AGL and that the secondary altimeter is programmed for dual deployment at apogee plus one second and 700 ft AGL plus one second. ⚠ Operation Hazard: Verify that the second deployment at 700 ft AGL occurs after apogee. Misprogrammed altimeters could cause premature or late deployment, destroying the launch vehicle.	Launch Vehicle Lead	Launch Vehicle Lead
Slide the sled into e-bay coupler.		Launch Vehicle Lead

Make sure apogee and main charges are oriented in the correct direction for deployment. Double check that they are connected to the correct altimeter channel. ⚠ Operation Hazard: Switching the charges will cause the main parachute to deploy at apogee leading to excessive decent times.		Launch Vehicle Lead
Connect terminal blocks to apogee and main. ⚠ Operation Hazard: Improperly securing the wires may prevent deployment.		Launch Vehicle Lead
SAFETY GLASSES REQUIRED Pack black powder charges. ⚠ Setup Hazard: All energetics must be kept away from heat sources.	Mentor	Mentor
SAFETY GLASSES REQUIRED Connect black powder charges to the other end of the terminal blocks. ⚠ Setup Hazard: Ensure that the the terminal blocks is not live before connecting the charges to prevent premature detonation.	Mentor	Mentor
SAFETY GLASSES REQUIRED Make sure black powder charges are oriented correctly and secured. ⚠ Operation Hazard: Switching the charges will cause the main parachute to deploy at apogee leading to excessive decent times.	Mentor	Mentor
SAFETY GLASSES REQUIRED Place e-bay in the launch vehicle. Be careful to ensure apogee and main charges are still oriented correctly. ⚠ Operation Hazard: Switching the charges will cause the main parachute to deploy at apogee leading to excessive decent times.		Launch Vehicle Lead

Section 4.1.4. Recovery Checklist

Recovery Checklist		
Task	**Required Personal**	**Initials**
Put nomex blankets on shock cord. ⚠ Operation Hazard: If blankets are not fastened correctly, parachutes could be damaged leading to the rocket free falling.		Safety Officer

Ensure all bodies are secured with shock cord. ⚠ Operation Hazard: If a body is not connected properly, it could separate and free fall.	Launch Vehicle Lead	Safety Officer
Verify all parachutes are in working condition without holes, tears, or burns. ⚠ Operation Hazard: If parachutes are damaged, the vehicle could fall fast enough to damage itself or personell.	Launch Vehicle Lead	Safety Officer
Pack all parachutes properly. ⚠ Operation Hazard: If parachutes are not packed properly, they may not deploy, causing the vehicle to free fall.		Safety Officer
Secure parachutes to their mounting points. ⚠ Operation Hazard: If parachutes are not secured properly, they could come detached from the shock cord and the vehicle will free fall.		Safety Officer

Section 4.1.5. Structural Checklist

Structural Checklist		
Task	**Required Personnel**	**Initials**
Make sure the upper and lower airframes are in working condition with no dents or fractures. ⚠ Operation Hazard: If the airframe is dented or fractured, parts could break upon launch and turn into several free falling objects.	Launch Vehicle Lead	Launch Vehicle Lead
Make sure the fins are in working condition with no bending or fractures. ⚠ Operation Hazard: If the fins are bent or fractured, they could break off upon launch and turn into free falling objects.	Launch Vehicle Lead	Launch Vehicle Lead
Make sure the nose cone is in working condition with no dents or fractures. ⚠ Operation Hazard: If the nose cone is dented or fractured, it may break in flight, creating free falling objects, or cause the vehicle to deviate from its predicted flight path.	Launch Vehicle Lead	Launch Vehicle Lead
Check that the EBay is properly secured to the upper airframe with screws. ⚠ Operation Hazard: If the EBay is not secured it could cause the upper and lower airframes to separate in flight likely resulting in multiple free falling objects and the loss of the vehicle.	Launch Vehicle Lead	Launch Vehicle Lead

Section 4.1.6. Assembly Checklist

Assembly Checklist		
Task	**Required Personnel**	**Initials**
Fit Nomex blankets into the launch vehicle. ⚠Operation Hazard: If blankets are not fitted properly, deployment may not occur and the rocket will free fall.		Safety Officer
Fit parachutes, ensuring they stay packed and are not tangled in shock cord. Ensure they are adequately protected from energetics by the Nomex blankets. ⚠Operation Hazard: If parachutes are not fitted properly or become tangled in the shock cord, they may not deploy and the rocket will free fall.		Safety Officer
Fit the payload retention system. ⚠Operation Hazard: If retention system is not properly fitted, the payload could separate in flight.		Payload Lead
Fit the upper and lower airframes together. ⚠Operation Hazard: Improperly fitting the airframes may lead to a deviation from the expected flight path and could cause them to separate in flight, endangering the vehicle and personnel.		Launch Vehicle Lead
Insert shear pins. ⚠Operation Hazard: If shear pins are not inserted, the airframes may separate in flight.		Launch Vehicle Lead

Section 4.1.7. Launch Checklist

Launch Checklist		
Task	**Required Personnel**	**Initials**
If the vehicle has been flown before, ensure that the Post-Flight Inspection Checklist has been completed. ⚠Operation Hazard: If the vehicle has failed the inspection, it may only be flown after the failure mode has been determined and a mitigation plan has been written, implemented, and verified.	Safety Officer	Safety Officer

Complete Payload Checklist.	Payload Lead	Payload Lead
Complete EBay Checklist.	Launch Vehicle Lead	Launch Vehicle Lead
Complete Structural Checklist.	Launch Vehicle Lead	Launch Vehicle Lead
Complete Recovery Checklist.	Safety Officer	Safety Officer
Complete Assembly Checklist.	Launch Vehicle Lead	Launch Vehicle Lead
SAFETY GLASSES REQUIRED Complete Motor Checklist.	Mentor	Mentor
Conduct final visual inspection to ensure launch vehicle is completely assembled. The motor retention screws must be fully tightened, shear pins must be inserted properly, and the EBay must be secured with screws to the upper airframe.	Launch Vehicle Lead Payload Lead Team Captain Safety Officer	Team Captain
Verify with RSO that vehicle is safe to launch. ⚠ Operation Hazard: The RSO has the final say on the safety of the vehicle.	RSO	Team Captain
Mount launch vehicle on the launch rail designated by the RSO. If there are high winds, the launch angle may be slightly adjusted to compensate. ⚠ Setup Hazard: Mounting the vehicle on the launch rail should only occur after the range has been cleared. ⚠ Operation Hazard: The launch angle should never be more than 20° from the vertical. Doing so violates the NAR High Power Rocket Safety Code and risks the vehicle colliding with personnel or objects on the field.		Team Captain

Secure new ignitor in motor. ⚠ Setup Hazard: To avoid premature ignition, do not connect the ignitor to the launch wire in this step.		Team Captain
Connect the ignitor to the launch wire. Check for igniter continuity. ⚠ Setup Hazard: Ensure the ignitor wire is not live before connecting the ignitor to avoid premature ignition.		Team Captain
Arm launch vehicle.	Team Captain	Team Captain

Section 4.1.8. Post-Flight Inspection Checklist

Post-Flight Inspection Checklist		
Task	**Required Personnel**	**Initials**
Ensure all components are accounted for. This includes the lower airframe, upper airframe, EBay, nose cone, nose cone parachute, drogue parachute, main parachute, nomex blankets, and the payload.		Safety Officer
Visually inspect the airframe and fins for damage such as dents, zippering, holes, cracks, and anything that would prevent the vehicle from being flown again. This includes checking internal components such as u-bolts and bulkheads.		Safety Officer
Check that all components are attached appropriately. The nose cone should still be secured to it's parachute by shock cord. The upper airframe should be secured to the EBay with screws and the retention system by shock cord. The lower airframe should be secured to EBay by shock cord. The drogue parachute should be secured to the lower airframe shock cord and the main parachute should be secured to the upper airframe shock cord.		Safety Officer
Check that the motor and the motor casing are still secured inside of the motor tube and that all ejection charges have been detonated. Properly dispose of the spent motor.		Safety Officer
Check that there are no holes or burns in any of the parachutes and that none of the parachute's coords have broken.		Safety Officer

Open the EBay and ensure that all components are still secured within it. Visually inspect all electrical components for damage.		Safety Officer
Download flight data from both altimeters.		Safety Officer
Visually inspect the UAV for damage such as dents, holes, cracks, and anything that would prevent the vehicle from being flown again.		Payload Lead
Verify that all electrical components are functional.		Payload Lead

Section 4.1.9. Troubleshooting Checklist

Because the Troubleshooting Checklist is not required to be completed to launch. The initials and required personnel column have been omitted. Once the retention system and UAV software is finalized, steps required for their troubleshooting will be added to this section.

Launch Vehicle Troubleshooting Checklist
Task
Connect both altimeters to a computer to check that the primary altimeter is set to deploy first at apogee then at 700 ft AGL and the secondary altimeter is set to deploy first at apogee plus one second and 700 ft AGL plus one second.
Power on the altimeters with a 9V battery. On startup, they will beep once per volt they are receiving. 9 beeps indicates 9V.
The altimeters can be tested by manually connecting the wires to simulate being connected to an ejection charge. If the altimeter emits one low beep every two seconds, it either does not detect any charges connected, is receiving less than 3.85V, or is not oriented vertically. Otherwise, it will emit a series of 4 beeps every two seconds. Each beep indicates the continuity of a channel. For example one low beep, followed by on high beep, then two low indicates that only channel 2 has continuity.

Section 4.2. Safety and Environment (Vehicle and Payload)

This section analyzes the risks associated with the construction, testing, and flight of the launch vehicle and the payload. Most importantly, these include hazards to safety of personnel, materials, and facilities but they also include risks to the project timeline and the budget. Section 4.2.1. through 4.2.4. analyze hazards to personnel, failure modes and effects analysis (FMEA), environmental conditions and rate them by severity and probability. The scales used to rank these are similar to the US Geological Survey's Risk Assessment Codes however they are defined specifically for each section to better rate the risks and hazards being analyzed. Section 4.2.5. Provides a series of checklists that the team will use at launch events to prevent failures and hazards at the launch.

Section 4.2.1. Personnel Hazard Analysis

Personnel Hazard Probability Definitions	
Rating	**Description**
A	The hazard expected to occur if it is not mitigated.
B	The hazard is likely occur if it is not mitigated
C	The hazard may occur if it is not mitigated.
D	The hazard is possible but unlikely to occur.

Table 4.2.1.1. Personnel Hazard Probability Definitions

Personnel Hazard Severity Definitions	
Rating	**Description**
I	Significant chance of death or permanent injury.
II	Possibility of major injuries requiring hospitalization or permanent minor disability.
III	Chance of injury requiring hospitalization or period of minor disability.
IV	May cause minor injury which may require first aid.

Table 4.2.1.2. Personnel Hazard Severity Definitions

Personnel Hazard Analysis						
Phase	**Hazard**	**Cause**	**Effect**	**Probability / Severity**	**Mitigation**	**Verification**
Launch	Motor Misfire	Failure of igniter or damage to motor prior to launch	There is a possibility of a delayed ignition which could lead to harm if personnel approach the launch vehicle too soon.	DII	The motor will only be handled by a certified mentor. The team will wait at least 60 seconds before approaching the launch vehicle and will follow all directions of the RSO.	Motor preparation is included in the Motor Checklist. Team members have been informed of misfire safety procedures in a mandatory safety briefing and will be reminded in mandatory pre-launch safety briefings.
	Premature Motor Ignition	Damage to the motor or accidental early ignition	It is possible that this could cause harm to any personnel in the area during ignition.	DI	New ignitors and motor propellants will be used. The motor will be correctly installed by a certified mentor and	Included in the Launch Checklist.

					ignited by the RSO.	
	Motor Ejected from launch vehicle	Improperly secured motor	This could cause the motor to go into freefall during flight. Another possibility is if it is still ignited could harm personnel in the area or destroy the launch vehicle, creating free-falling debris that could be dangerous.	CI	The motor will be correctly installed by a certified mentor. The motor retention system will be inspected prior to launch.	Included in the Motor and Launch Checklists.

