USLI

WORCESTER POLYTECHNIC INSTITUTE

G.O.A.T.S.

USLI PROJECT PRELIMINARY DESIGN REVIEW 2018 - 2019

November 2, 2018

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Acronym Dictionary

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

- 3D: Three Dimensional
- ABS: Acrylonitrile Butadiene Styrene
- AGL: Above Ground Level
- AIAA: American Institute of Aeronautics and Astronautics
- AMW: Animal Motor Works
- APCP: Ammonium Perchlorate Composite Propellant
- BS: Bachelor of Science
- BS/MS: Bachelor of Science and Master of Science
- CO_2: Carbon Dioxide
- CTI: Cesaroni Technology Incorporated
- EBay: Electronics Bay
- E-Match: Electric Match
- FAA: Federal Aviation Administration
- FEA: Future Excursion Area
- FMEA: Failure Modes and Effects Analysis
- Foreign National
- FPV: First person View
- FRR: Flight Readiness Review
- ft: Feet
- ft/s: Feet per second
- ft-lbf: Foot Pounds Force
- g: Grams
- GPS: Global Positioning System
- GSSS: Garden State Spacemodeling Society of New Jersey
- IMU: Inertial Measurement Unit
- in: Inches
- lbs: Pounds

- LiPo: Lithium Polymer (Battery)
- m: meters
- mA: Milliamps
- ME: Mechanical Engineering
- mL: Milliliters
- mm: Millimeters
- MMMSC: Maine Math, Missile, and Science Club
- MSDS: Materials Safety Data Sheets
- mW: Milliwatts
- N: Newtons
- N/A: Not Applicable
- NAR: National Association of Rocketry
- NASA: National Aeronautics and Space Administration
- Ns: Newton Seconds
- PDF: Portable Document Format (File Format)
- PDR: Preliminary Design Review
- PLA: Poly Lactic Acid (3D Printing Filament)
- PPE: Personal Protective Equipment
- RSO: Range
- sd: Secure Digital (Hardware Standard)
- TRA: Tripoli Rocketry Association
- UAV: Unmanned Aerial Vehicle
- USLI: University Student Launch Initiative
- V: Volts
- VDC: Direct Current Voltage
- WPI: Worcester Polytechnic Institute

Section 1. Summary

The goal of Worcester Polytechnic Institute (WPI) University Student Launch Initiative (USLI) team is to design a launch vehicle and payload to complete the requirements outlined in the Student Launch Handbook. In summary, these goals are to fly a launch vehicle containing a selected payload, which will (upon landing) deploy. In order to achieve these requirements, the team has split into two subteams; a launch vehicle team and a payload team. Each team will collaborate and design compatible parts to launch and deploy in sequence, land and complete the objectives outlined in the handbook. Upon test launches, marginal changes will be made to ensure success of our goals. All changes and tests will be reviewed by a mentor or Range Safety Officer, as well as safety protocols outlined by National Association of Rocketry (NAR) and the Federal Administration of Aviation (FAA).

Section 1.1. Team Summary

Section 1.1.1. Adult Educators

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Section 1.1.4. Members and Key Managers

WPI's USLI team currently consists of approximately 20 active members split among two subgroups. These subgroups are designated as the launch vehicle and payload teams. Additionally, the team has a logistics officer and two educational engagement officers.

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Section 1.1.6. NAR Section

The team intends to work with Maine Missile Math and Science Club (MMMSC) for test launches. Test launches may also be done with Garden State Spacemodeling Society of New Jersey (GSSS) in case of cancellations or other conflicts with MMMSC launches.

Section 1.2. Launch Vehicle Summary

The Launch Vehicle, composed of Always Ready Rocketry's Blue Tube 2.0, carbon fiber, and a fiberglass metal tip nose cone, has been designed to reach an apogee of approximately 4704ft. 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 a payload retention system made of inner tube dedicated to housing the selected payload for the duration of its flight.

The launch vehicle will be using an L class motor to propel itself and the selected payload to an apogee of 4704ft. Upon reaching this altitude, the Launch Vehicle's decent will be assisted by a drogue parachute that will be deployed using a black powder charge. Continuing on in its descent, upon reaching 700ft the launch vehicle will deploy via another black powder charge, a larger main parachute. Connected to the main parachute and upper airframe by shock cord, the payload retention system will then be ejected from the upper airframe. Additionally, this charge will also separate the nose cone from the upper airframe upon which the nose cone will then continue its own descent separate from the rest of the launch vehicle with its own parachute.

To elaborate on the payload retention system, it will be made out of inner tube that will be contained within the upper air frame of the launch vehicle. At an approximate altitude of 700ft this inner tube will be pushed out of the upper air frame, but still connected to it and the main parachute via shock cord. Our plan is to then, once landed, have the inner tube actively unfold to release the UAV. Therefore, the UAV will not ever leave the inner tube until after the launch vehicle has landed and the deployment is triggered.

The launch vehicle's flight data will be recorded using a Raven 3 Altimeter that will be housed in the electronics bay. The electronics bay will be bolted to the upper airframe and will also contain the launch vehicle's battery.

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 Proposal

Section 2.1. Launch Vehicle Changes

There have been a lot of changes to the launch vehicle since the proposal. Our initial design utilized 0.25in plywood for the fin design. As we delved deeper into the design process we found the launch vehicle would be landing at a speed of approximately 23.6ft/s. We felt that plywood would ultimately be unreliable as it would most likely end up snapping upon impact with the ground. To solve this issue we decided to change our design to have carbon fiber fins. This is because carbon fiber is significantly more durable than plywood and although it is heavier we were able to compensate for the extra weight by changing our selected nose cone.

The nose cone has been changed from a conical fiberglass nose cone to an ogive fiberglass nose cone with a metal tip. The decision to move to an ogive nose cone was mostly dependent on the fact that ogive nose cones are better aerodynamically than conical nose cones. This is due to the fact that ogive nose cones typically offer lower drag values than conical nose cones. Additionally, the metal tip helped to add more weight to the upper section of the launch vehicle, balancing out with the now heavier lower section of the launch vehicle making the launch vehicle more stable overall.

There has also been changes in regards to the recovery system of the launch vehicle. The drogue parachute, housed in the lower airframe, is now 36in. The size of the drogue parachute was increased mainly to aleve more tension in the shock cord upon deployment of the main parachute. Additionally, located in the upper airframe there will now be an 72in main parachute; the 36in nose cone parachute has not changed. The decision to decrease the main parachute from 84in to 72in was to better ensure our launch vehicle fit within the 90s decent time limit by speeding up its descent from 23.6 ft/s to 26.6ft/s.

The biggest change to the launch vehicle involves our new payload retention system design. The launch vehicle will now contain a section of inner tube approximately 12.5in in length that will act as the UAV's active retention system. This will be housed in the upper airframe of the launch vehicle until it is pushed out at 700ft with the nose cone, nose cone parachute, and main parachute. The UAV will be contained within the retention system for the duration of the flight. Once it has landed and the UAV can be switched on, the retention system will mechanically unfold to release the UAV.

Another change that was made to the launch vehicle was its overall size. The vehicle has now moved from its original length of 9.25ft to its new length of approximately 10.5ft. This was decided due to it overall benefiting by giving extra pack length room for parachutes and shock cord, stabilizing the launch vehicle even more, and adding extra space for the payload retention system.

The final change we have made to the launch vehicle is our motor selections. In the proposal we originally decided to go with the L935-IM-0 as our primary motor. However, we discovered with all the other changes made to the launch vehicle that although using these motors would place us closer to the mile high goal of 5500 ft, it also placed us 10 seconds out of range of the 90 second decent time limit. Therefore, in order to meet this criteria we decided to aim for our current apogee of 4704ft by using a L730-0 as our primary motor and keeping the L1030-RL-0 as our back-up motor.

Section 2.2. Selected Payload Changes

A critical change made regarding the payload was a redesign of the retention system. The team received feedback from NASA stating that the retention system previously selected to house the payload had to be part of the airframe of the launch vehicle. The first iteration of the retention system consisted of a pyramid-like structure that housed the quadcopter UAV and ejected it to fall separately from the airframe of the launch vehicle. The redesigned inner tube retention system to be contained within the outer airframe of the launch vehicle will now act as the retention system for the UAV. This will be accomplished by housing the UAV within a piece of bluetube that is cut into four separate sections which will actuate to orient the system to allow for the deployment of the UAV. The payload housing section of the airframe will be attached to the main parachute. This will allow for the payload to separate from the rest of the launch vehicle when pulled out by the main parachute and land completely intact. The retention system will no longer use sensors to confirm landing because it will be activated after visual confirmation of the launch vehicle's landing and receiving permission. There were no changes done to the design of the UAV itself.

Section 2.3. Project Plan Changes

Not much has changed with the project plan since the proposal. The timeline has mostly stayed the same. The Gantt chart has been updated to contain the funding, logistics, and engagement plans. The budget has increased due to using more expensive materials for some of the building. We are looking to fund through multiple different avenues. In addition to this, one of the outreach officers has decided to take up funding and the other has decided to focus mostly on outreach such as engagement.

Section 3. Vehicle Criteria

Section 3.1. Selection Design, and Rationale of Launch Vehicle

Section 3.1.1. Mission Statement

Our mission is to successfully fly our Launch Vehicle design on an L level motor to an expected apogee of 4704ft. It is our goal to then successfully ensure the Launch Vehicle's safe descent as well as the protection of the payload housed within. 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 the Launch Vehicle will deploy a larger main parachute via a 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. 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 correctly and 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 so 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
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 4704ft.
8. Upon reaching apogee a black powder charge will deploy the drogue parachute separating the upper and lower airframes
9. At 700ft 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. Recovery Subsystem

The launch vehicle will take off in one piece with a predicted apogee at 4704ft. The upper and lower airframes are fastened together with shear pins, as well as 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 36in 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 700ft 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 process for 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.

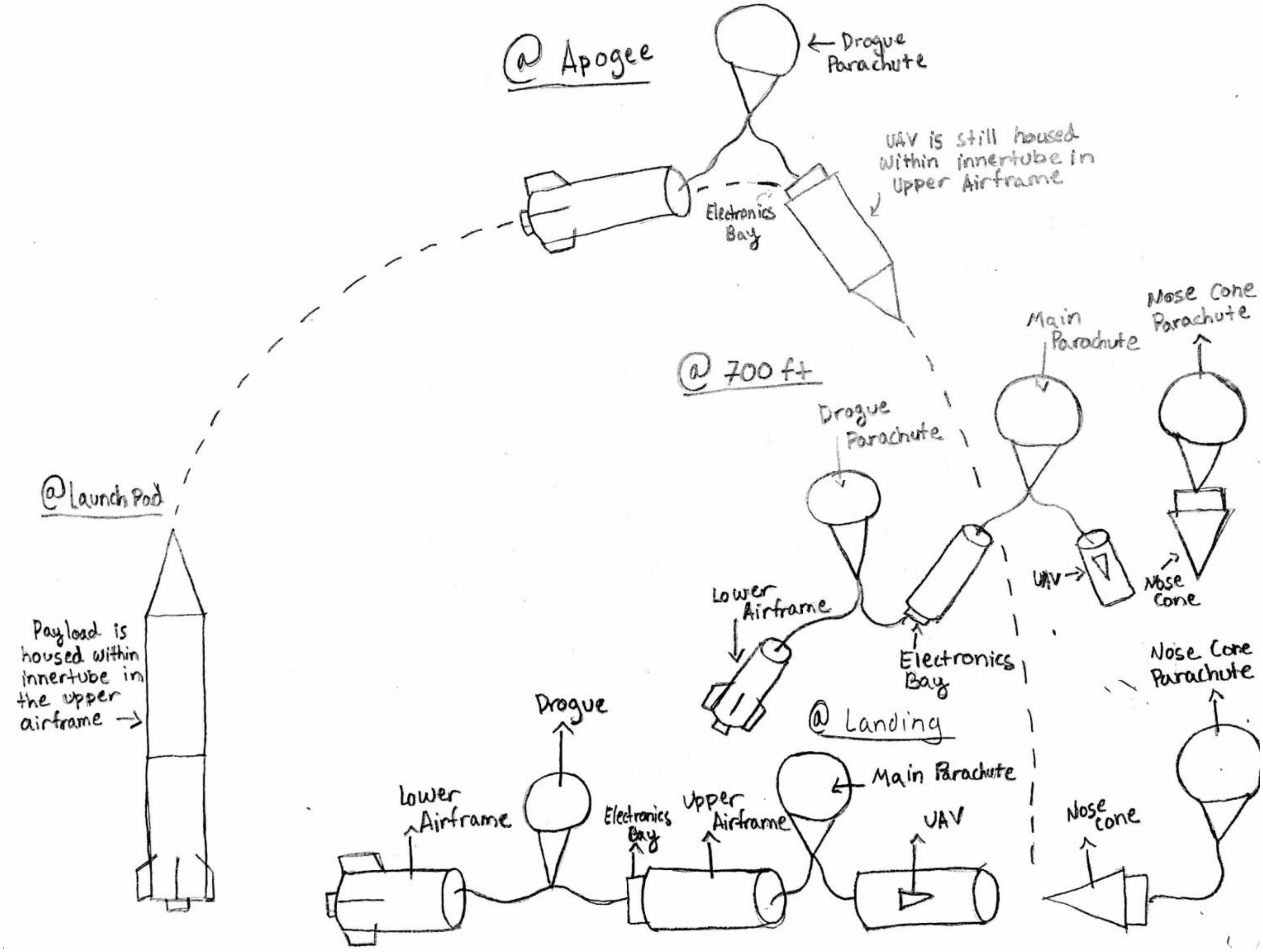


Figure 3.2.A. Mission Diagram

In order to reduce the amount of shock inflicted on the main parachute when deployed, it will not be directly connected to the airframe and payload with the shock cord. Instead, there will be an intermediate shock absorption system. This will consist of a section of bungee cord with aluminum shock links at each end. One shock link will be connected to the shock cord, connecting the upper airframe and payload to a quick link which is connected to the main parachute