	Parachute Failure	Improper packing of parachute, improper amounts of black powder charges, destruction of parachute by aerodynamic forces	Free falling bodies could cause harm to personal	BI	Parachutes will be inspected for tears, holes, and burns before launch. Powder Charges will be measured and weighed with an electronic scale by a mentor.	Included in the Recovery and E-Bay Checklists.
	Unpredictable Flight Path	Winds during flight or instability in thrust	This could cause the launch vehicle to enter undesired areas or potentially hit any personnel in the area.	DI	The launch vehicle will not be flown in unsafe weather such as in a strong crosswind. The mass of the launch vehicle and its fins will be designed to maximise stability. Before construction.	The stability will be verified by simulation. Members have been informed that no launches will occur in unsafe conditions at a mandatory safety briefing and will be reminded at a mandatory pre-launch

						safety briefing.
	Drogue Chute not Deployed at Apogee	Using too small a charge or too tight of a fit in the airframe could prevent the launch vehicle from deploying the drogue parachute. This could also happen if the parachute is not packed correctly.	This could cause the launch vehicle to go into freefall and potentially harm personnel.	DI	Drogue chute will have three redundant systems capable of deploying it. These are the primary altimeter, the secondary altimeter, and the motor ejection charge.	Included in the E-Bay checklist.

	Airframe Failure	Structural integrity could be compromised due to construction and fail during launch. It also could fail on landing and be unable to launch again.	Airframe failure during launch or flight could send out debris that could harm personnel. Failure upon landing could cause harm if there are personnel in the area where the launch vehicle lands.	DI	Damaged components will not be used and the vehicle will be properly packaged during transportation to prevent damage.	The vehicle will be constructed according to the specifications in the design.
	Shock Cord is Severed	Destruction by black powder charge, Burnt by charge detonation,	This could cause the launch vehicle to fall apart in the sky and become a projectile.	DI	A Nomex blanket will protect the shock cord from fire damage. The black powder charges will be measured carefully.	Included in the Recovery, E-Bay, and Assembly Checklists.

	Vehicle Flys Over or Lands Close to Spectators	An unpredictable flight path could cause the launch to veer over or close to spectators.	The launch vehicle could hit personnel in the area.	DI	The launch vehicle will be launched at a safe distance from any personnel and only in safe conditions. Launch angle will be slightly adjusted to account for wind.	Members have been informed of safe launch distance rules in a mandatory safety briefing and will be reminded in a mandatory pre-launch safety briefing.
	Electronics bay failure	Destruction by black powder charge, burnt by charge detonation, or loss of power	This could cause the altimeter to fail and prevent parachute deployment sending the launch vehicle or parts of it into freefall, potentially harming personnel, or prevent separation by charges.	CI	There will be a backup altimeter with a second power source on board in case of failure of the main altimeter. There also will be a set of backup black powder charges connected to the backup	Included in the E-Bay Checklist.

					altimeter.	
Payload Teleoperation	Loss of control of UAV	A poor connection or or other technical issue could cause the UAV to veer off of the desired course	This could cause it to veer towards personnel and harm them. The team will not fly the UAV with people near it.	CIV	A proper connection will be ensured prior to activating the UAV and there will be a failsafe in the case of a dropped connection or loss of control.	This will be demonstrated during the full-scale test.
Construction	Accidents with tools	May be caused by negligence, improper training, or damaged tools.	This would cause bodily harm to personnel. This could be anything from minor injuries to	CIII	Members will not use tools they are not trained on. Tools will only be used if they are	Members have been informed of tool safety rules in a mandatory safety briefing.

			disability.		properly maintained.	
	Inhalation of fumes or dust.	May occur while working with some materials like carbon fiber or when working with chemicals that create fumes such as epoxy.	Can cause damage to the respiratory system.	BIII	Any members working with these materials will wear proper PPE and work in a well ventilated area.	Members have been informed of PPE rules in a mandatory safety briefing.

	Accidental Ignition of energetics.	Could be caused by accidental exposure to heat or a mistake while wiring the charges or motor with igniters.	The detonation will be harmful to anyone near it, especially if they are working on the charges with their hands. If it is the motor that is ignited, it will become uncontrollable, possibly hitting people.	BII	Energetics will only be handled by certified mentors in a dedicated staging area. They will be inhibited until the launch vehicle is put on the launch pad.	Included in the Motor and Launch Checklists.
	Overheating of electronics	During testing, electronics could overheat and potentially ignite flammable materials.	Could result in burns if personnel do not expect electronics to be hot or significant danger and damage in the case of a fire.	CII	Electronics will be carefully monitored during testing in order to ensure they do not overheat.	Will be demonstrated in all tests of the payload.

	Debris	While cutting parts or fitting pieces together, it is possible that parts may break and create potentially dangerous debris	This debris could hit personnel and cause harm depending on the debris.	BIII	All personnel in the area when parts are being worked on will be required to wear all necessary PPE in order to ensure safety	Members have been informed of PPE rules in a mandatory safety briefing.

Table 4.2.1.3. Personnel Hazard Analysis

Section 4.2.2. Failure Modes and Effects Analysis (FMEA)

FEMA Probability Definitions	
Rating	**Description**
A	The failure is expected to occur if it is not mitigated.
B	The failure is likely occur if it is not mitigated
C	The failure may occur if it is not mitigated.
D	The failure is possible but unlikely to occur.

Table 4.2.2.1. FMEA Probability Definitions

FEMA Severity Definitions	
Rating	**Description**
I	Complete loss of the item or system.
II	Significant damage to the item or system. Item requires major repairs or replacement before it can be used again.
III	Damage to the item or system which requires minor repairs or replacement before it can be used again.
IV	Damage is negligible.

Table 4.2.2.2. FMEA Severity Definitions

Failure Modes and Effects Analysis						
Item	**Failure Mode**	**Cause**	**Effect**	**Probability/ Severity**	**Mitigation**	**Verification**
Launch Vehicle	Drogue parachute does not deploy.	Using too small an ejection charge, fitting the airframe too tightly, or improperly packing the drogue parachute.	The launch vehicle will enter free fall. The vehicle is likely to be lost when the main parachute deploys at 700 ft AGL, creating multiple free falling objects posing a dangerous hazard to personnel.	CI	A second altimeter will be set to detonate a redundant black powder charge at apogee plus 1 second. All altimeters will have their programming and wiring double checked.	Included in the E-Bay Checklist.

	Main parachute does not deploy.	Using too small an ejection charge, fitting the airframe too tightly, or improperly packing the main parachute.	The launch vehicle will descend at a controlled but fast rate leading to minor damage. While slower than free fall, this still poses a danger to personnel.	CII	A second altimeter will be set to detonate a redundant black powder charge at 700 ft AGL plus 1 second. All altimeters will have their programming and wiring double checked.	Included in the E-Bay Checklist.
	Motor misfire	Improperly installing the igniter, damage to the ignitor, or damage to the motor.	The rocket may still launch creating a dangerous situation when approached by personnel.	AIV	The motor will only be handled by a certified mentor. The team will wait at least 60 seconds before approaching the launch vehicle and will follow all directions of the RSO.	Included in a mandatory safety briefing for team members. This will be repeated in pre-launch safety breings.

	Motor ejected from launch vehicle	Failure to fully tighten motor retention screws.	The ejected motor becomes a free falling object. The motor casing is unlikely to be found.	CI	The motor will be properly installed by a certified mentor. The motor retention system will be inspected prior to launch.	Motor installation is included in the Motor Checklist. Final inspection is included in the Launch Checklist.
	Shock Cord is Severed	Loosening of improperly tied knots or not being fully protected by Nomex blankets.	The recovery system will be compromised leading to one or more free falling objects .	DI	A Nomex blanket will protect the shock cord from fire damage. The black powder charges will be measured carefully by a Mentor before use.	Included in the Recovery and Assembly Checklists.

	Mistimed Deployment	Improperly programing or wiring of an altimeter or damage to the altimeter.	If the deployment of the main parachute is affected, the rocket may either drift too far or not decelerate enough before landing. If the drogue parachute is affected, it is likely to cause significant damage to the vehicle as it will deploy at unsafe speeds. High probability of creating one or more free falling	CI	A second altimeter will be set to detonate redundant black powder charges at apogee plus 1 second and 700 ft AGL plus 1 second. All altimeters will have their programming and wiring double checked.	Included in the E-Bay Checklist.

			objects.			

	Motor failure	Damage to the UAV either before or in flight which may result from mishandling of the UAV or improperly securing it within the retention system. May also result from the force experienced on landing.	Either failure to lift off or loss of control.	CII	Motors will be properly installed and secured to ensure the best chance of motor success. The retention system will be designed to protect them from impact forces.	Drop tests will be performed to ensure that the retention system offers sufficient protection from landing forces. Pre-flight checks are included in the Payload Checklist.

	Airframe Failure	Damage to the UAV either before or in flight which may result from mishandling of the UAV or improperly securing it within the retention system. May also result from the force experienced on landing.	Either failure to take off or loss of control and possible loss of the UAV.	CI	The airframe will be constructed out of carbon fiber and designed to withstand forces expected in flight, launch, and landing.	Drop tests will be performed to ensure that the retention system offers sufficient protection from landing and flight forces.

	Electronics failure	Electronics may become damaged, disconnected, or not configured for flight when being handled prior to installation. Vibrations in flight may cause wires or ports to disconnect.	Failure to take off or a significant effect on control.	CII	The electronics will be properly secured with screws. Connections will either be made with solder or ports that can withstand the vibrations of the vehicle. The system will be configured for flight and tested before being integrated into the vehicle.	Drop tests will be performed to ensure that the retention system offers sufficient protection from landing and flight forces.
	Beacon retention system failure	The system may be damaged by mishandling during installation or by landing and launch forces	The UAV will not be able to deploy the payload.	CIV	The system will be tested prior to launch. Care will be taken not to damage or block moving parts	Included in the Payload Checklist.

Payload Retention System	Failure to Deploy	Part of the airframe may land on top of the system, it may fail to eject from the airframe.	The UAV will not be able to deploy.	DIII	The shock cord will be long enough to ensure that the airframe does not land near the system.	Included in the E-Bay Checklist.
	Premature Deployment	Controller triggers prematurely.	The UAV will be dropped into a free fall.	DI	The deployment will only be triggered manually with the permission of the RSO.	All tests of the retention system will demonstrate manual control. Members will be instructed to wait for the RSO's permission before deployment in a mandatory pre-launch briefing.
	Parachute lands on Top of the System	Possible result of the launch vehicle landing in a particular orientation with the parachute too close to the payload.	Will prevent the payload from deploying. If the payload is deployed, the UAV and parachute will likely be damaged.	CIII	The parachute will be attached to the shock cord rather than directly to the payload segment to increase distance from the payload to the parachute.	This will be verified by the full-scale launch demonstration.

Table 4.2.2.3. FMEA

Section 4.2.3. Environmental Concerns

Environmental Hazards Probability Definitions	
Rating	**Description**
A	The condition is expected to have negative effects if it is not mitigated.
B	The condition is likely have negative effects if it is not mitigated
C	The condition may have negative effects if it is not mitigated.
D	The condition is possible but unlikely to have negative effects.

Table 4.2.3.1. Environmental Hazards Probability Definitions

Environmental Hazards Severity Definitions	
Rating	**Description**
I	The condition may cause death or permanent disability to personnel or loss of the system.
II	The condition may cause major injuries or significant damage to the system.
III	The condition may cause injury or minor damage to the system.
IV	The condition may cause minor injury or negligible damage to the system.