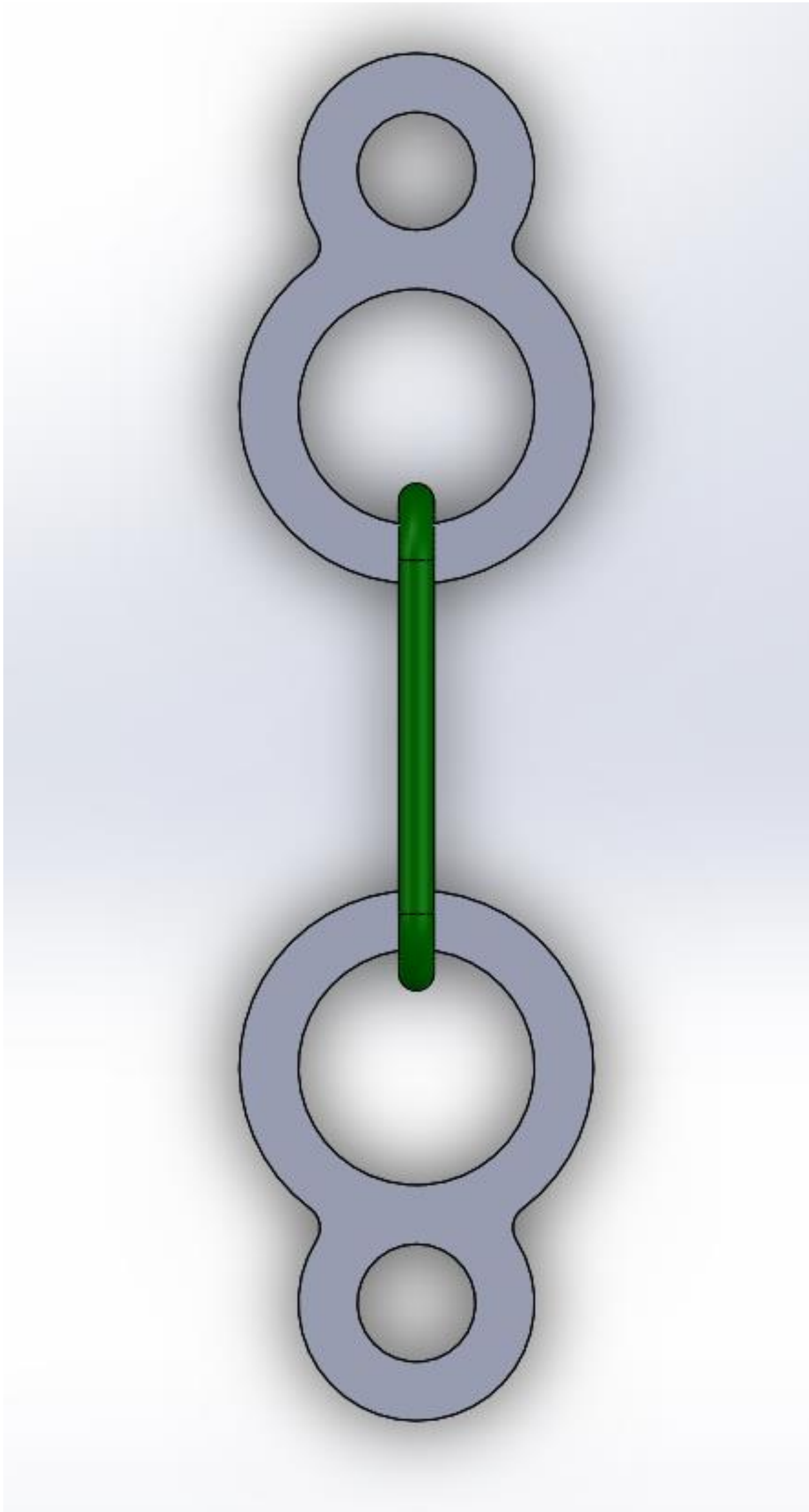


Figure 3.2.B. Shock Links

Section 3.3. Recovery Calculations

All calculations were done using Open Rocket and Matlab. In this section we calculate the kinetic energy of each independent section of the launch vehicle and we calculate and plot its downrange drift. The following is our Matlab code.

Section 3.3.1. Clear the Workspace

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

Section 3.3.2. 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 = 0.59348; % Section 1 (Main Rocket) mass (slug)
m2 = 0.10236; % Section 2 (Nose Cone & Harness) mass (slug)
m_tot = m1 + m2;

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 = 4704; % Apogee altitude (ft)
main_deploy_alt = 700; % Main chute altitude (ft)

fprintf('Section 1 is the rocket airframe, electronics bay, and payload retainer. Section
2 is the nose cone\n');
```

```
Section 1 is the rocket airframe, electronics bay, and payload retainer. Section 2 is the
nose cone
```

Section 3.3.3. 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( (m1 * 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('\n~~~ Descent Times ~~~\n');
fprintf('Descent time for Section 1: %0.3f sec\n', total_t_1);
fprintf('Descent time for Section 2: %0.3f sec\n', total_t_2);

fprintf('\n~~~ Ground Hit Velocities ~~~\n');
fprintf('Ground hit velocity for Section 1: %0.3f ft/sec\n', v2_1);
fprintf('Ground hit velocity for Section 2: %0.3f ft/sec\n', v2_2);
```

```
~~~ Descent Times ~~~
Descent time for Section 1: 91.034 sec
Descent time for Section 2: 93.218 sec

~~~ Ground Hit Velocities ~~~
Ground hit velocity for Section 1: 24.629 ft/sec
Ground hit velocity for Section 2: 22.872 ft/sec

Terminal velocity under drogue chute: 63.949 ft/sec
Velocity at main chute deployment: 63.949 ft/sec
```

Section 3.3.4. Calculating 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

fprintf('\n~~~ Kinetic Energies ~~~\n');
fprintf('Kinetic Energy of Section 1 upon landing: %0.3f lbf*ft\n', ke_1);
fprintf('Kinetic Energy of Section 2 upon landing: %0.3f lbf*ft\n', ke_2);
```

```
~~~ Kinetic Energies ~~~
Kinetic Energy of Section 1 upon landing: 180.001 lbf*ft
Kinetic Energy of Section 2 upon landing: 26.773 lbf*ft
```

```
~~~ Kinetic Energies ~~~
Section 1 and Section 2 are still attached after drogue chute deployment.
Their indivual kinetic energies and the total kinetic energy of the vehicle are below.
Kinetic Energy of Section 1 under drogue chute: 1213.493 lbf*ft
Kinetic Energy of Section 2 under drogue chute: 209.296 lbf*ft
Kinetic Energy of total vehicle (Section 1 + Section 2) under drogue chute: 1422.789 lbf*ft

The sections separate at 700ft AGL. Below are their kinetic energies from separation to just
before landing
Kinetic Energy of Section 1 just before landing: 180.001 lbf*ft
Kinetic Energy of Section 2 just before landing: 26.773 lbf*ft
```

Section 3.3.5. Calculating 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
```