Table 4.2.3.2. Environmental Hazards Severity Definitions

Environmental Hazards Analysis					
Phase	**Environmental Condition**	**Effect**	**Probability / Severity**	**Mitigation**	**Verification**

Launch	Birds	If the launch vehicle hits a bird, it could damage the launch vehicle and alter its trajectory depending on the size of the bird. It will also harm the bird	DII	The launch vehicle will not be launched while there are birds too close to it.	The RSO is responsible for the final decision to launch. In the Launch Checklist, arming the launch vehicle is the final step.
	Strong winds	Unsafe alterations to launch vehicle's trajectory	BIV	Expected drift will be calculated and mitigated. The vehicle's launch angle may be adjusted slightly to compensate for wind.	The RSO is responsible for the final decision to launch and may call for a delay if winds are too high. Launch angle adjustment is included in the Launch Checklist.
	Inclement weather	Unsafe alterations to launch vehicle's trajectory and launch vehicle itself.	AI	The team will not launch in inclement weather.	The RSO is responsible for the final decision to launch. In the Launch Checklist, arming the launch vehicle is the final step. Based on the local weather forecast, the officers may decide

					to cancel the team's launch.
	Trees	Due to winds or an unpredicted flight path caused by a component failure, the launch vehicle or payload could end up hitting or landing in a tree.	CII	Expected drift will be calculated and mitigated. The vehicle's launch angle may be adjusted slightly to compensate for wind.	The RSO is responsible for the final decision to launch and may call for a delay if winds are too high. Launch angle adjustment is included in the Launch Checklist.
	Plants and animals.	High temperature exhaust from the motor has a chance to light flammable objects on fire if they are too close.	BIV	The vehicle will be launched on a launch rail with a blast deflector. The area will be cleared of flammable materials.	The team will only launch at launch events with an FAA Waiver hosted by NASA, GSSS, and MMMSC. The Launch Checklist explicitly states to mount the vehicle on a launch rail.

Payload Operation	Plants and animals.	Losing control of the UAV could result in it damaging plants and possibly any animals in the area.	CIII	A proper connection will be ensured prior to activating the UAV and there will be a failsafe in the case of a dropped connection or loss of control.	UAV failsafes will be demonstrated before the full scale test.
	Obstruction.	A plant, rock, or other object could get in the way of the retention system opening and get damaged or prevent the system from functioning.	DIV	The retention system will be designed to open slowly in order to minimize potential damage to any surroundings.	Retention system actuation speed is limited by the high gear ration of the linear servos. This will be demonstrated in all tests of the retention system.

Table 4.2.3.3. Environmental Hazards Analysis

Section 4.2.4. Project Risks Analysis

Project Risk Probability Definitions	
Rating	**Description**
A	The risk is expected to have negative effects if it is not mitigated.
B	The risk is likely have negative effects if it is not mitigated

C	The risk may have negative effects if it is not mitigated.
D	The risk is possible but unlikely to have negative effects.

Table 4.2.4.1. Project Risks Probability Definitions

Project Risk Severity Definitions	
Rating	**Description**
I	Irrecoverable failure.
II	Significant loss of money, time, or major design overhaul.
III	Minor loss of money, time, or minor design overhaul.
IV	Negligible effect to design, timeline, and budget.

Table 4.2.4.2. Project Risks Severity Definitions

Project Risks Overview						
Risk	**Probability/ Severity**	**Schedule Impact**	**Budget Impact**	**Design Impact**	**Mitigation**	**Verification**
Launch Cancellation	BIV	Launch delayed until next available date	None	None	The team will finish construction well before competition deadlines to ensure there are multiple launches that can be attended. The team also has GSSS as a back up launch organizer.	The team has these buffers built into the Gantt Chart.

Destruction of Full Scale	CII	The launch vehicle will need to be rebuilt over the course of two to three weeks. In addition to this, time will be needed to correct design flaws.	May cost upwards of $2000 depending on how much of the launch vehicle is salvageable.	Will likely require a major design overhaul to prevent such a failure in the future.	All checklists will be completed before launch. All aspects of the design will be looked over by multiple members and mentors to catch any possible errors. The launch vehicle will be constructed to the specifications of the design.	Completing all checklists requires the approval by all officers who are responsible for validating that all steps have been completed. throughout its construction, the vehicle's dimensions will be inspected to ensure they remain within tolerance.
Failure to secure travel funding	CII	None	Because SGA does not cover airfare, if funding is not secured members would only be able to attend if they paid $650 out of pocket. This will significantly limit the number of	None	Outreach officer will reach out to multiple companies well in advance of the competition. Other funding methods will be explored as well. Members have been informed that they may need to pay up to $650 to attend the competition.	The progress of funding is reviewed at bi-weekly advisor meetings to see if the team is on track and to decide on further steps to take to meet funding goals.

			members who can attend the competiti on.			
Damaged or delayed during shipping	CI	Would cause a delay would likely be impossible to make as it would be too close the the actual competiti on time.	None	None	The launch vehicle will be packed safely and shipped with a via a reputable shipping company to arrive slightly ahead of the team.	The package will be reviewed by the officers before shipping to verify that the motion of all components is safely restricted.

Damage to construction material.	BIII	May cause a delay to order new components from one day to two weeks depending on what was broken.	Will cost the team the amount needed to purchase the replacement.	Small design changes could be made to avoid long wait times. For example, using a differently sized quicklink.	Extra components will be ordered where possible. There is a section of the budget that covers unexpected expenses such as these.	The team will keep an inventory to track materials purchased.
Destruction of payload.	CII	Likely two to three weeks to reorder parts, rebuild, and fix design flaws.	May cost up to $749. Actual value is likely to vary as many components are likely to be salvageable.	Large design changes are likely required to resolve the issue with the payload or the launch vehicle, depending on which one was the source of the issue.	Prototype testing will occur before the construction of the final payload. The launch vehicle will undergo its own testing before they are tested together.	The full scale test will not occur until all preliminary tests have been completed.

Destruction of payload prototype.	BIII	Will require a few days to correct design flaws which lead to its destruction.	May cost up to $722. Actual value is likely to vary as many components are likely to be salvageable.	Depending on the cause of failure, will likely require at least a minor change and at most an overhaul.	To minimise budget and schedule impact, prototypes will not use all the same materials as the final payload. In particular, prototypes will not have a carbon fiber airframe.	Completing all checklists requires the approval by all officers who are responsible for validating that all steps have been completed. Throughout it's construction, the vehicle's dimensions will be inspected to ensure they remain within tolerance.
Injury	CIII	One or two days will be required to determine the cause of the injury and how it can be prevented in the future.	None	None	The team will follow all safety procedures and proper tool use. All members are required to attend a safety briefing and sign a form indicating their understanding of the safety requirements.	Team members have been informed of safety procedures in a mandatory safety briefing and will be reminded in mandatory pre-launch safety briefings.

Table 4.2.4.3. Project Risks Analysis

Section 5. Payload Criteria

Our selected design for our payload is a quadrotor UAV housed within a cylindrical retention system composed of Blue Tube. The tube will hold the UAV as well as a 3D printed stand to hold the UAV in place. When activated, the tube will open up, opening its four arms and righting itself in the process to deploy the UAV. The unfolding Blue Tube design allows for a very simplistic and reliable system, containing few parts to minimize points of failure. With regards to ejecting an inner tube mass from the outer airframe, our organization has used this design before and has proven its success through rigorous testing.. It also is very space efficient, being a cylinder housed within another cylinder, very little space is wasted and gives us greater space inside for electronics and the UAV itself. The UAV and other electronic systems will be well protected inside the airframe including shock-absorbing foam and securely mounted inside the tube. It is for these reasons that this retention system was selected as our final design over the previously considered alternatives involving the outer airframe unfolding mechanism or a system for ejecting the UAV directly from the airframe after landing.

Changes regarding the operation of the UAV are detailed in section 2.2

Figure 5.1. Retention System With UAV

Section 5.1. Materials and dimensions

The payload retention system is composed of Blue Tube 2.0 that was selected as the material for its main airframe body and four unfolding petals. The retention system is responsible for encasing, protecting, and housing the UAV during the course of its flight. Its final design incorporates a MatterHackers NylonX 3D printed internal structure that acts as the support for the internal components of the retention system and its electronics. Within the retention system are four servo mounting flaps, also 3D printed from Nylon X, that hold the linear servos that actuate to unfold the Blue Tube quarter pipe petals. The payload retention system will have a bulkhead located on one end that shock cord will be attached to. Many components will be fitted with shock-absorption padding to prevent damage from the vibrations they will experience during flight. Dimensional drawings of the system are below.

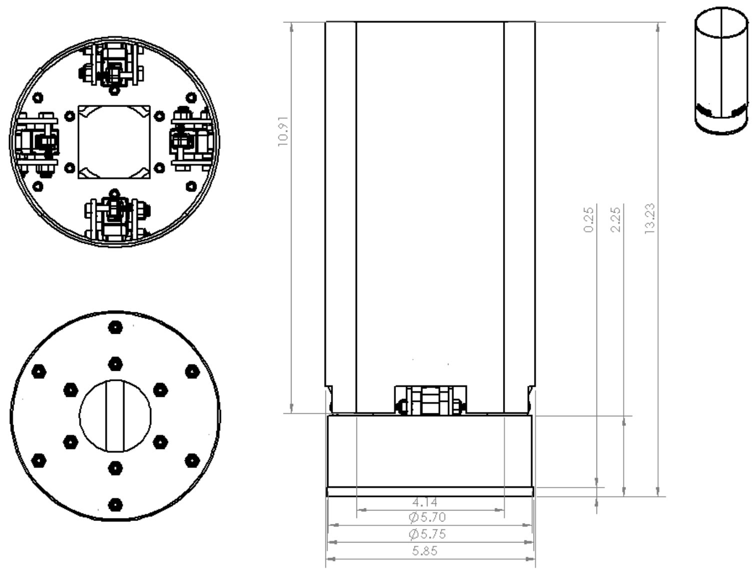


Figure 5.1.1.Retention System Dimensioned Side View

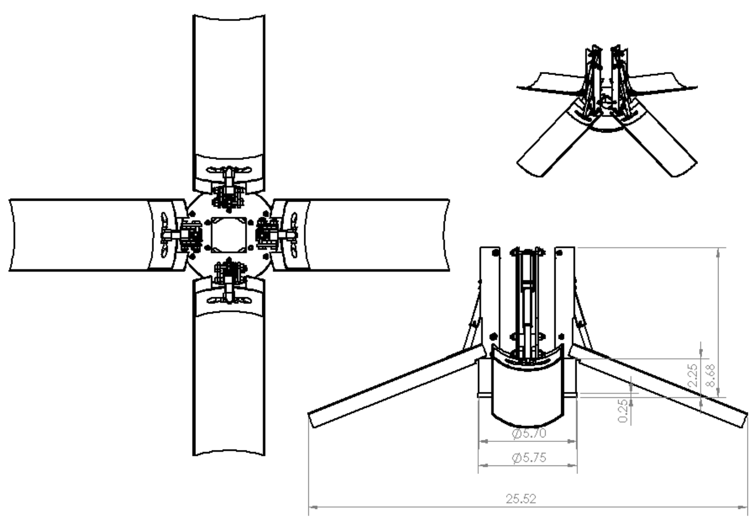


Figure 5.1.2. Retention System Dimensioned Top View

The UAV's main body is composed of two carbon fiber plates each to hold the four linear servos arranged in a square. Carbon fiber was chosen as the material of these pieces for its strength and reliability. The arms of the UAV, 3D printed from NylonX, can fold outwards and are spring-loaded such that as the retention system unfolds the arms of the UAV will naturally lower and lock in place when fully extended in flight position. Additionally NylonX 3D printed spacers are in place to act as further support for the UAV. There is also a mechanism in place to hold the beacon in flight and drop it at the FEA.