Section 3.3.6. Plotting 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)');
```

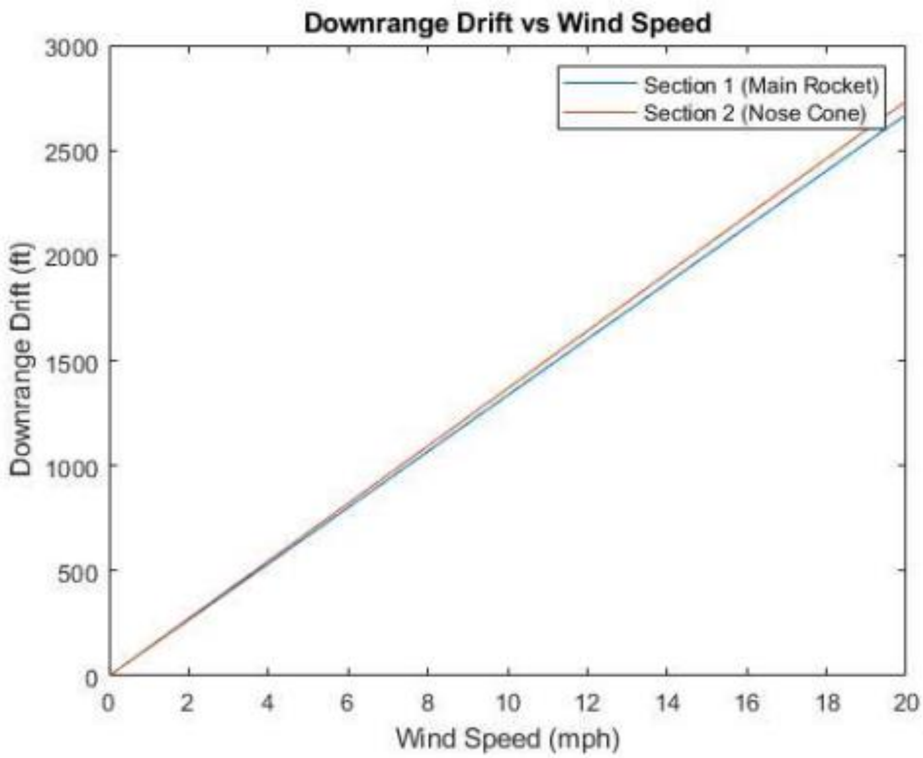


Figure 3.3.6.A. Downrange Drift vs Wind Speed

Section 3.4. Launch Vehicle Design Review

Section 3.4.1. Summary

The purpose of this section is to evaluate the steps our team took towards our final launch vehicle design. During the design process the team considered multiple materials, components, and electronics in order to come up with what we felt was a solid launch vehicle design. The launch vehicle will split into 4 main sections over the course of its flight. These sections are distinguished as the nose cone, upper airframe, lower airframe, and payload retention system.

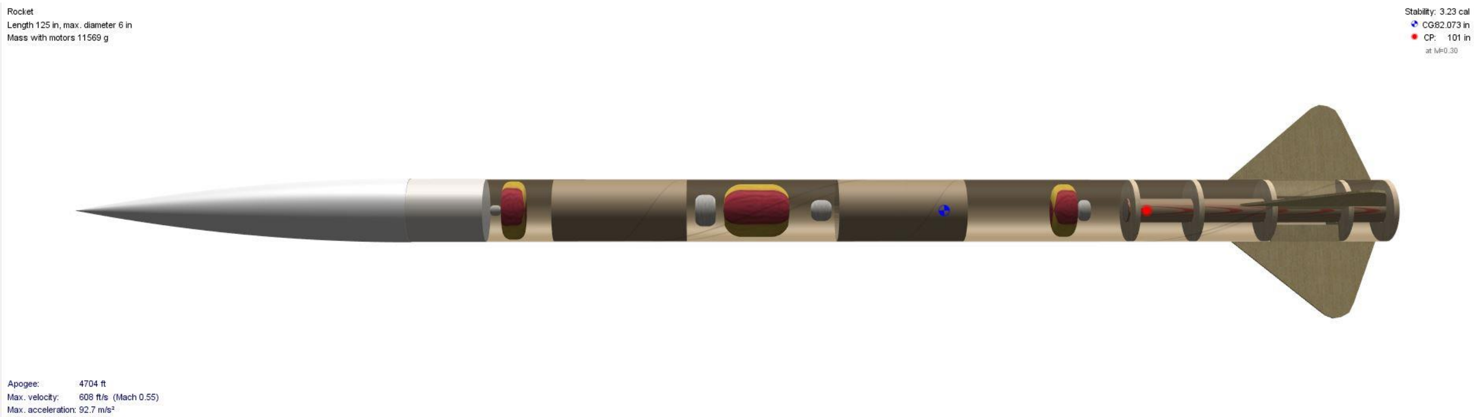


Figure 3.4.1.A. Launch Vehicle

Section 3.4.2. The Lower Airframe

During the design process of the launch vehicle several designs were considered within the lower airframe. For this section of the launch vehicle the main concerns centered around the fin shape and material, motor selection and motor tube, and number of centering rings.
The original design of the launch vehicle included four fins that were going to be made of plywood. We 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.

To address this issue two new fin materials were considered: fiberglass G10 sheets and carbon fiber sheets. For both of these materials the team worked to compare and contrast the pros and cons of each in regards to weight, strength, toughness, thermal characteristics and price before settling on carbon fiber as our new fin material.

When comparing the weight of fiberglass to that of carbon fiber we found that carbon fiber is lighter than fiberglass. This was considered a pro of carbon fiber over fiberglass as we knew with both materials being heavier than plywood that changing the fins to these materials could have a negative effect on the stability of the launch vehicle.

For strength we found that both materials were very strong and could withstand the speed of our ground hit velocity, however carbon fiber is much more rigid than fiberglass. Fiberglass is able to flex and can be prone to extreme flex patterns whereas carbon fiber experiences 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. Fiberglass, however being such a flexible material has a higher yield stress than that of carbon fiber. Fiberglass can therefore withstand higher

forces for longer amounts of time than carbon fiber. This is because as we found out when researching the strength of both materials, fiberglass is a more flexible material whereas carbon fiber is a more rigid material.

As we continued to look into both materials we felt it was important to consider thermal characteristics and the affect weather might have on each material. Being 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 whereas fiberglass does not. This means carbon fiber will shrink or expand less than fiberglass when exposed to extreme weather conditions.

The final characteristic we looked into before settling on carbon fiber fins involved pricing. Although carbon fiber is more expensive than fiberglass 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. Therefore, carbon fiber was the material we chose to replace plywood for our fins.

Although carbon fiber is more durable than plywood it is heavier and impacted the stability of the launch vehicle. In order to compensate for this we went with a metal tipped nose cone in order balance out the weight.

Additionally, The shape of the fins was changed to a more rounded triangular shape rather than the jagged trapezoidal shape in our original design. This change was made in order to benefit the launch vehicle aerodynamically in terms of drag. Therefore, the curvature of the new fins allows for there to be less drag during liftoff. In addition to this the fin tabs were altered to be smaller than the fins themselves in order to reduce the amount of carbon fiber, thus reducing the weight impact on the overall launch vehicle.

The motor that we decided to use in the final design of the launch vehicle is the L730-0. The motor will be contained within a motor mount made of blue tube.

The amount of centering rings on the motor mount was changed to five. The amount of centering rings was changed because the new inner tube is longer. In addition for compensating for this increase in length the centering rings also helped with stability in our launch vehicle and the motor tube.

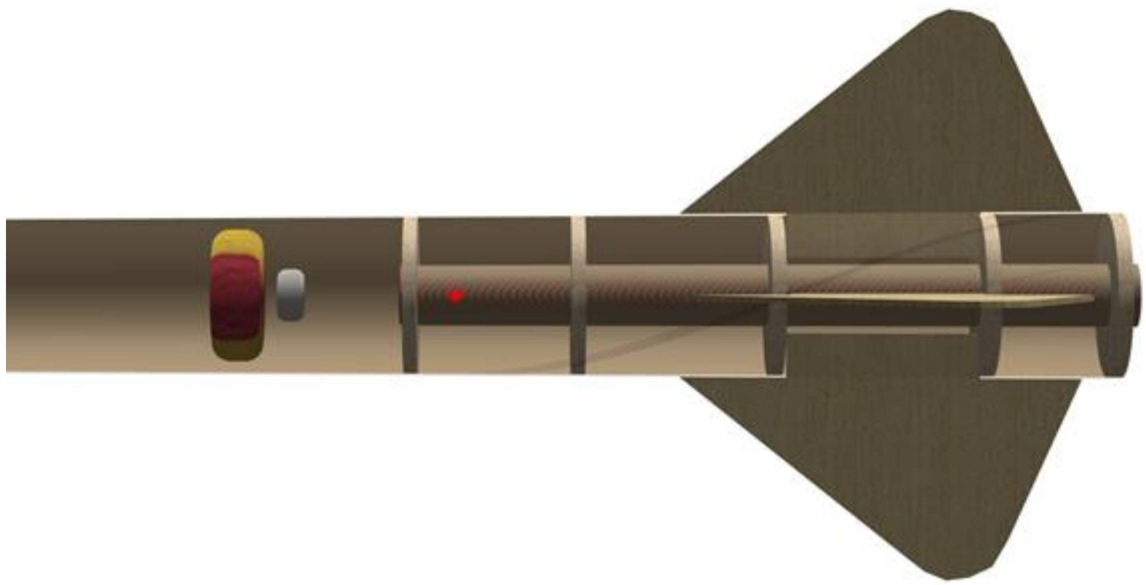


Figure 3.4.2.A. Lower Airframe Side

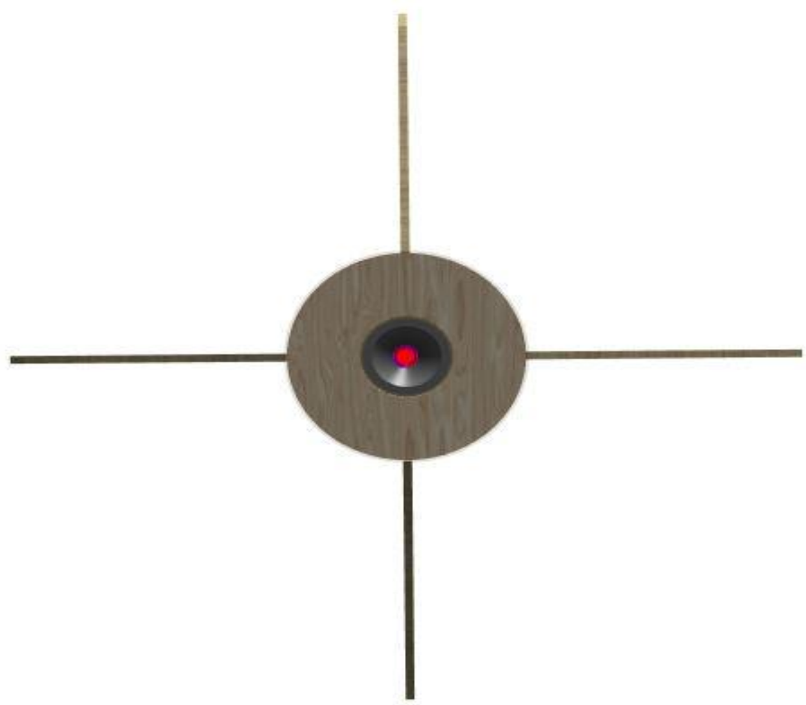


Figure 3.4.2.B. Lower Airframe Bottom

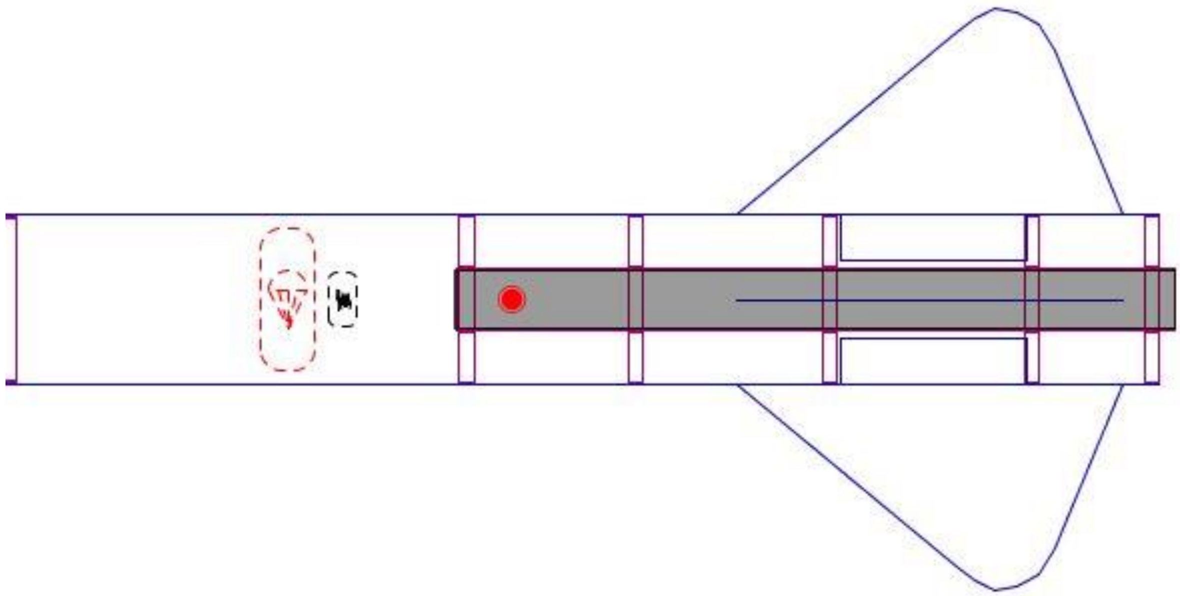


Figure 3.4.2.C. Lower Airframe Sketch

Section 3.4.3. Electronics Bay Coupler

The electronics bay will be made of an inner diameter coupler. The coupler will be composed of bluetube with a 1in ring of the outer tube 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 upper airframe 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 inner tube 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.

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.

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.

Another part of the electronics bay we looked at multiple options for was in what kind of switch we wanted to use for the altimeters. We went with 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 are looking for something that would stay on after triggered in order to comply with the rules set by NASA.

Figure 3.4.3.A. 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.

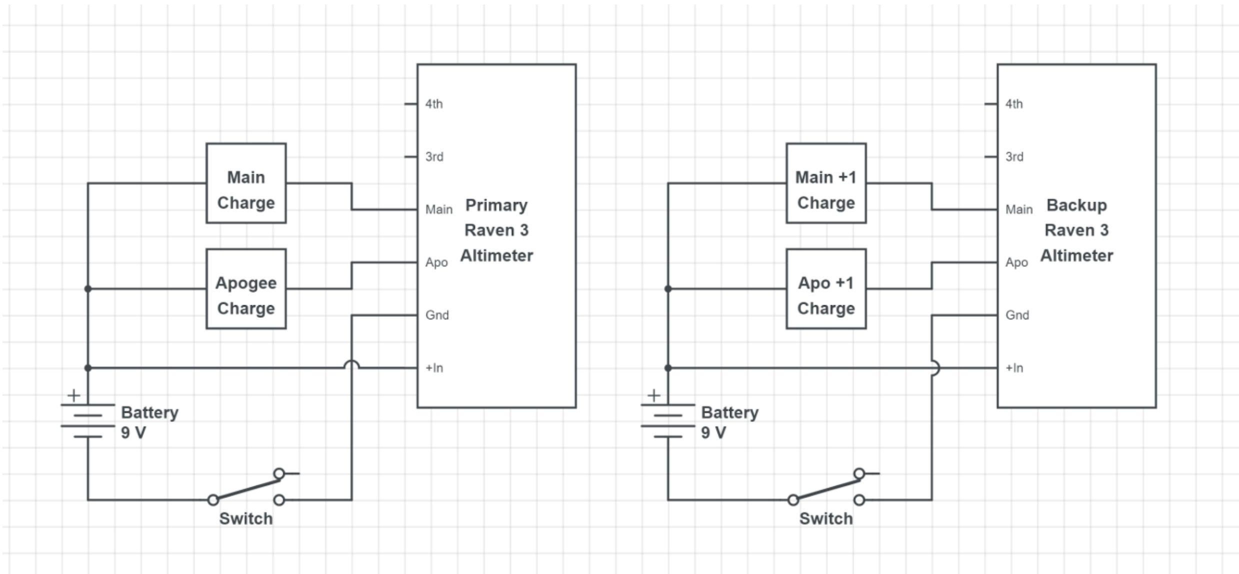


Figure 3.4.3.B. Circuit Diagrams

Section 3.4.4. Upper Airframe

The launch vehicle main body upper airframe will be constructed out of 6in x 0.074in x 72in blue tube 2.0 that will be cut down to 45.85 inches. Although more expensive than some other materials used to construct high powered launch vehicle bodies, blue tube was selected as the material of choice because it is highly resistant to abrasion, cracking, and other forms of damage making it a durable alternative to phenolic and carbon fiber. It is also a far lighter material than fiberglass. Due to its durability, it is commonly used by WPI's AIAA chapter.

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 electronics bay houses a Raven 3 altimeter that will be wired to an external switch on the main body of the launch vehicle. The altimeter along with the launch vehicle's chosen Turnigy Graphene 65C LiPo battery will be secured using a 3D-printed mounting plate, screws, and washers.

Some changes to the initial proposal were made to help ensure both a safer and what we believe will lead to a more successful flight and mission. The main change to the design was the re-working of the payload housing and system. Switching from an in-flight deployable system to one that releases the payload from the system once they have both landed. The launch vehicle will now contain a section of 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. This will be housed in the upper airframe of the launch vehicle until it is pushed out at 700ft with the nose cone, nose cone parachute, and main parachute. We believe this will be a more effective housing system due to the fact that the payload will be more secure within the launch vehicle, easier to operate, and safer during flight and landing.

The upper airframe of the launch vehicle originally housed the selected payload along with three parachutes, the nose cone parachute, the payload parachute, and the main parachute. The parachutes will still be made out of ripstop nylon and connected to their corresponding components by nylon shock cord. But, modification was necessary to counterbalance the changes discussed above with the movement of the parachute associated with the payload itself. The payload parachute no longer exists due to the new system. However, both the nose cone parachute and the main parachute remain in the upper airframe.

The main parachute was moved from the tip of the payload to in between the upper airframe and the payload once the system is released at 700ft. The main parachute was moved to this location in order to take some of the weight of the main body off of the payload and rely on the main parachute only on one side. While the nose cone parachute remained the same size, 36in, the main parachute was changed from 84in to 72in to reduce the descent time of the system.

Figure 3.4.4.A. Upper Airframe Side

Section 3.4.5. Payload Retention System

The payload retention system will be constructed out of blue tube split into four quarter pipe sections. There will be a linear servo on each side of it, allowing it to be opened and orient itself upright simultaneously. There will be the small base and four large “petals” of the tube opening that will orient the whole system. There will be an Arduino Nano onboard which will receive our signal upon receiving permission to open the retention system to deploy the UAV for launch.

Section 3.4.6. Payload

The payload will be a folding quadcopter made of 3D-printed parts from NylonX filament and custom-cut carbon fiber. Its arms will fold down with the retention system and are designed such that they will unfold and lock into place as the retention system opens. Onboard will be a PixHawk Mini controller board that we will communicate with to pilot the UAV. There will be four 5-inch carbon fiber propellers on four brushless motors controller by the PixHawk. There will be a linear servo onboard which holds in the beacon and will actuate to release it upon reaching the Future Excursion Area. We will have an First Person View (FPV) camera onboard to see where the UAV is from a monitor at our base station.

Section 3.4.7. Nose Cone

The nose cone has a length of 31.5in, a diameter of 6in, and wall thickness of 0.079in. It has an ogive shape and is made of fiberglass with a metal tip. The picture below displays the chosen shape of the nose cone.

The original design was a fiberglass conical nose cone. It was 31in long with a diameter of 6in and wall thickness of 0.079in. This was changed to an ogive shape because ogive nose cones are more aerodynamic. They offer lower drag values than conical nose cones.

A metal tipped nose cone was chosen to counteract the weight of the new carbon fiber fins. The new fins originally caused the launch vehicles stability to drop significantly due to the weight of the carbon fiber. By choosing a metal tipped nose cone we were able to restabilize the launch vehicle as the metal balanced out the lost weight due to the carbon fiber.

Other options for nose cone shapes consist of parabolic, elliptical, bi-conic, 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 bi-conic 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. Ultimately when choosing between a fiberglass conical and fiberglass ogive nose cone, we felt that the material and overall aerodynamic properties of the ogive nose cone made it the best decision for our launch vehicle.

Figure 3.4.7.A. Nose Cone Side

Section 3.4.8. Parachute and Recovery System

The recovery system consists of multiple shock cords and parachutes. All shock cords will be made of 1in diameter tubular nylon. At apogee, a black powder charge will deploy the drogue parachute, which will be connected by shock cord to the upper and lower airframes. The drogue parachute will be made of ripstop nylon and have a diameter of 36in. As the launch vehicle descends, the main parachute will be deployed by a second black powder charge at an altitude of 700ft. The main parachute will also be made of ripstop nylon, but will have a diameter of 72in. An example of the type of parachute that will be used is shown in Figure 3.4.8.A.

Connected to the main parachute and upper airframe by shock cord, the payload retention system will also be ejected from the upper airframe at 700ft. The payload retention system will consist of an inner tube, which will remain connected to the main parachute and upper airframe via shock cord. The second black powder charge will also 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. The nose cone parachute will be made of ripstop nylon and have a diameter of 36in. All of our parachutes will be supplied by Spherachutes.

Changes to the recovery system include the increase in size of the drogue parachute to 36in to remove some of the tension on the shock cord upon deployment of the main parachute. The size of the main parachute was decreased in size from 84in to 72in to better ensure the launch vehicle's descent does not exceed the 90s descent time limit set by NASA.

Figure 3.4.8.A. Parachute

Section 3.5. Parachute Calculations

All calculations were done using Open Rocket and Matlab. In this section we calculate the kinetic energy of each independent section of the launch vehicle and we calculate and plot its downrange drift. In order to present the matlab code in a way that's easy to follow, the contents of this section include:

- Clear the Workspace
- Input Constants
- Calculating Descent Profiles for Various Parachute Sizes
- Plotting Results

Section 3.5.1. Clear the Workspace

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

Section 3.5.2. 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 = 0.6; % Section 1 (Main Rocket) mass (slug)
m2 = 0.1; % Section 2 (Nose Cone & Harness) mass (slug)
m_tot = m1 + m2;

Cd = 0.75; % Coefficient of drag for parachutes

apogee_alt = 4704; % Apogee altitude (ft)
main_deploy_alt = 700; % Main chute altitude (ft)
```

Section 3.5.3. Calculating Descent Profiles for Various Parachute Sizes

```
drogue_area = pi * 3^2 / 4; % Cross-sectional area of drogue chute
v_initial = sqrt( (m_tot * g) / (0.5 * rho_apo * Cd * drogue_area) ); % Hit velocity
t_initial = (apogee_alt - main_deploy_alt) / v_initial; % Flight time under drogue


% Define range of parachute diameters to test
diam_min = 1;
diam_max = 10;
diam_step = 0.2;

test_diamaters = [diam_min : diam_step : diam_max];

% Initialize matrix to store results
hit_v = zeros(4,numel(test_diamaters));

for i = 1:numel(test_diamaters)

    d = test_diamaters(i); % Chute diameter


    area = pi * d^2 / 4; % Cross-sectional area

    v_1 = sqrt( (m1 * g) / (0.5 * rho_sl * Cd * (area+drogue_area)) ); % Hit velocity
    t_1 = t_initial + main_deploy_alt / v_1; % Total flight time

    v_2 = sqrt( (m2 * g) / (0.5 * rho_sl * Cd * area) ); % Hit velocity
    t_2 = t_initial + main_deploy_alt / v_2; % Total flight time

    hit_v(:,i) = [v_1; t_1; v_2; t_2]; % Put results into results matrix

end
```

Section 3.5.4. Plotting Results

```
figure()
hold on;
yyaxis left;
plot (test_diamaters, hit_v(1,:));
plot([0, diam_max], [25, 25]);
xlabel('Parachute Diameter (ft)');
title('Main Parachute Sizing Study');
yyaxis right;
plot (test_diamaters, hit_v(2,:));
plot([0, diam_max], [90, 90]);
ylabel('Descent Time (sec)');
legend('Ground Hit Velocity (ft/sec)','25 ft/sec','Descent Time','90 Seconds');
hold off;


figure()
hold on;
yyaxis left;
plot (test_diamaters, hit_v(3,:));
plot([0, diam_max], [25, 25]);
xlabel('Parachute Diameter (ft)');
title('Drogue Parachute Sizing Study');
yyaxis right;
plot (test_diamaters, hit_v(4,:));
plot([0, diam_max], [90, 90]);
ylabel('Descent Time (sec)');
legend('Ground Hit Velocity (ft/sec)','25 ft/sec','Descent Time','90 Seconds');
hold off;
```

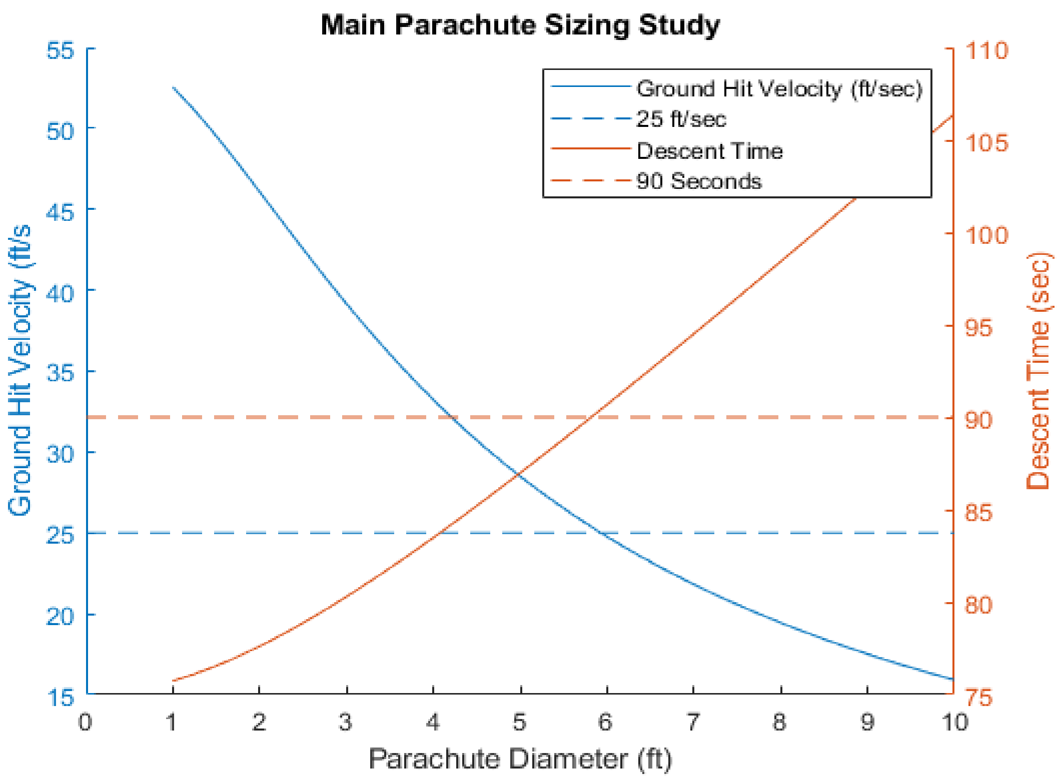


Figure 3.5.4.A. Main Parachute Sizing Study

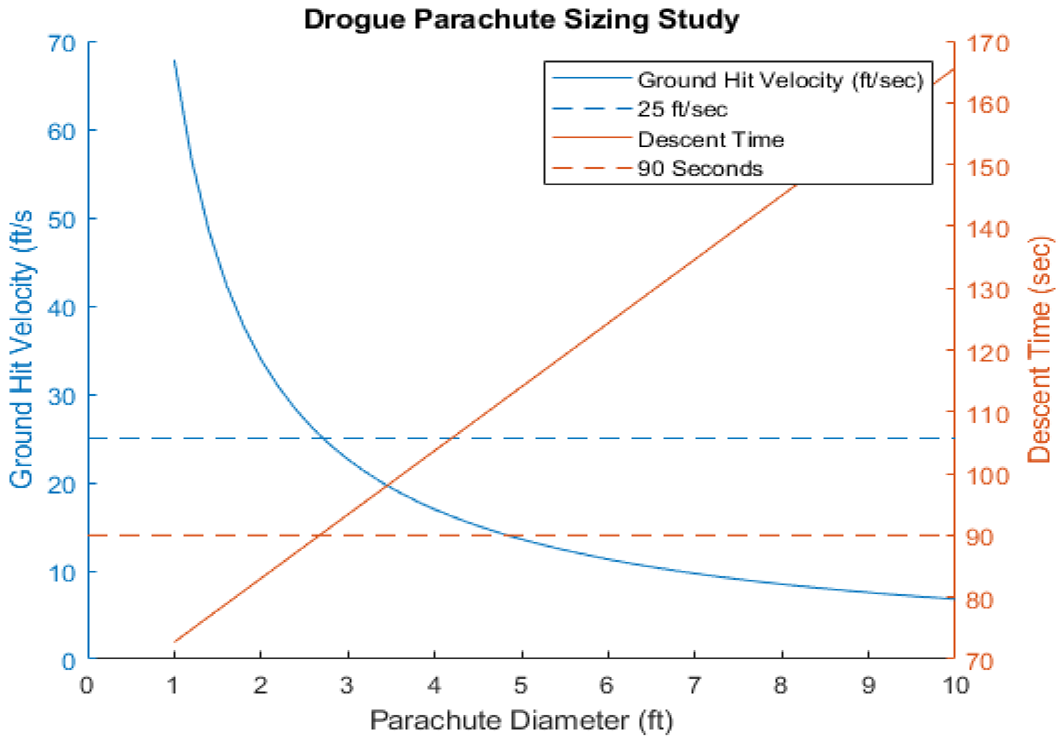


Figure 3.5.4.B. Drogue Parachute Sizing Study

Section 3.6. Motor Selection

From our original proposal, our motor has changed from the L935-IM-0 motor to the L730-0 to accommodate other changes to our launch vehicle. While the L935 is a more powerful motor placing us closer to the goal of reaching 4704 ft, the launch vehicle would exceed the 90 second descent time limit. In order to decrease the decent time while maximizing the apogee altitude, we switched to the L730-0 motor. In the event of unforeseen circumstances, our backup motor will remain the L1030-RL.

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. All of the following simulations for each motor were obtained using Open Rocket. The simulation resulted in an apogee of 4,704ft 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.