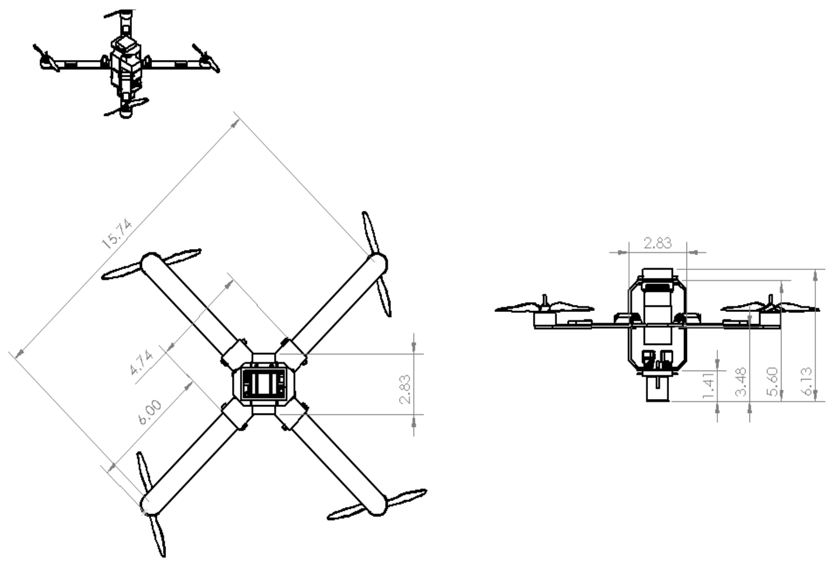


Figure 5.1.3. UAV Extended Dimension View

Section 5.2 Electronics

An Arduino Nano is the main processor of our retention system, which will receive signals from the ground station and receive the command to activate the retention system to deploy UAV for launch. There will be four linear servos, each of them will be oriented on aside of the retention system so that it will actuate to unfold and end up upright regardless of starting orientation. The LM2596 DC-DC converter will regulate the voltage of a 2 cell lithium polymer battery arrangement, covered in bright tape for identification. The retention system will be tracked with a tracking module consisting of a NEO-6MV2 and Adafruit RFM96W LoRa radio transceiver which will be powered by the retention system’s Arduino Nano and battery. This transceiver will additionally listen for the signal sent by the ground station to unfold the retention system and activate the UAV using contact pads. The contact pads will complete a circuit between the electrical ground of the retention system, the coil of the latching relay on the UAV, and a digital pin of the Arduino, with the resistance of the coil limiting the current load on the pin to prevent damage to it. There will be a rotary switch included the retention system so that it can safely be powered on and off while fully secured.

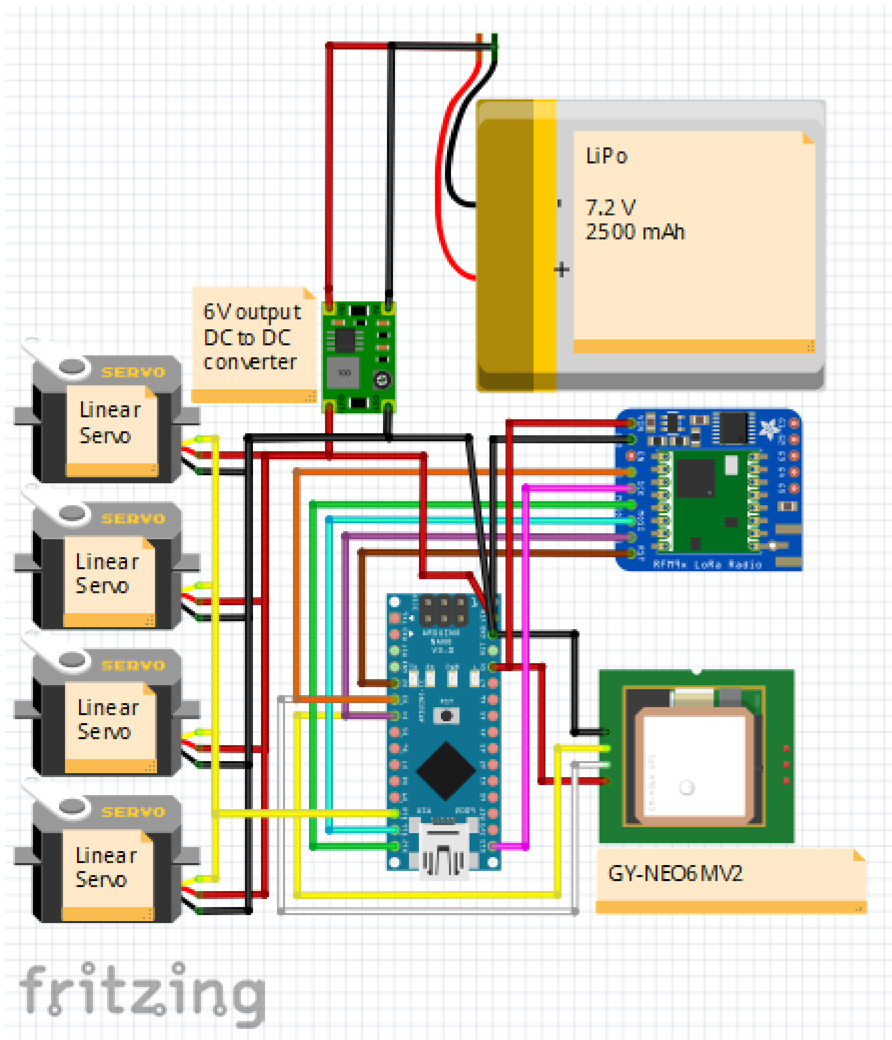


Figure 5.2.1. Retention System Electronics

The UAV utilizes various electronic components. A Pixhawk mini will be used as the main processor of the UAV. The Pixhawk contains a GPS that will be used for tracking the location of the UAV. A telemetry radio included with the Pixhawk and used to communicate between the ground station and UAV. The UAV will have four brushless dc motors and four electronic speed controllers powered by two 1000mAh LiPo batteries connected in parallel, both of which will be covered in brightly colored tape for recognition. A 60 Amp continuous capable relay will be wired in series with the batteries so that the UAV will be completely powered off during the flight of the rocket.

The team was initially going to use an NRF24L01+ as our transceiver, however, in testing, the team discovered that the range of these transceivers was not going to suit the requirements. Even with each having an antenna and the ground station using a 24dBi 2.4GHz Grid Parabolic Antenna, the transmission was not reliable. instead an Adafruit RFM95w LoRa radio transceiver will be placed on each of the parts of the rocket that need to be tracked. In the tests, the LoRa proved to be much more effective than the NRF24L01+. The module containing the LoRa will be connected the same as our previous design but with the new transceiver. Each of them will transmit GPS data collected by a NEO-6MV2 gps to a ground station. The ground station will consist of another LoRa system connected to a computer. The drone retention system will listen for an activation signal in addition to transmitting gps data.

Section 5.3 Component interaction

The retention system and launch vehicle will be friction fit within the the upper airframe. It will be secured to the main parachute and the upper airframe by shock cord. It will be ejected at 700ft AGL by a black powder charge triggered by the main altimeter. In the case that the system fails to deploy, there is a secondary charge that will be triggered by a secondary altimeter at 700ft AGL plus one second.

Section 5.4 Calculations

The estimated final weight of the UAV is 632 grams, making the thrust required by each of the four motors 158 grams. The test in section 6.1.2 shows that when producing this thrust the motor draws a little less than 3 Amps, giving an estimated continuous current draw of 12 Amps to the battery. At this rate, the 2000mAh battery will need to be recharged after 10 minutes of flight time. The mission of delivering the beacon to the FEA was estimated to require no more than 5 minutes, giving us double the flight time as a safety precaution should something go wrong and additional human intervention needed during the mission.

With an estimated final weight of 632 grams and the maximum thrust our selected motors can produce being about 650 grams, the UAV will have a maximum thrust to weight ratio of one to four, making for a stable and well-mobile aerial vehicle for the mission.

As the battery to be used to power the retention system will have a capacity of 2500mAh, with the Arduino Nano drawing about 19mA, the GPS 45mA, and the LoRa transceiver a maximum of 100mA, a maximum constant current load of 164mA will be required by the battery. At this rate it will need to be recharged after about 15.5 hours, giving us the maximum time our rocket can remain on the launch pad before the retention system requires recharging.

Section 6. Project Plan

Section 6.1. Testing

Multiple tests have been completed to insure a thorough design. Through these multiple tests different design iterations have been made to create a more thoughtful and fleshed out design. Therefore creating a more successful designs all around.

Section 6.1.1. Launch Vehicle Tubular Nylon Shock Cord Demonstration

To verify the team's selection of shock cord, the team planned to test the maximum force the shock cord. The team has planned to test this before the FRR, however, in the meantime, the team organized a demonstration. To do this, a 40 lb weight was tied to one end while the other was fixed to a metal bar. This was chosen to add a significant safety factor over the 25.5 lb weight of the rocket. The weight was then dropped a distance of 15 in. This information was used to calculate the force experienced by the rocket.

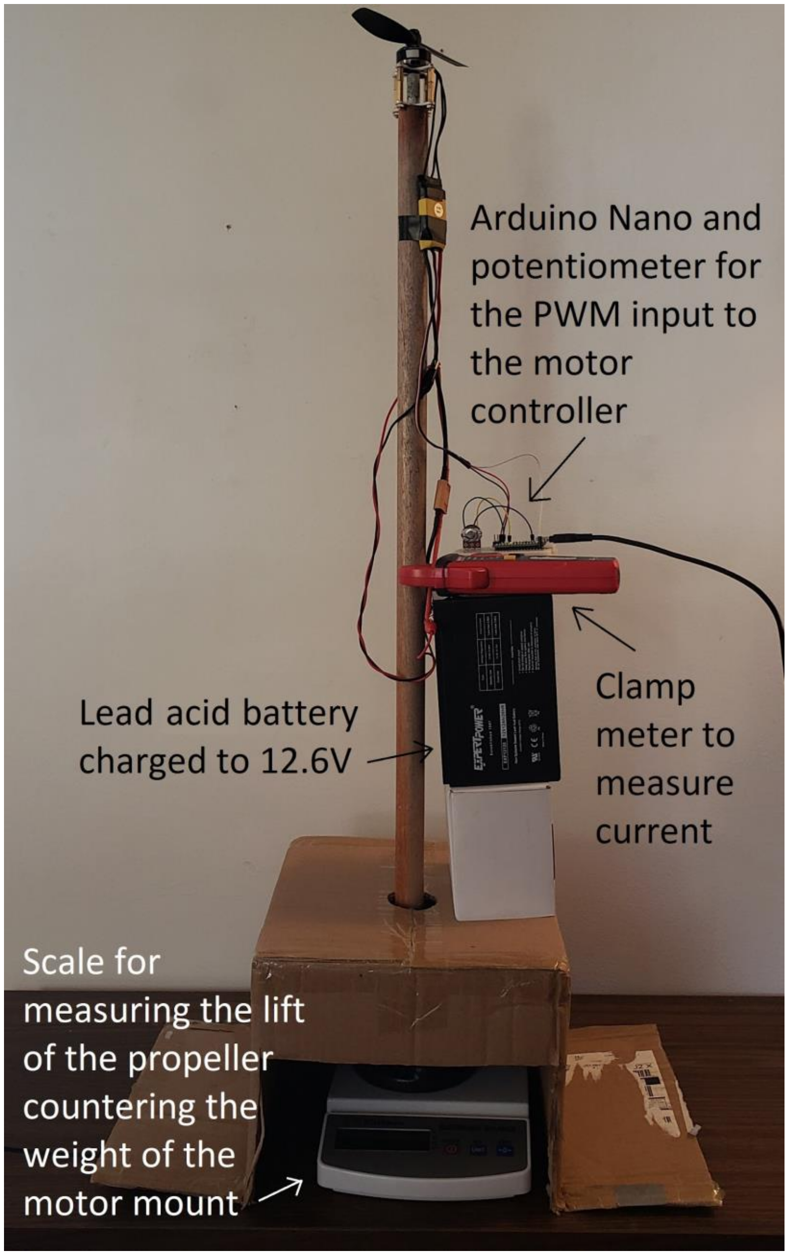
$$v = \sqrt{2\,a\,\Delta x} \qquad 8.94\,\frac{ft}{s} = \sqrt{2 * 32\,\frac{ft}{s^2} * 15\,in}$$