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

Figure 3.6.A. Motor Specifications

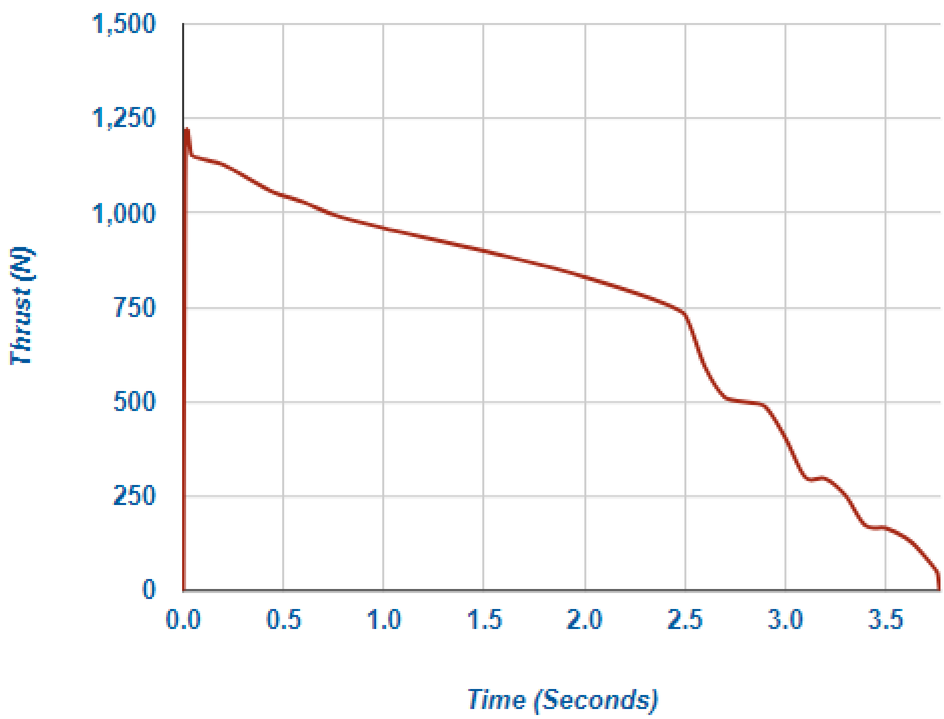


Figure 3.6.B. Thrust vs Time

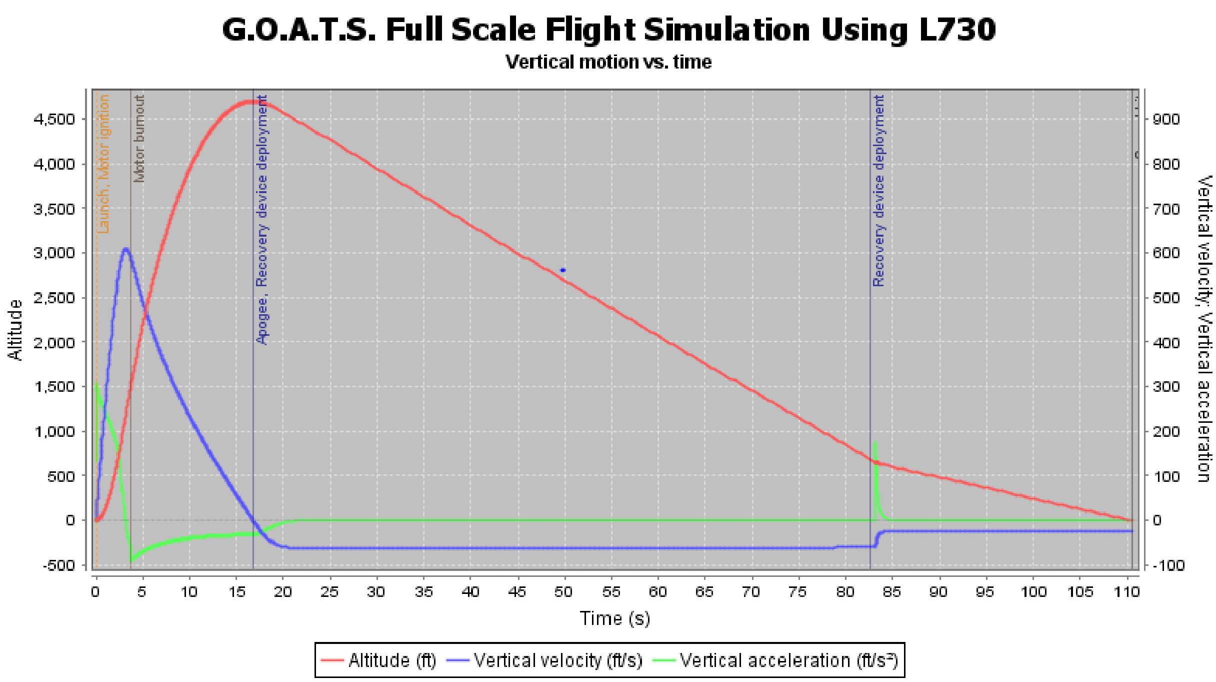


Figure 3.6.C. Flight Simulation

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 with a descent time of 91.5 seconds.

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 3.6.D.. Backup Motor Specifications

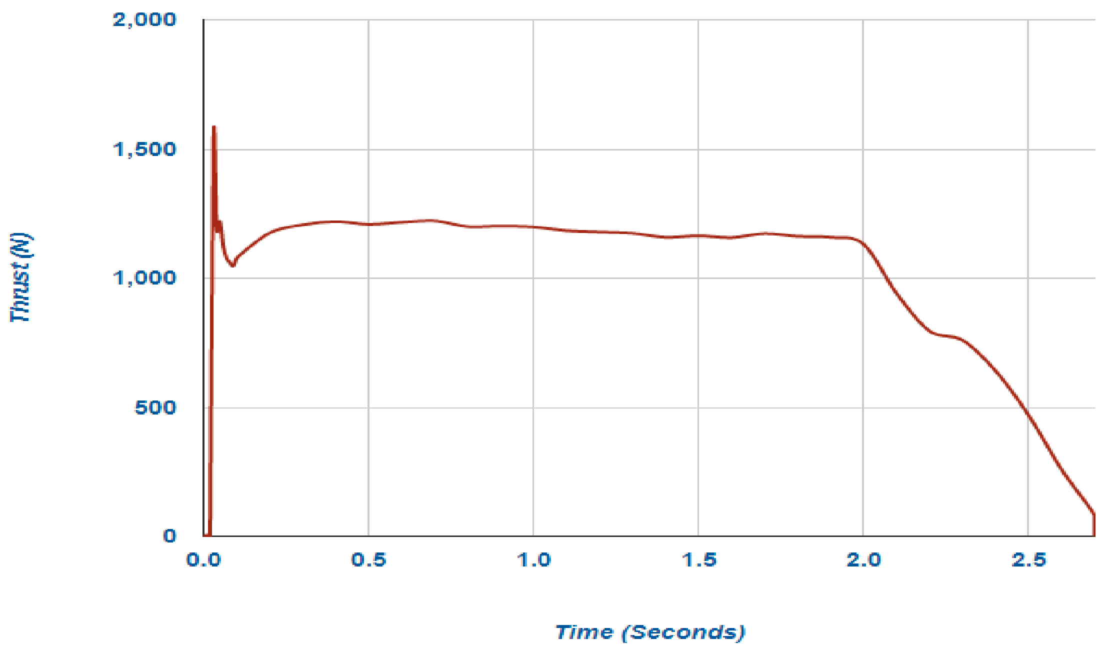


Figure 3.6.E Backup. Thrust vs Time

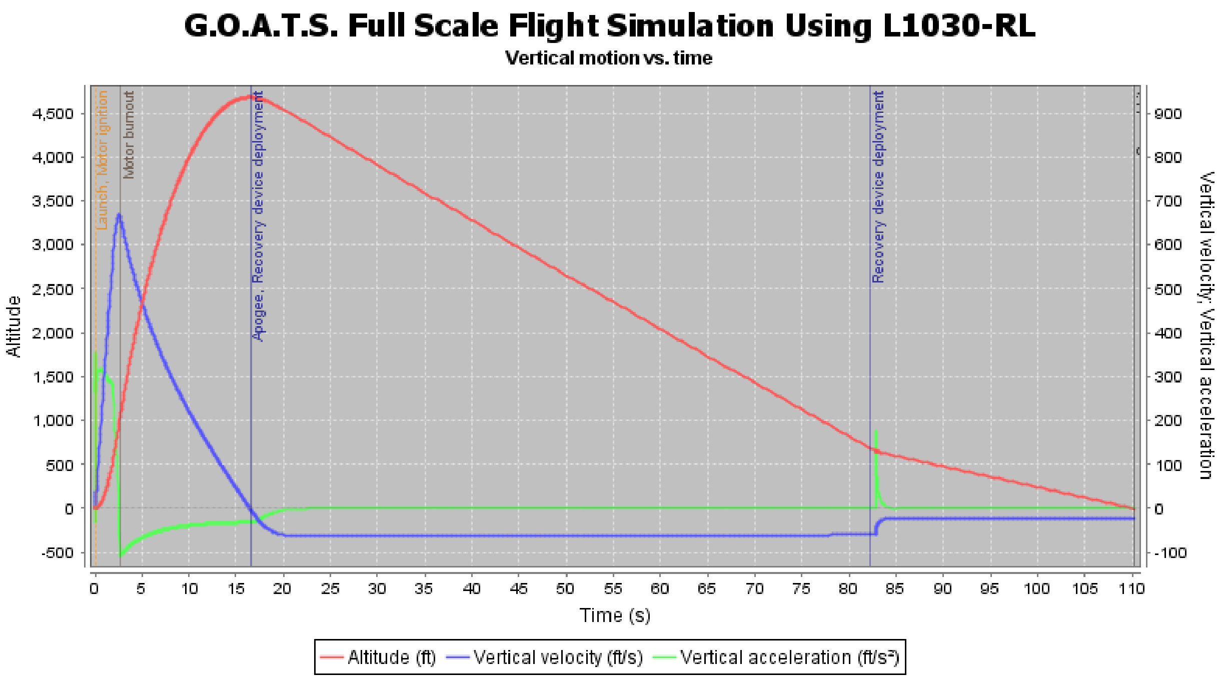


Figure 3.6.F. Backup Flight Simulation

We also considered other Cesaroni Technology Inc. rocket motors such as the L265-0, K300-CL-0, K750-8, and K820-BS-8. These motors either did not reach as high of an altitude as the L730-0 or exceeded the descent time of 90 seconds. The parameters and flight simulations of each motor are shown below.

The L265-0 motor is 25.6in in length, 2.13in in diameter and has a total impulse 2645Ns. The simulated apogee is 4,032ft with a descent time of 82.9 seconds. As can be seen, the apogee is 665ft lower than that of the L730-0 motor.

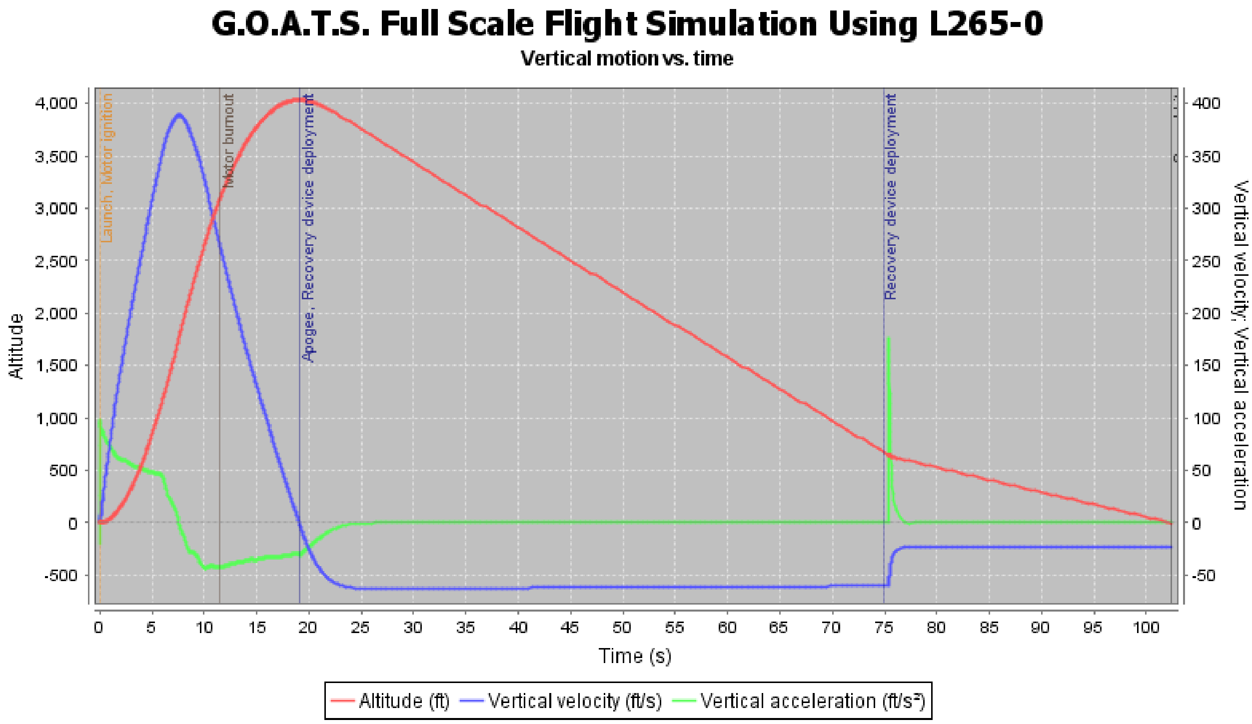


Figure 3.6.G. Alternate Motor 1 Flight Simulation

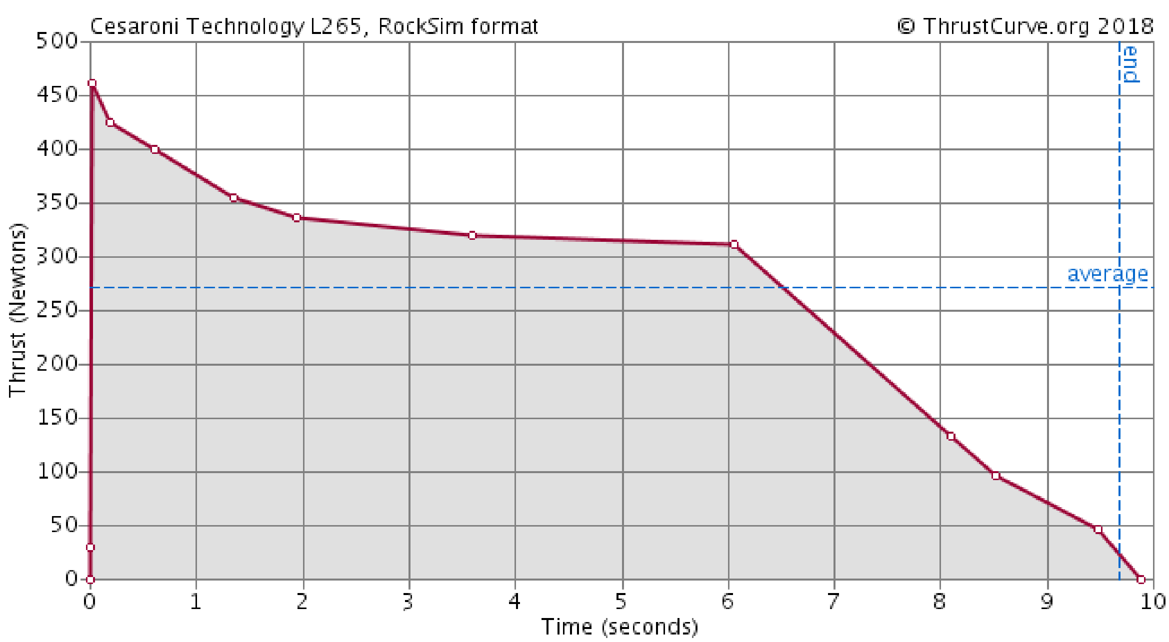


Figure 3.6.H. Alternate Motor 1 Thrust vs Time

The K300-CL-0 is 25.6in in length, 2.13in in diameter and has a total impulse of 2987Ns. The simulated apogee is 4,082ft with a descent time of 84.2 seconds. While the descent time is within the 90 seconds requirement, the apogee is 615ft lower than that of the L730-0.

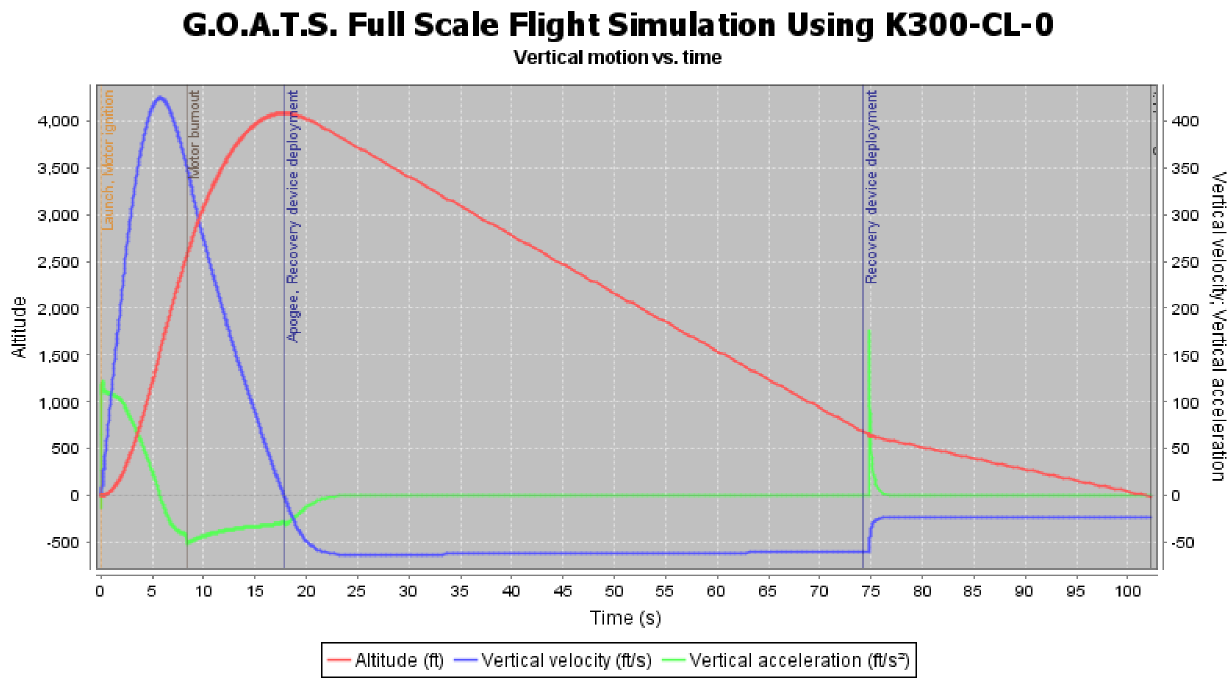


Figure 3.6.I. Alternate Motor 2 Flight Simulation

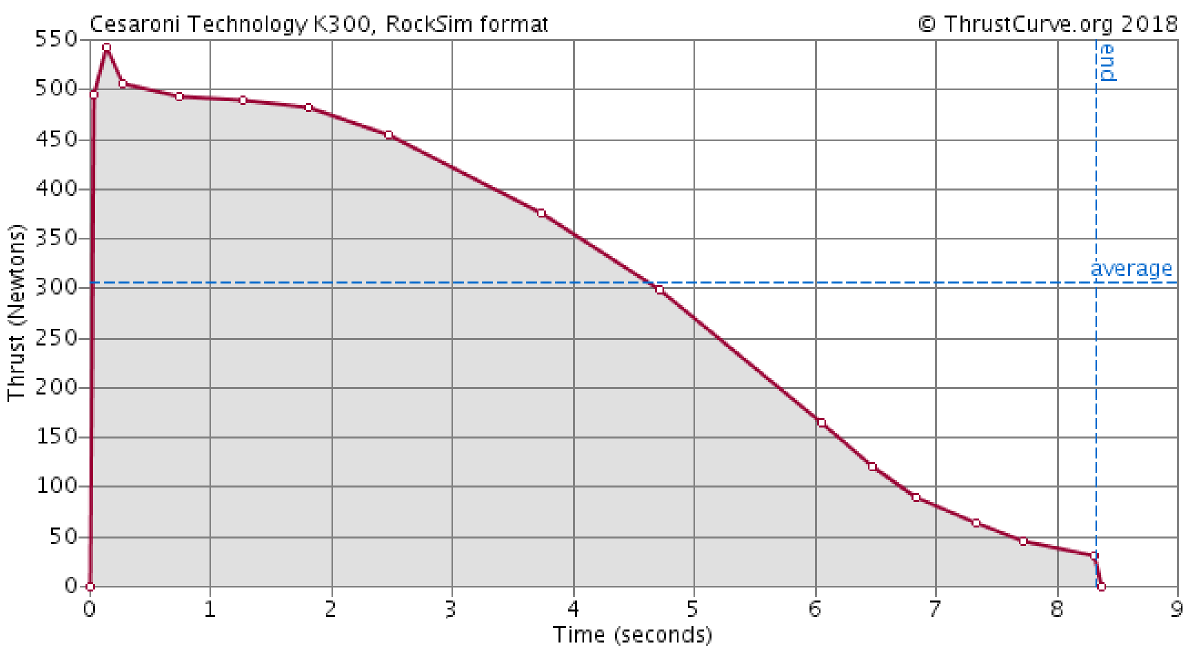


Figure 3.6.J. Alternate Motor 2 Thrust vs Time

The K750-8 motor is 22.6in in length, 2.13in in diameter, and has a total impulse of 2312Ns. The simulated apogee is 3,831ft with a descent time of 77.9 seconds. This apogee is 866ft lower than that of the L730-0 motor.

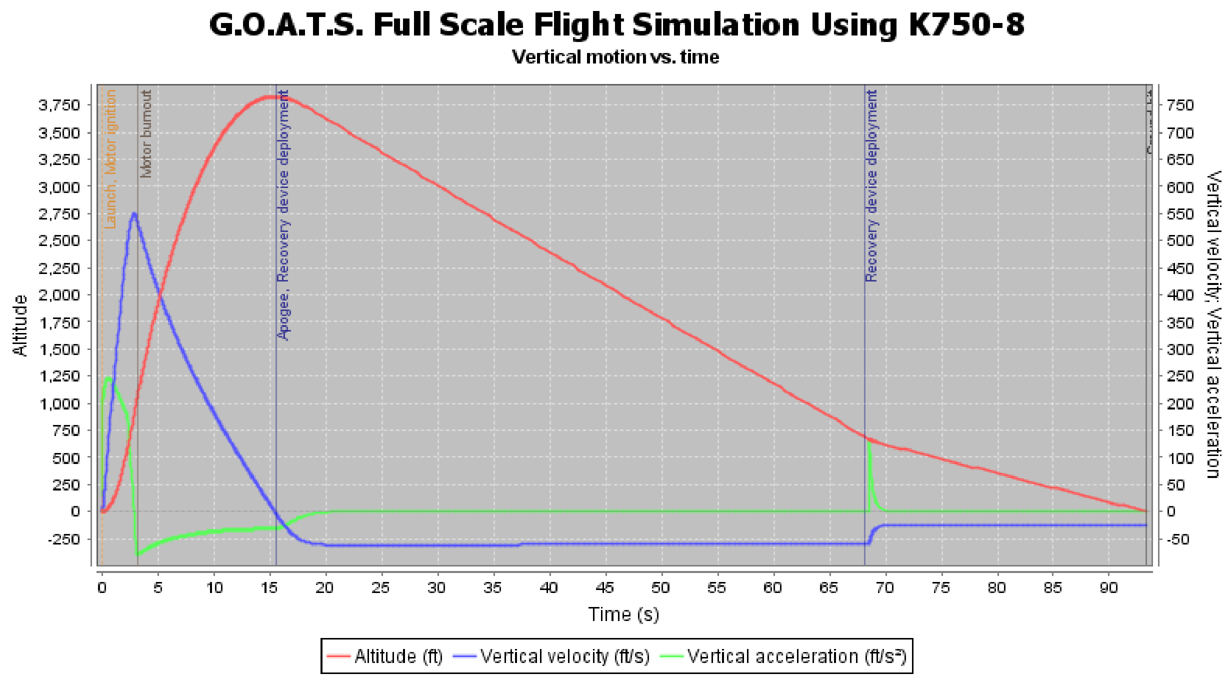


Figure 3.6.K. Alternate Motor 3 Flight Simulation

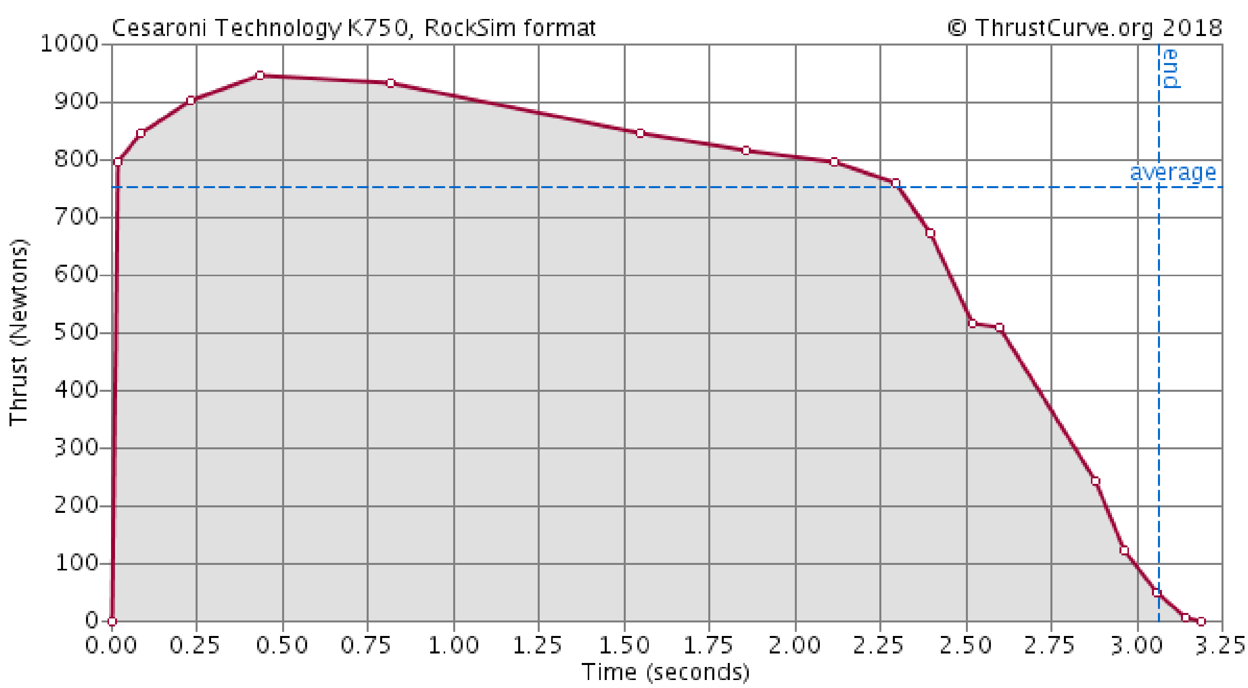


Figure 3.6.L. Alternate Motor 3 Thrust vs Time

The K820-BS-8 motor is 22.5in in length, 2.13in in diameter and has a total impulse of 2383Ns. The simulated apogee is 4,008ft with a descent time of 80.8 seconds. This apogee is 689ft lower than that of the L730-0 motor.