$$P = mv \qquad 11.11\,slug\,\frac{ft}{s} = 1.24\,slugs * 8.94\,\frac{ft}{s}$$

$$F = \frac{P}{t} \qquad 111.14\,lbs = \frac{11.11\,slug\,\frac{ft}{s}}{.1\,s}$$

Section 6.1.2. Payload Testing

A significant test regarding the design of the payload, specifically the UAV, was determining the power required by the motors providing the thrust to keep it airborne. The purpose of this test was to determine if the lower power required by stronger motors with wider propellers and the estimated maximum flight time of the UAV would justify the weight and volume they would require. Due to self-imposed desired size and weight constraints for the retention system, propellers no wider than 9 inches in diameter were considered for the final design. To drive the propellers, two brushless DC motors known for their robustness were tested. First, the Lumenier RX2206-13 2000KV with a 6 inch diameter and 4.5 inch pitch propeller and then the A2212/13T 1000KV with both an 8 inch and 9 inch diameter propeller, each with a 4.5 inch pitch. The testing apparatus used which can be seen in figure Figure 6.1.2.1. consisted of the motor mounted to a wooden pole with weights secured to the bottom to prevent it from falling over or moving undesirably during the test. This mount was placed onto a digital scale to measure in grams the force of thrust put out by the propeller to counter the weight of the rig. A lead acid battery charged to 12.6V, the voltage of a lithium polymer battery at full charge, was used to provide electrical power to the motor, securing it to a box covering the scale to prevent the wind from the propeller from significantly affecting the weight measurement. A clamp multimeter was used to measure the current and an Arduino Nano with a rotary potentiometer was used to generate the Pulse Width Modulation (PWM) square wave required by the motor controller. Once everything was safely secured, using the serial interface between the Arduino and a laptop to see the voltage of the potentiometer controlling the PWM duty cycle, the throttle to the motor controller was increased in increments of 10% starting from 0% to record 10 data points. The thrust produced and the corresponding current drawn by the three different motor and propeller configurations tested with this apparatus at increasing throttle levels can be seen in Figure 6.1.2.2..


Arduino Nano and potentiometer for the PWM input to the motor controller
Lead acid battery charged to 12.6V
Clamp meter to measure current
Scale for measuring the lift of the propeller countering the weight of the motor mount

Test 6.1.2.1

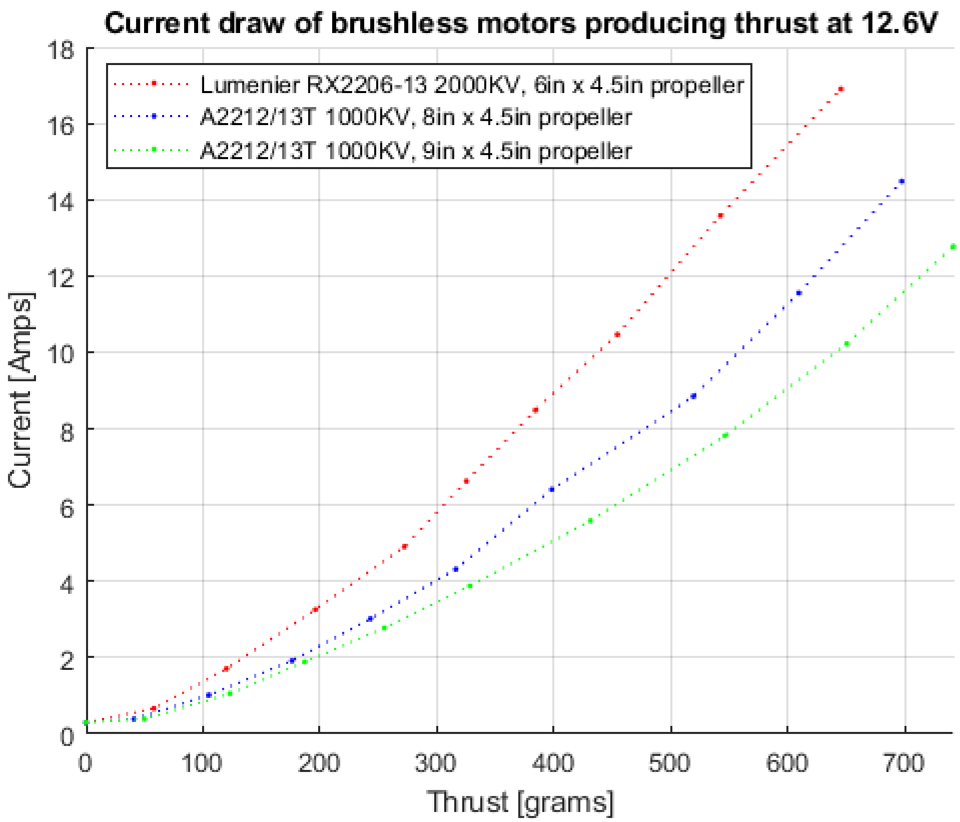


Figure 6.1.2.2. Current vs. Thrust Test Data

Through this test it can be determined that the motors perform as expected. As a brushless motor with a lower KV value will spin slower than one with a higher value at the same voltage, it will correspondingly provide greater torque desirable for larger propellers moving a greater amount of air. The result which can be clearly visualized in the graph is that the 1000KV motor draws less current than the 2000KV motor to produce the same thrust spinning its propeller. It was for these reasons that the A2212/13T 1000KV motor was an initial choice for the UAV, however the constraints of size and weight played a significant role in the final selection. From the batteries intended for use in the UAV selected primarily for their size and weight, the estimated final weight of the UAV without motors and propellers is 508 grams. From this value, the thrust required by each of the four motors to keep the UAV airborne would be 158 grams for the 6 inch propeller, 178 grams for the 8 inch propeller, and 180 grams for the 9 inch, pertinent calculations of which be found in greater detail in section 5.4. These values are of concern as they affect the estimated maximum flight time of the UAV, with an important observation being that the three motor and propeller configurations draw closer to the same current at a lower thrust output and begin to diverge as the thrust increases. From these values and the current each of these configurations would constantly require for stable flight for a quadcopter of the size intended by our design, it can be determined that the difference in the flight time between them would not justify the additional size and weight of the larger propellers. This conclusion made from this test played a significant role in the selection the 6 inch propellers and 2000KV motors to fly the UAV.

Section 6.2. Requirements Compliance

In order to ensure a successful year requirements had to be met and verified. This has been completed for both handbook requirements and team derived requirements. All requirements have been verified through one of the four methods. Testing is used for checking specific characteristics and parameter. Analysis is used to explain or interpret a methodic and detailed test. Inspection is used to determine conditions and status through investigation. Demonstration is used to check the future success of a task.

Section 6.2.1. Handbook Requirements

General Requirements			
NASA Requirements	**How we Plan to Meet Them**	**Method**	**Verification**
1.1. Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of 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).	We will make sure that the work is completed by students and not mentors.	Inspection	We will verify this by making sure that no mentors work on the paperwork.

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.	We will include all of the listed requirements for the project plan	Inspection	We will use a Gantt chart and stick to a rigid schedule to make sure that everything is completed and done on time.
1.3. Foreign National (FN) team members must be identified by the PDR and may or may not have access to certain activities during launch week due to security restrictions.	We will make sure our Foreign Nationals are identified by the PDR.	Inspection	We will verify this by asking the team multiple times.
1.4. The team must identify all team members attending launch week activities by the Critical Design Review (CDR). Team members will include:	We will make sure that all members are identified by the CDR.	Inspection	We will verify this by creating a checklist.
1.5. The team will engage a minimum of 200 participants in educational, hands-on STEM activities, as	We will participate in multiple outreach event throughout the year.	Inspection	We will verify that we are completing these task by looking at the Gantt chart

defined in the STEM Engagement Activity Report, by FRR.			and taking numbers of participants at event.
1.6. The team will establish a social media presence to inform the public about team activities.	We will create multiple social media platforms and continually update them.	Demonstration	We will verify this looking at the amount of followers we have.
1.7. Teams will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone.	We will email and submit our documents a day before the deadline in order to limit risks of submitting late.	Inspection	We will verify this by checking with the handbook and the Gantt Chart
1.8. All deliverables must be in PDF format.	We will make sure to convert them for submission.	Demonstration	We will varitying by making sure all finalized documents are saved in PDF form.
1.9. In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Every document will have a Table of Contents	Demonstration	We will verify that there is a table of content before submitting.
1.10. In every report, the team will include the page number at the bottom of the page.	Page numbers will be programmed to be at the bottom of every page	Demonstration	We will verify that there is a page number at the bottom of every page

			before submitting.
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 sufficient Internet connection.	We will make sure to get everything ahead of the due date.	Demonstration	We will verify everything by making a checklist that we will follow
1.12. All teams will be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted on the launch field. Eight foot 1010 rails and 12 ft 1515 rails will be provided. The launch rails will be canted 5 to 10 degrees away from the crowd on launch day.	We will build our launch vehicle for the appropriate launch pad design.	Testing	We will verify this by testing the vehicle with the proper launch pad.
1.13. Each team must identify a "mentor." A mentor is defined as an adult who is included as a team	We have found a mentor that has all of the prior experience we need.	Demonstration	We will verify this by routinely communication.

member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor must maintain a current certification, and be in good standing, through the NAR or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week.			

Table 6.2.1.A. General Requirements

Vehicle Requirements			
NASA Requirements	How we Plan to Meet Them	Method	Verification

2.1. The vehicle will deliver the payload to an apogee altitude between 4,000 and 5,500 feet 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	Our launch vehicle will have an apogee of 4683 feet, within the acceptable range.	Demonstration	We will use an on-board Raven 3 Altimeter to verify our altitude during test launches.
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.	We will base our target altitude on the value of our expected apogee. This value is currently 4683ft AGL.	Analysis	We will use the data from the altimeter during test launches to confirm our expected apogee.
2.3. The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner.	Our launch vehicle will have 2 Raven 3 barometric altimeters on board.	Inspection	Before launching both altimeters will be double checked that they are programmed correctly and then after flight we will acquire the data off of them in order to determine our final altitude.

2.4. Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	We will be using an external switch for the altimeters.	Inspection	Holes will be drilled into the coupler for the switches to fit in snuggly. They will be secured such that they won't come out during flight.
2.5. Each altimeter will have a dedicated power supply.	Each Altimeter will be supplied with a 9V battery.	Inspection	As part of the launch checklist we will make sure all batteries are fresh and securely connected to its corresponding altimeter.
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).	The arming switch we have chosen can only be switched on and off using a precision screwdriver.	Demonstration	The switch will be left in the on position and then the screwdriver will be put away so that there's no worry of the switch being accidently shut off.
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	We will use materials durable enough to withstand the forces of flight and landing	Testing	The Sub-scale and test launches will help to determine whether or not a stronger material needs to be looked into.

repairs or modifications.			
2.8. The launch vehicle will have a maximum of four independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.	We have limited our design to four independent sections.	Inspection	Our four sections will be defined as the nose cone, upper airframe, lower airframe and payload retention system.
2.8.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least one body diameter in length.	All coupler shoulders will be at least 6in long.	Inspection	The coupler for the e-bay is 6in on either side.
2.8.2. Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	The nose cone shoulder will be at least 6in long.	Inspection	The nose cone shoulder is 7.13in.
2.9. The launch vehicle will be limited to a single stage.	Our Launch Vehicle will only have one stage.	Inspection	Only one motor will be used in the design and flight of the launch vehicle.