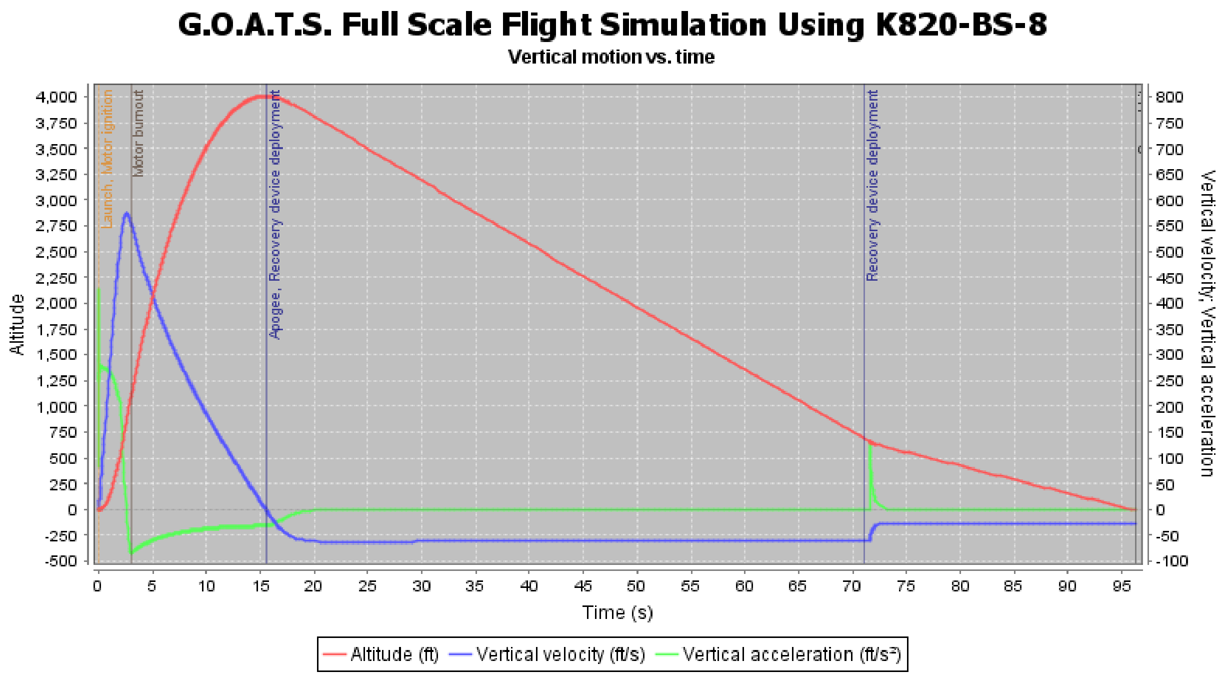


Figure 3.6.M. Alternate Motor 4 Flight Simulation

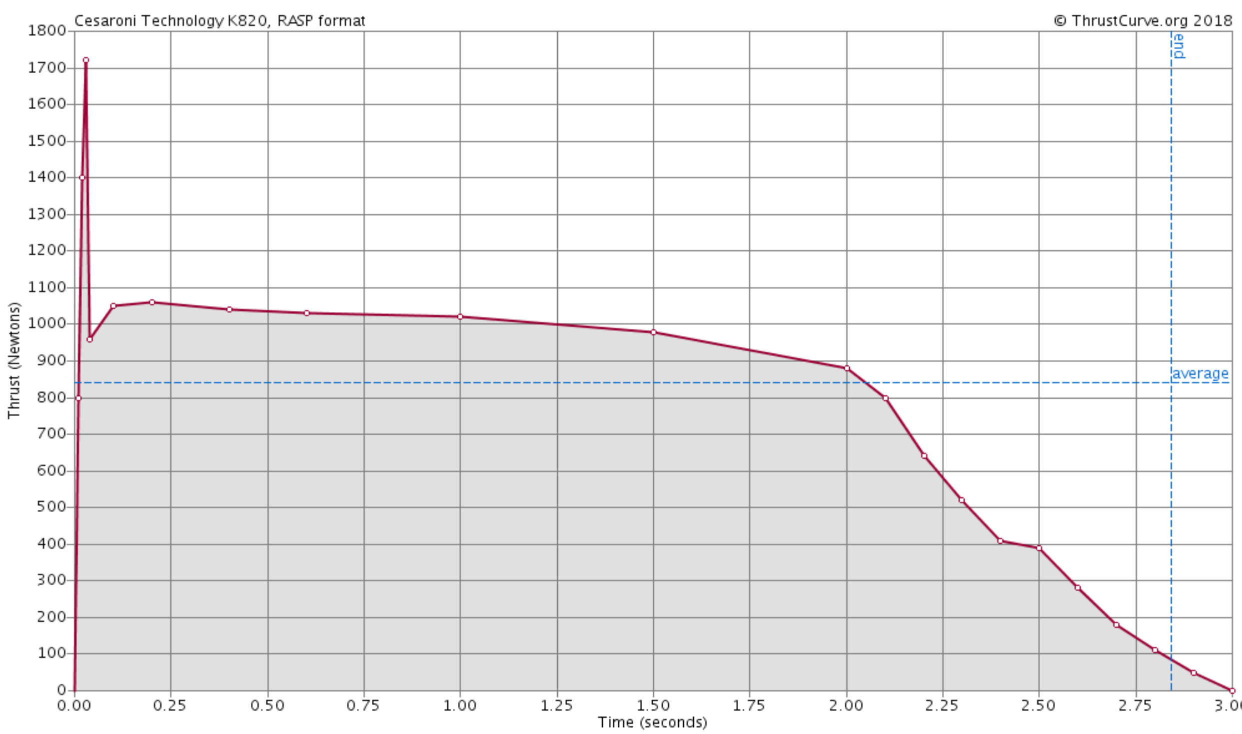
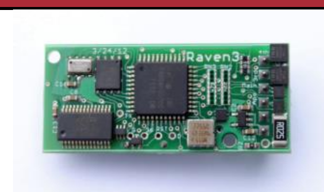


Figure 3.6.N. Alternate Motor 4 Thrust vs Time

As can be seen, The L730-0 motor produced the highest apogee while staying within the descent time limit of 90 seconds which is why it has been chosen as the main rocket motor.

Section 3.7. Devices for Mission Performance

3.7.1. 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.	
Nordic semiconductor nRF24L series RF Transceiver	Transmits and receives GPS data.	

Arduino Nano	Manages the module and makes everything work together.	
Nine Volt Battery	Necessary to power electronics	

3.7.2. Launch Vehicle Body Tracking System

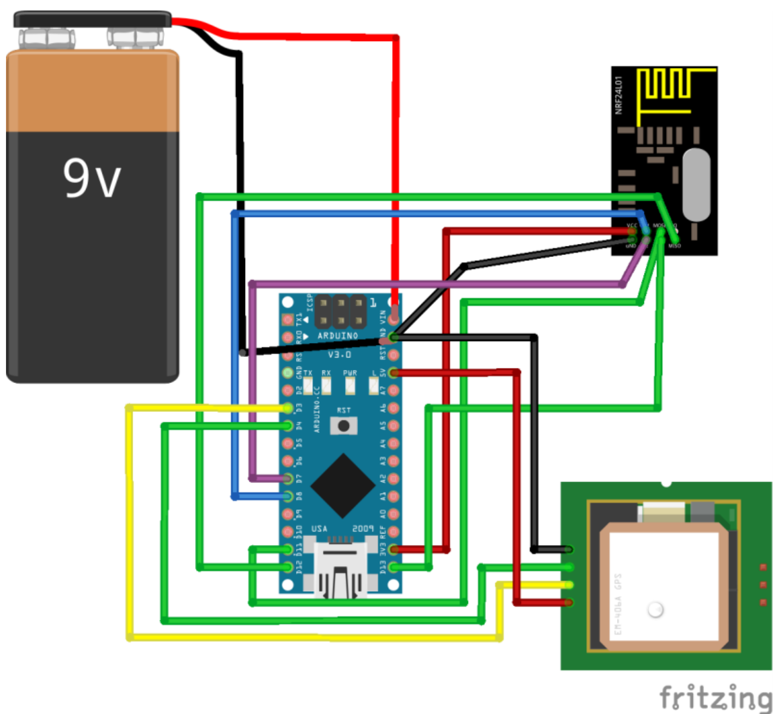


Figure 3.7.2.A. GPS Circuit Diagram

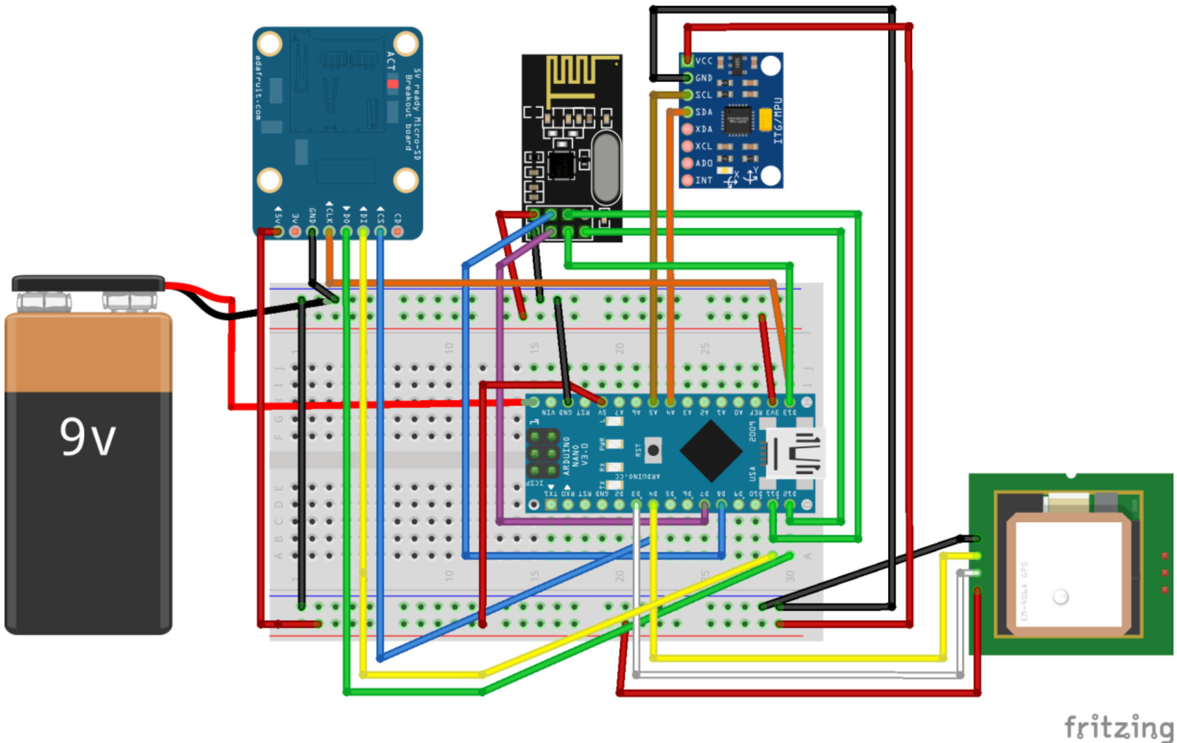


Figure 3.7.2.B. Full GPS Circuit Diagram

The upper airframe, lower airframe, payload, and nose cone will be tracked with the GPS in section 3.2. 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, nRF24L 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 nRF24L+, with the attached antenna. The transceiver is connected to an arduino which outputs data to a laptop.

For the more simplistic module in figure 3.7.2.A., 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 3.7.2.B., 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

As the team has already launched their sub scale test, the next step is to finalize the launch vehicle design and construct a full scale test. This section analyzes the risks associated with the construction with a larger vehicle. 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 4.1 through 4.4 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 4.5. Provides a series of checklists that the team will use at launch events to prevent failures and hazards at the launch.

4.1. Personnel Hazard Analysis

The personnel hazard analysis looks at the possible hazards that may come up throughout the project and analyse them by probability and severity. It focuses on conditions that could be harmful to team members and bystanders.

4.1.1. Probability/Severity Definitions

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 4.1.1.A. 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 4.1.1.B. Personnel Hazard Severity Definitions

4.1.2. Analysis

Personnel Hazard Analysis					
Phase	**Hazard**	**Cause**	**Effect**	**Probability/ Severity**	**Mitigation**
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 Range Safety Officer (RSO).
	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 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.
	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 added with care and will be examined before launch. Powder Charges will be measured and weighed with an electronic scale.

	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 with stability in mind. Before construction, the results will be verified by simulation.
	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 multiple redundancy systems capable of deploying it.

	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	Structural integrity will be kept in mind during the construction of the launch vehicle in terms of the load it will bear and any forces it may experience. Will be properly packaged during transportation to prevent damage.
	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.

	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, keeping wind direction in mind.
	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 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.
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 disability.	CIII	All team members have have been instructed on proper safety practices. Members will not use tools they are not trained on. Tools will only be used if they are 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 Personal Protective Equipment (PPE) and work in a well ventilated

					area.
	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. All electronics will be tested before being connected to energetics.
	Overheating of electronics	During testing, electronics could overheat and potentially ignite.	If it results in a fire, it could harm people in the area or potentially spread further.	CII	Electronics will be carefully monitored during testing in order to ensure they do not overheat.

	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

Table 4.1.2.A. Personnel Hazard Analysis

4.2. Failure Modes and Effects Analysis

The FMEA ranks possible failure modes by probability and severity with a focus on the hardware itself. Their causes and effects are also considered along with how they might be mitigated.

4.2.1. Probability/Severity Definitions

FMEA 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 4.2.1.A. FMEA Probability Definitions

FMEA 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 4.2.1.B. FMEA Probability Definitions

4.2.2. Analysis

Failure Modes and Effects Analysis					
Item	**Failure Mode**	**Cause**	**Effect**	**Probability/ Severity**	**Mitigation**
Launch Vehicle	Drogue parachute does not deploy.	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.	The launch vehicle enters a dangerous free fall. If the main parachute deploys at these high speeds, it will likely damage the airframe.	BI	Drogue chute will have multiple redundancy systems capable of deploying it.