2.10. The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.	All materials necessary for the rocket's success will be prepared in advance.	Inspection	There will be a launch day checklist to ensure everything that can be prepared beforehand is ready to go.
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.	The ability of the vehicle to stay in launch-ready mode for a minimum of two hours will be tested before competing in the competition.	Demonstration	Using brand new batteries we will use the test launches as a way to ensure the vehicle can stay in launch-ready mode for two hours.
2.12. The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated launch services provider.	We plan to meet this by using the igniter supplied with the motors	Analysis/Testing	We will verify this at our test launches.
2.13. The launch vehicle will require no external circuitry or special ground support equipment to	We will only use the igniter that came with the specific motor and what's supplied at the launch pad to initiate launch.	Demonstration	We will verify this at test launches.

initiate launch (other than what is provided by the launch services provider).			
2.14. The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the NAR and TRA.	We will only be using motors manufactured by CTI	Inspection	We will check and verify these motors are approved and certified by the NAR before ever placing them in the launch vehicle
2.14.1. Final motor choices will be declared by the CDR milestone.	A final design of the launch vehicle will be finished by the CDR in order to determine the best appropriate motor		there will be no further changes of the launch vehicle design or motors by the 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	We will take all precautions to accurately choose the best and most safe motor for our launch vehicle. This is in order to avoid having to change the motor after the CDR with the final design is submitted.	Analysis/Testing	calculations and simulations will be used to confirm the efficiency of the motor in our launch vehicle before submitting the CDR so it never has to be changed.

milestone, regardless of the reason.			
2.15. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:	N/A-We will not be using pressure vessels	N/A	N/A
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.	N/A-We will not be using pressure vessels	N/A	N/A
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.	N/A	N/A	N/A
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,	N/A	N/A	N/A

including the number of pressure cycles put on the tank, by whom, and when.			
2.16. The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newton-seconds (L-class). The total impulse provided by a High School or Middle School launch vehicle will not exceed 2,560 Newton-seconds (K-class).	We have only been looking at L-class and K-class motors throughout the design process	Inspection	We will calculate the chosen primary and backup motor's impulse in order to ensure they fit within the L-class limit. Our launch vehicle currently has an L730 as its primary motor
2.17. The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	We will use Open Rocket to simulate the stability of the launch vehicle.	Demonstration	Our current launch vehicle design has a stability of 3.36.
2.18. The launch vehicle will accelerate to a minimum velocity of 52 ft/s at rail exit.	We will use Open Rocket to ensure the launch vehicle will accelerate to at least 52 ft/s at rail exit	Demonstration	Our launch vehicle currently has a rail exit velocity of 60ft/s

2.19. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets.	We will scale our full scale design down and build a smaller version of it for the subscale.	Testing/Analysis	Our sub-scale launch vehicle was built early due to limited launches during the winter months in New England. Its launch was on Oct. 20th in Berwick Maine and was successful.
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.	The subscale model was designed to match the full scale launch vehicle as accurately as possible.	Demonstration	The subscale was divided into 4 main pieces just like the full scale with a piece of aluminum tethered to the launch vehicle to simulate the weight of the UAV
2.19.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude.	The Subscale model had an electronics bay housing a Raven 3 altimeter.	Analysis	Using this altimeter we were able to get the apogee altitude and flight data for the subscale.
2.19.3. The subscale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	All new parts will be ordered for the subscale rocket test.	Inspection	The subscale was built completely from scratch with new materials.
2.19.4. Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to	The subscale launch vehicle's altimeter will be used to recover flight data	Inspection/Analysis	We were able to successfully receive flight data from the raven 3 altimeter located in the

meet this requirement.			electronics bay of the subscale
2.20. All teams will complete demonstration flights as outlined below.	Demonstration flights will be scheduled for the team	Demonstration	These will be mandatory for all members
2.20.1. Vehicle Demonstration Flight - All teams will successfully launch and recover their full scale rocket prior to FRR in its final flight configuration. The rocket flown must be the same rocket to be flown on launch day. The purpose of the Vehicle Demonstration Flight is to validate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at	Test flights will be held in Berwick, Maine at their launch site. The team intends to work with MMMSC for test launches. The launch vehicle will not be changed after test flights. All hardware will be thoroughly checked after flight to ensure everything is in good condition and working properly.	Inspection	Test flights are scheduled according to launch dates for the Berwick Maine launch site. The launch vehicle will be built such that any damage is negligible and it can be launched again at the competition.

apogee, main chute at the intended lower altitude, functioning tracking devices, etc.).			
2.20.1.1. The vehicle and recovery system will have functioned as designed.	The launch vehicle recovery system will be assembled as described in all designs and simulations.	Inspection	Extra care will be taken to ensure parachutes are placed in the correct packing order and each tethered or piece landing separate will be equipped with its own GPS system
2.20.1.2. The full scale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	All components have been designed for the USLI launch vehicle. No designs will be used from previous launch vehicles made by the WPI AIAA chapter.	Demonstration	The full scale will be constructed using all new materials specified in the budget
2.20.1.3. The payload does not have to be flown during the full scale Vehicle Demonstration Flight. The following requirements still apply:	N/A	N/A	N/A
2.20.1.3.1. If the payload is not flown, mass simulators will be used to simulate the payload mass.	If the payload is ready to be flown by test launches mass simulators will be measured just in case.	Testing/Demonstration	Mass simulators will be brought to the test launch regardless of whether or not the payload is ready to fly just in case.

2.20.1.3.2. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.	Mass simulators will be secured within the payload retention system so that they are located in the same place the payload would be	Inspection	We will ensure we have the necessary materials to ensure the mass simulators are placed in the best position to simulate as if the actual UAV was there.
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 Vehicle Demonstration Flight.	N/A	N/A	N/A
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.	We will use the motor in our design for our test launches	Demonstration	We will make sure the simulations continue to check out with the motor we are chosen and that we have it on hand when we go to launch

2.20.1.6. The vehicle must be flown in its fully ballasted configuration during the full scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full scale launch vehicle.	We will not make any changes to the launch vehicle or its flight configuration after the CDR submission	Inspection	The launch vehicle will be flown in identical configurations for the test and competition flights
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 RSO.	The launch vehicle will not be changed after the successful test flight	Inspection	We will make sure we are satisfied with our final design before we go to launch to ensure we won't need or want to make any changes after
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.	The launch vehicle will provide data for the FRR with its electronics bay and raven three altimeter during flight	Testing	We will receive data from the altimeter for the FRR after the launch vehicle has landed
2.20.1.9. Vehicle Demonstration flights must be completed by the FRR submission deadline. If the	Demonstration flights will be completed before the FRR	Demonstration	We will take extra care to make sure our launch vehicle and payload are both working in top

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.			order to avoid have to redo our demonstration flights
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 rocket flown must be the same rocket to be flown on launch day.	Demonstration flights will be completed prior to the payload demonstration flight	Demonstration	We will make sure our Gantt chart accounts for this so that the launch vehicle is ready to fly and complete its demonstration flight prior to that of the payload
2.20.2.1. The payload must be fully retained throughout the entirety of the flight, all retention mechanisms must function as designed,	The payload will be housed in its own retention system that will stay within the launch vehicle for the duration of its flight	Inspection	We will verify that the payload has stayed contained safely within the payload retention system once it has landed.

and the retention mechanism must not sustain damage requiring repair.			
2.20.2.2. The payload flown must be the final, active version.	The payload will be the final active version proposed in the CDR	Inspection	No changes will be made to the UAV after the CDR to ensure it's the final active version
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.	N/A	N/A	N/A
2.20.2.4. . Payload Demonstration Flights must be completed by the FRR Addendum deadline. No extensions will be granted.	Payload demonstration flights will be completed by the FRR	Demonstration	The payload will be finished with building in time to get the demonstration flights done before the FRR deadline
2.21. An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA required Vehicle	N/A	N/A	N/A

Demonstration Re-flight after the submission of the FRR Report.			
2.21.1. Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly the vehicle at launch week.	N/A	N/A	We will make sure to submit the FRR on time
2.21.2. Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight requirement will not be permitted to fly the payload at launch week.	N/A	N/A	N/A
2.21.3. Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly	N/A	N/A	N/A

the payload at launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.			
2.22. Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	The only protuberance, the electronics bay switch will be located aft of the burnout center of gravity	Inspection	Multiple team members will check to confirm the switch is located in the correct place
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. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	The Teams name and contact information will be written on the side of the launch vehicle	Inspection	Permanent marker will be used to ensure the name and contact information of the team doesn't fade or get wiped off during the duration of the competition
2.24. Vehicle Prohibitions	N/A	N/A	N/A

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.	We will not be using canards or camera housings on the launch vehicle	Inspection	These components will not be included in the design of the launch vehicle
2.24.2. The launch vehicle will not utilize forward firing motors.	The launch vehicle will not use forward firing motors	Inspection	The launch vehicle will be designed using Cesaroni Tech motors approved and certified by the NAR
2.24.3. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	The launch vehicle will not use motors that expel titanium sponges	Inspection	The launch vehicle will be designed using Cesaroni Tech motors approved and certified by the NAR
2.24.4. The launch vehicle will not utilize hybrid motors.	The launch vehicle will not be designed for hybrid motors	Inspection	The launch vehicle will be designed using Cesaroni Tech motors approved and certified by the NAR
2.24.5. The launch vehicle will not utilize a cluster of motors.	The launch vehicle will not be designed for a cluster of motors	Inspection	The launch vehicle will be designed using Cesaroni Tech motors approved and certified by the NAR

2.24.6. The launch vehicle will not utilize friction fitting for motors.	We will not use friction fitting for motors instead we will use a motor retention system	Inspection	The motor retention system will be put together using screws, clips to hold on the motor, and a screwdriver
2.24.7. The launch vehicle will not exceed Mach 1 at any point during flight.	The launch vehicle will be designed in Open Rocket to not exceed Mach 1 at any point during flight	Inspection	The launch vehicle's simulated speed is Mach .55.
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).	Any ballast incorporated into the launch vehicle will not exceed 10% of the unballasted weight	Analysis	Calculations will be condoned to confirm any ballast is within the 10% margin
2.24.9. Transmissions from onboard transmitters will not exceed 250 mW of power.	The GPS tracking transmitters we plan to use are rated for less power than the specified output maximum	Analysis	We will ensure the output power of all transmitters does not exceed this limit prior to their integration into the launch vehicle
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	The amount and type of metal will be limited in the design of the launch vehicle. There will be no excessive use of metal.	Inspection	The only metal components currently incorporated in our launch vehicle design involves quick links, u-bolts, nuts, bolts, screws,

necessary to ensure structural integrity of the airframe under the expected operating stresses.			and a metal tipped ogive nose cone.

Table 6.2.1.B. Vehicle Requirements

Recovery Systems Requirements			
NASA Requirements	**How we Plan to Meet Them**	**Method**	**Verification**
3.1. The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.	The launch vehicle will have a 36in drogue parachute programmed to deploy at apogee, a 72in main parachute and 36in nose cone parachute programmed to deploy at 700ft	Inspection	A Raven 3 Altimeter will be used to program the dual deployment system on the launch vehicle ensuring the drogue parachute deploys at apogee, and the main and nose cone parachute deploys at 700ft

3.1.1. The main parachute shall be deployed no lower than 500 feet.	The main parachute will be deployed at 700ft	Inspection	The Raven 3 Altimeter will be programmed to deploy the main parachute at 700ft
3.1.2. The apogee event may contain a delay of no more than 2 seconds.	The primary altimeter will release the drogue parachute at apogee and the secondary altimeter will release the drogue parachute at apogee plus one	Inspection	We will use software to ensure both altimeters are programmed to accurately follow these guidelines
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	A ground ejection test will be done before the subscale and full scale launches	Testing	Ground ejection tests will be scheduled in the Gantt chart in order to ensure they are planned accordingly
3.3. At landing, each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf	Each independent section will have its kinetic energy calculated to confirm it is below 75 lbf-ft.	Analysis	All kinetic energy values are below this limit
3.4. The recovery system electrical circuits will be completely	Launch vehicle electrical components will be kept separate from payload electrical components	Inspection	Launch vehicle electrical components will be housed in its

independent of any payload electrical circuits.			electronics bay whereas payload electrical components will be housed within the payload
3.5. All recovery electronics will be powered by commercially available batteries.	Recovery electronics such as the gps system and Raven 3 Altimeter will be powered with commercially available batteries	Inspection	Electronics will be powered using 9V batteries
3.6. The recovery system will contain redundant, commercially available altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	The launch vehicle will be using two raven three altimeters one primary and one secondary.	Testing	We will verify both altimeters are working as they are supposed to before launch
3.7. Motor ejection is not a permissible form of primary or secondary deployment.	The motor will not be used as a form of primary of secondary deployment	Inspection	Deployment will be triggered using the primary and secondary Raven three altimeters.
3.8. Removable shear pins will be used for both the main parachute compartment and the drogue	Shear pins will be placed on both the upper and lower airframes	Inspection	The launch vehicle will be checked before launching to ensure shear pins are where they need to be.

parachute compartment.			
3.9. Recovery area will be limited to a 2,500 ft. radius from the launch pads	To ensure the launch vehicle lands within this radius it has been designed to fit the 90s decent limit	Analysis	Using Open Rocket simulations we are able to monitor our descent time during the construction of the launch vehicle.
3.10. Descent time will be limited to 90 seconds (apogee to touch down).	The launch vehicle's design takes this into account adjusting parachute sizes to fit in this descent time limit	Analysis	Using Open Rocket simulations we are able to monitor our descent time during the construction of the launch vehicle. Additionally the launch vehicles descent time will be timed when we go to test launches.
3.11. An electronic tracking device will be installed in the launch vehicle and will transmit the position of the	A GPS tracking device will be located on each independent piece of the launch vehicle	Inspection	The GPS tracking device will be checked before launch to ensure it is transmitting data correctly

tethered vehicle or any independent section to a ground receiver.			
3.11.1. Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.	Any untethered piece of the launch vehicle will contain its own GPS tracking device	Inspection	The nose cone and the rest of the launch vehicle body along with the payload will have their own GPS tracking device
3.11.2. The electronic tracking device(s) will be fully functional during the official flight on launch day.	GPS tracking devices will be bought new to ensure there is no damage done to them and to ensure they will work properly	Inspection	GPS tracking devices will be checked before launch to ensure they are transmitting data correctly
3.12. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	The GPS devices will be wired such that they are not affected by the other electronics on the launch vehicle	Inspection	All wiring will be checked more than once and tested to ensure there is no interference
3.12.1. The recovery system altimeters will be physically located in a separate compartment within the vehicle	The e-bay will be divided into two separate compartments. One will house the altimeters for recovery the other will house the gps tracking device	Inspection	The altimeters will be checked to ensure there is no interference between it and the gps device

from any other radio frequency transmitting device and/or magnetic wave producing device.			
3.12.2. The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.	Recovery system electronics will be shielded from onboard transmitting devices	Inspection	Recovery system devices will be checked to ensure there is no interference due to other transmitting devices
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.	Recovery system electronics will be shielded from other onboard devices	Inspection	Recovery system devices will be checked to ensure there is no interference due to other devices
3.12.4. The recovery system electronics will be shielded from any other onboard	Recovery system electronics will be shielded from other onboard devices	Inspection	Recovery system devices will be checked to ensure there is no interference

devices which may adversely affect the proper operation of the recovery system electronics.			due to other devices

Table 6.2.1.C. Recovery System Requirements

Payload Requirements			
NASA Requirements	**How we Plan to Meet Them**	**Method**	**Verification**
4.2 College/University Division – Each team will choose one experiment option from the following list.	We will select only one experiment option.	N/A	We selected the UAV experiment option.
4.2.1 An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring.	N/A	N/A	N/A
4.2.2 If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety. Option 1: Deployable Rover/Soil Sample Recovery Option 2: Deployable UAV/Beacon Recovery	N/A	N/A	N/A

4.3 Deployable Rover / Soil Sample Recovery Requirements	N/A	N/A	N/A
4.3.1 Teams will design a custom rover that will deploy from the internal structure of the launch vehicle.	N/A	N/A	N/A
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.	N/A	N/A	N/A
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.	N/A	N/A	N/A
4.3.4 After deployment, the rover will autonomously move at least 10 ft. (in any direction) from the launch vehicle. Once	N/A	N/A	N/A

the rover has reached its final destination, it will recover a soil sample.			
4.3.5 The soil sample will be a minimum of 10 mL.	N/A	N/A	N/A
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.	N/A	N/A	N/A
4.3.7. Teams will ensure the rover's batteries are sufficiently protected from impact with the ground.	N/A	N/A	N/A
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	N/A	N/A	N/A

4.4 Deployable Unmanned Aerial Vehicle (UAV) / Beacon Delivery Requirements	N/A	N/A	N/A
4.4.1. Teams will design a custom UAV that will deploy from the internal structure of the launch vehicle.	We will design our own UAV and internal retention system.	N/A	The UAV will be of our own design and built alongside the launch vehicle team to ensure an internal retention structure.
4.4.2. The UAV will be powered off until the rocket has safely landed on the ground and is capable of being powered on remotely after landing.	We will have our UAV powered off until it is confirmed landed by a visual confirmation and powered on after that.	Inspection	We will verify that the launch vehicle has landed and power on the rover remotely.
4.4.3. The UAV will be retained within the vehicle utilizing a fail-safe active retention system. The retention system will be robust enough to retain the UAV if atypical flight forces are experienced.	The UAV retention system will be encased within the body of the launch vehicle and designed to be robust enough to handle any forces it might experience in flight.	Inspection	The UAV retention system will be carefully inspected prior to installation and installed with care to keep it within the launch vehicle.

4.4.4 At landing, and under the supervision of the Remote Deployment Officer, the team will remotely activate a trigger to deploy the UAV from the rocket.	At launch, we will wait until the RDO gives us a go-ahead to activate the UAV.	N/A	We will communicate with the RDO to ensure proper methods are followed
4.4.5. After deployment and from a position on the ground, the UAV will take off and fly to a NASA specified location, called the Future Excursion Area (FEA). Both autonomous and piloted flight are permissible but all reorientation or unpacking maneuvers must be autonomous.	Our UAV retention system will unpack and prepare the UAV for launch autonomously. After unpacking, the UAV will be teleoperated to deliver the beacon.	Demonstration	After anRDO confirms the landing of our retention system, we will send the signal to autonomously unpack the UAV and proceed to pilot it.
4.4.6 The FEA will be approximately 10 ft. x 10 ft. and constructed of a color which stands out against the ground.	N/A	N/A	N/A
4.4.7 One or more FEA's will be located in the recovery area of the launch field. FEA samples will be	N/A	N/A	N/A

provided to teams upon acceptance and prior to PDR			
4.4.8 Once the UAV has reached the FEA, it will place or drop a simulated navigational beacon on the target area.	Our UAV will have a retention system for the beacon that will release once it has reached the FEA.	Inspection	We will have an onboard camera that will be used to verify the UAV is over the FEA.
4.4.9 The simulated navigational beacon will be designed and built by each team and will be a minimum of 1 in W x 1 in H x 1 in D. The school name must be located on the external surface of the beacon.	Our beacon will be a 1 inch cube with the WPI seal on it.	Inspection	We will measure the cube and store it within the UAV and launch vehicle in such a way it maintains shape and design.
4.4.10 Teams will ensure the UAV's batteries are sufficiently protected from impact with the ground.	We will have the batteries placed within the UAV such that they are protected from punctures and direct impacts should the UAV fail.	Testing	The UAV will be tested prior to launch to verify battery safety.
4.4.11 The batteries powering the UAV will be brightly colored, clearly marked as a fire hazard,and easily distinguishable from other UAV parts.	The batteries will be colored brightly and marked as fire hazards, clearly visible as its own part.	Inspection	We will make sure with multiple people that the batteries are clearly visible and marked.

4.4.12 The team will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).	We will be aware of and abide by all FAA regulations that apply.	Inspection	We will verify the rules defined by the FAA are followed by the final design and our intentions of use.
4.4.13 Any UAV weighing more than .55lbs will be registered with the FAA and the registration number marked on the vehicle.	If the payload is greater than .55lbs, the team will register it with the FAA and ensure it is clearly marked with its registration number.	Inspection	Based on our final design of the UAV, we will determine the weight and follow through with registration if necessary.
4.5 Team-Designed Payload Requirements (High School/Middle School Division)	N/A	N/A	N/A
4.5.1 Team-designed payloads must be approved by NASA. NASA reserves the authority to require a team to modify or change a payload, as deemed necessary by the Review Panel, even after a proposal has been awarded.	N/A	N/A	N/A

4.5.2. Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.	N/A	N/A	N/A
4.5.3. The experiment must be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	N/A	N/A	N/A
4.5.4. Any experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event.	N/A	N/A	N/A
4.5.5. Unmanned aerial vehicle (UAV) payloads, if designed to be deployed during descent, will be	N/A	N/A	N/A

tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAV.			
4.5.6 Teams flying UAVs will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).	N/A	N/A	N/A
4.5.7 Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.	N/A	N/A	N/A

Table 6.2.1.D. Payload Requirements

Safety Requirements			
NASA Requirements	**How we Plan to Meet Them**	**Method**	**Verification**
5.1. Each team will use a launch and safety checklist. The final	The team will write detailed checklists. They will cover all tasks that are required to launch the launch vehicle safely.	Inspection	At launch events, the Safety Officer will check off tasks on a

checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.			physical or digital copy of the checklists.
5.2. Each team must identify a student safety officer who will be responsible for all items in section 5.3.	The team captain will appoint the safety officer.	Inspection	The information of the safety officer is included on relevant documents.
5.3.1. The safety officer will monitor team activities with an emphasis on Safety during design of vehicle and payload, construction of vehicle and payload, assembly of vehicle and payload, ground testing of vehicle and payload,	The safety officer will attend all the events. They will actively advise members on safety matters.	N/A	When planning events, the availability of the safety officer will be confirmed in advance.

subscale launch tests, full scale launch tests, launch day, recovery activities, and STEM engagement activities.			
5.3.2. The safety officer will implement procedures developed by the team for construction, assembly, launch, and recovery activities.	The safety officer will host safety briefings for members. Attendance is required to participate in building and launch activities.	N/A	Members must sign a form indicating their understanding of safety procedures.
5.3.3. The safety officer will manage and maintain current revisions of the team's hazard analyses, failure modes analysis, procedures, and MSDS/chemical inventory data.	Hazard analysis, FMEA, procedures, and MSDS will be made available to all members and will be updated regularly.	N/A	Members will be made aware they have access to these materials as part of a safety briefing.

5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analysis, and procedures.	The safety officer will organize the writing of these sections by delegating tasks to specific members and overseeing the sections completion.	Inspection	The safety officer's sections will be validated by the captain.
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 does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions	Prior to the launch of any vehicles, the RSO will be informed of how the launch vehicle is intended to perform. This includes the expected apogee, recovery method, payload, and any other details they request. The team will follow all rules set forth by the club running the event.	N/A	No launch vehicle will be flown until the RSO has been explicitly told how the craft is intended to perform and the RSO has given explicit permission to launch.

to the local club's President or Prefect and RSO before attending any NAR or TRA launch.			
5.5. Teams will abide by all rules set forth by the FAA.	Members will be briefed on FAA regulations. The Safety Officer will attend all launch events to advise members and ensure compliance with all laws.	Inspection	The team will only launch rockets at launch events organized by a rocketry club with a FAA waiver.

Table 6.2.1.E. Safety Requirements

6.2.2. Team Derived Requirements

Vehicle Requirements			
Requirement	Justification	Method	Reference
There must be at least one successful full scale launch before competition	The team will aim for the opportunity to conduct multiple full scale test launches	Testing	The data for these test launches will be available by the FRR
All components cut or dremeled will be sanded to ensure edges are smooth such that all pieces fit together as designed	Every object that needs it will be sanded as needed	Inspection	The launch vehicle will be checked for sharp or rough edges during construction
The rotary switch will only be switched on by, the rocket lead, director of system integration, mentor,	The team aims to prevent any tampering or accidents when it comes to the devices in the e-bay and	Inspection	Only certain members will be able to use the arming switch or check devices in the e-bay

payload lead, or team members familiar with the e-bay	ensuring they are all programmed and working correctly		
The e-bay will be organized such that devices and wiring are neatly placed and easy to access	The electronics bay has been designed with two compartments to keep everything organized	Inspection	This will be verified visually by the rocket lead and payload lead.
Energetics and Motors will only be handled during travel by first and foremost the team mentor, and then the faculty advisor.	The team wants to ensure the safety of its members especially if they have less experience in handling energetics	Inspection	This will be verified visually and verbally by the team mentor, and faculty advisor.
All members will wear all required safety garments if they desire to participate in the construction of the launch vehicle	The team wants to ensure the safety of its members. If someone does not comply with these rules they will be asked to leave	Inspection	This will be verified visually and verbally by the team faculty advisor, mentor, and officer board
All dimensions will be checked with the rocket lead or Director of System Integration before cutting into any component	This limits the amount of errors and ensures the integrity and accuracy of the final design	Inspection	This will be confirmed visually and verbally by the rocket lead or Director of System Integration

Table 6.2.2.1 Team Derived Vehicle Requirements.

Recovery Requirements			
Requirement	Justification	Method	Reference
All parachutes will be checked for correct sizes	This is to avoid errors that may affect lateral drift of descent time	Inspection	This will be verified using the parachute sizing in simulations as well as by the team members assigned to recovery
Shock cord will be accordion folded and	To absorb more shock	Inspection	This will be verified visually by team

secured using a piece of tape such that it can easily rip apart			members assigned to recovery and can be found in section 3.4
Parachutes will be packed with nomex blankets for protection	To avoid damage due to energetics during flight	Inspection	This will be verified visually by recovery team members and tested during test launches.
Altimeters will be triple checked for correct programming and orientation	To avoid any errors in orientation or programming that may cause the launch vehicle to, deploy parachutes incorrectly, or sustain damage	Inspection	This will be verified by the team mentor and rocket lead as well with multiple simulated tests and checks
Kinetic Energy of each individual section shall not exceed 75 lbf-ft.	Values have been calculated to ensure this	Analysis	Verified via calculations and data

Table 6.2.2.2. Team Derived Recovery Requirements.

Payload Requirements			
Requirement	Justification	Method	Reference
There must be at least one successful full scale test before competition	The team will aim for the opportunity to conduct multiple full scale tests	Testing	The data for these tests will be available by the FRR
The UAV will be organized such that all components and electronics are easily accessible	The UAV has been designed to have a minimal form factor and easy access to all parts	Inspection	This will be verified visually by payload lead.
Ensure all components of UAV are functioning as desired	The UAV must have all components working to complete beacon delivery	Testing	A systems check will be run to ensure all parts are in working order
UAV and beacon will be securely mounted	The UAV and beacon must remain	Inspection	This will be verified visually by payload

within the retention system	undamaged during launch vehicle flight in order to successfully complete beacon delivery		lead
The UAV will have a maximum of at least twice the flight time estimated to be needed to complete the mission	Should any abnormalities in the flight of the UAV occur, sufficient time will be allowed for analysis and corrective measures applied by a human operator to aid in the mission	Analysis/testing	Sections 5.4 and 6.1.2 provide details regarding the processes by which components were selected to ensure this requirement was met

Table 6.2.2.3. Team Derived Payload Requirements.

Section 6.3. Budgeting and Timeline

In this section there is an in depth budget cost ranging from every expense made or will be mader for the success of the competition. Alongside with a funding plan in order the make sure that it is as realistically as possible and to make sure that this is logistically possible. The timeline has been used over the year to make sure all deadline are met and that nothing is done out of order.

Section 6.3.1 Budget

Full Scale & Sub-Scale Rocket:						
Component	**Specific Item**	**Quantity**	**Price**	**Total**	**Vendor**	**Comments**
Nose Cone	6" Fiberglass Metal Tipped Nose Cone	1	$149.95	$149.95	Madcow Rocketry	-
Main Tube	Blue Tube 2.0 6"x0.074"x72"	2	$105.95	$211.90	Always Ready Rocketry	Airframe
Centering Rings	Plywood ½"x2'x4'	0	$15.50	$0.00	Home Depot	Already Owned
Fins	Carbon Fiber Sheets	1	$342.75	$342.75	Dragon Plate	-

Motor Tube	Blue Tube 2.0 54mmx.062"x 48"	1	$23.95	$23.95	Always Ready Rocketry	Airframe
Inner Tube	Blue Tube 2.0 6'x0.077"x48"	1	$66.95	$66.95	Always Ready Rocketry	Coupler
Motor Case	Cesaroni 29mm 6XL-Grain Case	1	$143.27	$143.27	Apogee Components	-
Flight Computer	Raven 3 Altimeter	0	$155.00	$0.00	Feather weight Altimeters	Already Owned
Full Scale Battery	Turnigy Graphene 65C LiPo	0	$15.69	$0.00	Hobby King	-
Arming Switch	Full Scale Rocket Rotary Switch	1	$10.33	$10.33	Apogee Components	-
Wiring	Wiring	0	$5.00	$0.00	WPI	Already Owned
Main Engine	L730CL 54-6GXL Reload Kit	2	$182.60	$365.20	AMW ProX	-
Backup Engine	L1030 RL	0	$175.00	$0.00	AMW ProX	Will buy as needed
Separation Charges	Black Powder Charges	0	$0.00	$0.00	WPI	Already Owned
Shear Pins	2-56x1/2" Nylon Screws	0	$10.64	$0.00	McMaster-Carr	Package of 100
Rail Buttons	1515 Rail Buttons	2	$6.00	$12.00	AMW ProX	-
Nomex Blankets	Sunward 18in Nomex Blanket	0	$10.49	$0.00	Apogee Rockets	Already Owned
Igniter	Full Scale Igniter	0	Free	Free	WPI	Already Owned

Parachutes	36" Drogue	1	$35.50	$35.50	Spherachutes	Already Owned
Parachutes	72" Hemisphere	1	$82.50	$82.50	Spherachutes	Already Owned
Parachutes	36" Hemisphere	1	$30.00	$30.00	Spherachutes	Already Owned
Shock Cord	BlueWater 1" Tubular Webbing (130 ft.)	130	$0.45	$58.50	REI	130 in, $0.45/in, 4000 lb breakforce
U-Bolts	U-Bolts	0	Free	Free	WPI	Already Owned
Motor Retention	Hanger Wire	0	Free	Free	WPI	Already Owned
Quick Links	316 Stainless Steel Quick Link	0	$5.08	$0.00	McMaster-Carr	Already Owned
Swivel Mounts	Swivel 12/0 1500 lb	0	$4.00	$0.00	AMW ProX	Already Owned
Nuts/Bolts/ Washers	Assorted	0	$15.00	$0.00	McMaster-Carr	Already Owned
Blue Tape	ScotchBlue 1.88"x60yds	0	$6.58	$0.00	Home Depot	Already Owned
Gorilla Tape	Gorilla 1-7/8x35yds	0	$8.98	$0.00	Home Depot	Already Owned
Subscale						
Main Tube	2.15"x0.062"x 48"	2	$23.99	$47.90	Always Ready Rocketry	Airframe
Nose Cone	54mm Plastic Nose Cone	1	$14.80	$14.80	Apogee Components	Nose Cone
Motor Tube	1.15"x.062"x2 4"	1	$6.25	$6.25	Always Ready Rocketry	Motor Tube
Inner Tube	2.15"x0.062"x 8"	1	$8.95	$8.95	Always Ready Rocketry	Inner Tube
Motor Casing	Pro-29 4G	1	$26.00	$26.00	AMW ProX	Motor Casing

Flight Computer	Raven 3 Altimeter	0	$155.00	$0.00	Feather weight Altimeters	Already Owned
Battery	9V Battery	0	$11.55	$0.00	Amazon	Already Owned
Arming Switch	Sub Scale Arming Switch	1	$9.93	$9.93	Apogee Components	-
Wiring	Wiring	1	$5.00	$0.00	WPI	-
Parachutes	30” Hemisphere	1	$26.75	$26.75	Spherachutes	Already Owned
Parachutes	18” Hemisphere	1	$14.00	$14.00	Spherachutes	Already Owned
Parachutes	18”Drogue	1	$21.50	$21.50	Spherachutes	Already Owned
Main Engine	H118CL	0	Free	Free	AMW ProX	Already Owned
Separation Charges	Black Powder Charges	0	Free	Free	WPI	Already Owned
Full Scale Total	$1,532.80					
SubScale Total	$176.08					
Total	$1,708.88					

Table 6.3.1.1. Launch Vehicle Budget

Payload:

Component	Specific Item	Quantity	Price	Total	Vendor	Comments
Processor	Arduino Nano	2	$22.00	$44.00	Arduino	Capsule Processor
Processor	Pix Hawk Mini	1	$164.99	$164.99	Amazon	UAV Processor
LiPo Battery	3.7v 2000mAh	6	$12.50	$75.00	Adafruit	-
ESCs	Lumenier 30A BLHeli_S OPTO	4	$13.00	$54.00	GetFPV	-
Brushless Motor	RotorX RX1404B	4	$15.00	$60.00	GetFPV	-
Servos	L16-R	2	$70.00	$140.00	Spektrum	-
Transceiver	NRF24L01	3	$19.95	$59.85	Amazon	-

3D Printer Filament	Nylon X	1	$136.24	$136.24	-	-
Carbon Fiber	1ftx1ft sheet	1	$136.24	$136.24	Dragon Plate	-
GPS NEO 6MV2	NEO 6M	3	$8.55	$25.65	-	-
Overhead	Cover for additional components	1	$50.00	$50.00	-	-
Payload Total	$945.97					

Table 6.3.1.2. Payload Budget

Logistics:						
Component	**Specific Item**	**Quantity**	**Price**	**Total**	**Vendor**	**Comments**
Test Launch	Participation Fee	10	$5.00	$50.00	MMMSC	-
Certifications	Level 1 and 2	4	$25.00	N/A	MMMSC	-
Hotel Rooms	(4 nights) 2 Double Beds	5	$90	$1,800	Host Hotel	-
Shipping to Competition	Full-scale Rocket	1	$300	$300	UPS	-
Flights	Flight Tickets	18	$326	$5,868	-	Flights will be paid for by students or sponsors
Logistics Total	$7,718					

Table 6.3.1.3. Logistics Budget

	Preferred Option:	AIAA Selected and Current Option:
Total With Logistics:	Total With Logistics Minus Flight Cost:	Total Without Logistics:
$10,373	$4,505	$2,655
Total With Logistics accounting for shipping:	Total With Logistics Minus Flight Cost+shipping:	Total Without Logistics Plus Shipping:
$10,673	$4,505	$2,955

Table 6.3.1.4. Combined Budget

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Section 6.3.2. Funding Plan

Funding plans include (but not limited by) obtaining money from WPI's local AIAA chapter, the SGA private funding from students, fundraising and corporate sponsorships. A portion of the AIAA budget has already been set aside for use by the WPI USLI team, as well as some funding from the SGA. Additional requests are to be submitted to the SGA to assist in meeting travel costs.

Additionally, a corporate sponsorship request package has already been created and (after approval by the Student Activities Office) been sent to various local companies. Primary needs of corporate sponsorship are travel costs and additional building expenses. Secondary requests are to be sent to more companies, until our funding needs have been met.

Section 6.3.3. Timeline

The timeline has been created as a Gantt chart. It is broken up into sections consisting of a proposal, logistics/sponsorship, vehicle, payload, preliminary design review, critical design reviews, flight readiness review, and competition. The burgundy colored cells are used for milestones, the gray is for meetings and the time worked on, and the peach is for college breaks.