	Main parachute does not deploy.	Using too small a charge or too tight of a fit in the airframe could prevent the launch vehicle from deploying the main parachute. This could also happen if the parachute is not packed correctly.	If the drogue parachute has deployed, the launch vehicle will descend at a controlled but fast rate leading to minor damage. If the drogue parachute has not deployed, the launch vehicle will impact the ground in free fall leading to a loss of the entire system.	BII	The main chute will have multiple redundancy systems capable of deploying it.
	Motor misfire	Failure of igniter or damage to motor prior to launch	This could cause damage to or result in the destruction of the launch vehicle.	DI	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 ejected from launch vehicle	Improperly secured motor or airframe failure	This, if it occurs during flight, could send the launch vehicle into freefall and potentially damage or destroy it.	CI	The motor will be correctly installed by a certified mentor. The motor retention system will be inspected prior to launch.
	Shock Cord is Severed	Destruction by black powder charge, burnt by charge detonation, or severed on a sharp edge	This could cause the launch vehicle to come apart and send pieces into freefall, likely damaging or destroying them	DI	A Nomex blanket will protect the shock cord from fire damage. The black powder charges will be measured carefully.
	Electronics bay failure	Destruction by black powder charge, burnt by charge detonation, poor electrical connections, 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 or prevent separation by charges.	CII	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 altimeter.

Payload	Parachute on top of UAV	The launch vehicle and payload may land in such a way that a parachute ends up on top of the payload.	This could cause the rotor of the UAV to get caught in the parachute and cause damage to or destroy the UAV.	DIII	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.
	Motor failure	The UAV could become damaged in flight and cause a failure of one or more of the motors.	This could cause the UAV to veer of the desired flight path, fall during flight, or completely fail to take off. The two former options could damage the UAV further.	CII	Motors will be properly installed and secured to ensure the best chance of motor success.
	Frame failure	The UAV could become damaged in flight and cause a failure in the frame.	This could potentially cause the UAV to veer of the desired course or completely destroy the UAV.	CI	The UAV will be built with structural integrity in mind and secured in the launch vehicle with the best chance of it surviving in mind.

	Electronics failure	The UAV could become damaged in flight and cause the onboards electronics to fail.	This could cause the UAV to veer of the desired flight path and cause damage or fail to start entirely.	CI	The electronics will be secured in the UAV with the best chance of their survival in mind.
	Beacon retention system failure	The UAV could become damaged in flight and cause the retention system to fail.	This could cause damage to the beacon or internally to the UAV depending of the severity of the failure.	CIII	The beacon will be secured and the retention system will be installed with the best chance of its survival in mind.
Payload Retention System	System failure	The retention system could become damaged and/or open prior to landing.	This could cause the payload and/or other electronics to go into freefall and potentially damage them.	CII	The retention system will be built with structural integrity in mind and installed carefully to prevent it from opening early.

Table 4.2.2.A. FMEA

4.3. Environmental Conditions

Environmental concerns ranks possible hazards that may occur in the launch with their probability and severity. The effects on safety, hardware, and the environment are considered along with mitigation strategies.

4.3.1. Probability/Severity Definitions

Environmental Conditions 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 4.3.1.A. Environmental Conditions Probability Definitions

Environmental Conditions 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 4.3.1.B. Environmental Conditions Severity Definitions

4.3.2. Analysis

Environmental Concerns				
Phase	Environmental Condition	Effect	Probability/ Severity	Mitigation
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.
	Strong winds	Unsafe alterations to launch vehicle's trajectory	BIV	Alter course and adjust trajectory to prevent launch vehicle's landing from leaving the exclusion zone. If the RSO deems the winds to be too high, the team will wait for the winds to die down.
	Inclement weather	Unsafe alterations to launch vehicle's trajectory and launch vehicle itself.	AI	The team will not launch in inclement weather.

	Trees	Due to winds or an unpredicted flight path, the launch vehicle or payload could end up hitting or landing in a tree.	CII	The launch vehicle will be aimed in a direction with wind in mind and far from any trees to ensure the best chance of avoiding trees.
	Motor exhaust	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.
	Ignition of motors or energetics.	Overheated motors or energetics could start a fire and light any flammable objects in the area.	CIII	The electronics will be inspected and tested to prevent shorts and anything else that could cause overheating. Motors will be safely installed and arranged in a way to prevent them from stalling or being affected by other things that may overheat them.

Payload Teleoperation	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.
Payload Retention System	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.

Table 4.3.2.A. Environmental Concerns

4.4. Project Risks

Project risks analyzes the probability and severity of risks to the project as a whole. Where applicable, the quantitative effects on the schedule, budget, and overall design are considered along with mitigation strategies.

4.4.1. Probability/Severity Definitions

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 4.4.1.A. Project Risk 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 4.4.1.B. Project Risk Severity Definitions

4.4.2. Analysis

Project Risks Overview					
Risk	**Probability/ Severity**	**Schedule Impact**	**Budget Impact**	**Design Impact**	**Mitigation**
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.

Destruction of Full Scale	CII	The launch vehicle will need to be rebuilt over the course of two to three weeks. Additional 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 or mentors to catch any possible errors. The launch vehicle will be constructed to the exact specifications.
Failure to secure travel funding	CII	None	Because WPI's Student Government Association (SGA) does not cover airfare, if funding is not secured members would only be able to attend if they paid $326 out of pocket. This will significantly limit the number of members who can attend the competition.	None	Engagement officers will reach out to multiple companies well in advance of the competition. Other funding methods will be explored as well.

Damaged or delayed during shipping	DI	Would cause a delay would likely be impossible to make as it would be too close the the actual competition time.	None	None	The launch vehicle will be shipped with a via a reputable shipping company to arrive slightly ahead of the team.
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.
Destruction of payload in testing.	CII	Likely two to three weeks to reorder parts, rebuild, and fix design flaws.	May cost up to $500 depending on what components of the payload can be salvaged.	Large design changes are likely required to resolve the issue with the payload or he 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.

Destruction of payload prototype.	BIII	Will require a few days to correct design flaws which lead to its destruction.	No greater than $500. Likely less as some parts may be salvageable and prototypes may use some cheaper components for testing.	Depending on the cause of failure, will likely require at least a minor change and at most an overhaul.	Before construction, the components will be verified to withstand flight and impact forces. To minimise budget impact, prototypes may not use all the same materials as the final payload. For example, the carbon fiber airframe
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.

Table 4.4.2.A. Project Risk Overview

4.5. Launch and Assembly Checklists

In order to ensure the success of the flight and the safety of personnel, the team will use checklists to ensure all operations are successful. The launch vehicle will not be launched until all tasks on every checklist has been verified as complete.

4.5.1. Payload Launch Checklist

Payload Checklist	
Task	**Verified**
Ensure payload has charged batteries.	
Perform an electronics systems check.	
Ensure communications are functional.	
Verify the structural and mechanical components are in working order.	
Configure electronics for flight.	
Pack payload within the retention system.	

Table 4.5.1.B. Payload Checklist

4.5.2. Motor Checklist

Motor Checklist	
Task	**Verified**
Ensure all components are in working condition. The motor is not to be used if it has been tampered with.	
Confirm with the RSO that the motor is safe.	
Assemble the motor and prepare it for flight.	
Mount the motor on the launch vehicle and ensure that it is securely fitted.	

Table 4.5.2.A. Motor Checklist

4.5.3. EBay Checklist

EBay Checklist	
Task	**Verified**
Place a charged 9V battery on the sled for each altimeter.	
Plug each altimeter into a computer and test that each is programmed for dual deployment at apogee and 700ft.	
Slide the sled into ebay coupler.	
Make sure apogee and main charges are oriented in the correct direction for deployment.	
Connect terminal blocks to apogee and main.	

Pack black powder charges.	
Connect black powder charges to the other end of the terminal block.	
Make sure black powder charges are oriented correctly and secured.	
Place ebay in the launch vehicle be careful to ensure apogee and main charges are still oriented correctly.	

Table 4.5.3.A. EBay Checklist

4.5.4. Recovery Checklist

Recovery Checklist	
Task	**Verified**
Put nomex blankets on shock cord.	
Ensure all bodies are secured with shock cord.	
Verify all parachutes are in working condition without holes or tears.	
Pack all parachutes properly.	
Secure parachutes to their mounting points.	

Table 4.5.4.A. Recovery Checklist

4.5.5. Structural Checklist

Structural Checklist	
Task	**Verified**
The airframe is in working condition with no dents or fractures.	
The fins are in working condition with no bending or fractures.	
The nose cone is in working condition with no dents or fractures.	
Check that the EBay is properly secured to the upper airframe.	

Table 4.5.5.A. Structural Checklist

4.5.6. Assembly Checklist

Assembly Checklist	
Task	**Verified**
Fit Nomex blankets into the launch vehicle. Ensure they adequately protect from energetics.	
Fit parachutes, ensuring they stay packed and are not tangled in shock cord.	
Fit the payload retention system.	
Fit airframe components together.	
Insert shear pins.	

Table 4.5.6.A. Assembly Checklist

Section 5. Payload Criteria

The objective of our team's selected payload design will be to deliver the beacon to a Future Excursion Area using an effective and robust robotic system. This system, consisting of a strong retention mechanism housing a remotely piloted UAV, will be configured to land after launch without being too close to the rest of the launch vehicle airframe, house the UAV such that it will not unintentionally move or become damaged during flight and withstand atypical flight forces, orient itself upright from any initial landing orientation, allow the UAV to be deployed, and be able to stably fly short distances using long range communication and release the beacon above a Future Excursion Area. Our team considers such a system which can satisfy all of these requirements in a reliable manner a successful experiment.

Section 5.1. Selection, Design, and Rationale of payload

Having received feedback on our initial decided design and discovering of its lack of compliance with certain regulations in the launch handbook, our team immediately began working to redesign our system to better fit these requirements while keeping intact our goals of achieving the objective in a vigorous and reliable manner. As was previously determined, the use of a quadrotor would be the most optimal choice of UAV as opposed to a tricopter or helicopter, as these designs possess greater complexity from a mechanical and control standpoint along with the convoluted means by which they would need to be compacted into and interact with the launch vehicle airframe.

Our original design consisting of a pyramid-like retention system to land separately from the launch vehicle airframe and house the quadrotor by folding up its arms was inspired from the use of a similar design used in NASA mars rover missions, though due to its separation from the airframe it would not be permitted in competition. From this knowledge, it quickly became our team's priority to modify this concept to satisfy the requirements of keeping the retention

system a component of the launch vehicle body but retaining its highly effective orientation and deployment structure, as the concept of unfolding to achieve a certain alignment from any initial landing configuration has long proven its reliability.
To achieve this goal, we brainstormed and reviewed many ideas, a process which resulted in three final designs for this system from which we would select our decided best option with regards to reliability, feasibility, mechanical simplicity, and space efficiency. These design alternatives consist of a now cylindrical retention system similar to our previous design which will unfold and right itself to release the UAV, one made to be a section of the launch vehicle's outer airframe and another similar to the first only instead a piece of the launch vehicle's inner tube which will be pushed out of the outer airframe during flight, and a design to push the UAV out of the outer airframe after landing and unfold its arms to position itself for takeoff. The rationale behind the selection for our final design is as follows in the table below.

	Feasibility	Reliability	Mechanical simplicity	Space efficienc y
Outer airframe retention system	- System won't be air-tight, risk of fast-moving air leaking into the capsule and damaging the payload as well as unstable flight of the launch vehicle - Failure of the system holding itself together could result in great damage to it and or the launch vehicle during flight	- System could potentially break apart during launch, measures must be taken to strengthen the design and acceptably lower the risk of this happening - Would not be contained within the airframe, thus no need to separate and risk becoming stuck inside the launch vehicle during flight	- Actively unfolds, relatively straightforward actuations, small margin for failure - Uses common launch vehicle components, black powder and parachute release, for separation from the rest of the airframe	- Highly effective use of space in the launch vehicle, almost none wasted
Inner tube retention system	- Greatly simplifies issues from the design which utilizes the outer airframe, little chance of it becoming damaged or damaging the rest of the launch vehicle	- Could become stuck within the outer airframe and be unable to separate during descent - System concept has been rigorously performed and tested by our team,	- Actively unfolds, relatively straightforward actuations, small margin for failure - Uses common launch vehicle components, black powder and parachute release, for	- Very effective space efficienc y, little wasted

	- System has been used in our organization's launch vehicle design for a long time	proven to be successful	separation from the rest of the airframe	
UAV ejection from within airframe system	- Never before attempted by our organization - System will be well protected within the airframe of the launch vehicle	- Damage risked to the UAV during ejection - Could greatly damage the launch vehicle and UAV if activated prematurely - The UAV could become stuck within the airframe	- Requires strong actuation, potentially damaging to the UAV	- Potentially less space efficient than the other design options - More lightweight than the others

Table 5.1.A. Design Choices

The final design selected for our team's payload is the inner tube capsule which will be pushed out of the outer airframe during the descent of the launch vehicle. After carefully evaluating and comparing the alternatives, this system was determined to be the most simple, robust, and the least likely to receive or inflict damage throughout the process of the flight. The greatest rationale behind the selection of this system was due to it's high familiarity with what our organization has done with high powered rocketry in the past, having a launch vehicle which ejected a payload from within the airframe during flight which falls separately, though in this case it will fall while still attached to the upper airframe but not too close to it. As inner tube was specified to be part of the launch vehicle's airframe, this design satisfied the requirement of creating a system which complied with the regulations of the competition while still keeping intact the idea of reorienting from any initial landing position, as it will do this by separating into four actuating quarter pipe sections of the cylindrical body to effectively unfold and push itself upright, similar to our previous design. The other alternatives for this system were determined to possess less inherent safety and reliability than the one we selected for our final design, requiring us to work harder to strengthen them through further testing if we wanted to bring them closer to an acceptable design, something we felt would not be worth the time and effort given an alternative system satisfied all requirements while remaining a concept executed many times before by our team. The design selected will be housed within an inner tube piece at the top of the upper air frame of the launch vehicle body with its corresponding parachute attached using shock cord to a bulkhead on the bottom, giving it the characteristic of descending while upside down with respect to its initial launch configuration. It will perform its operations just like our previous design, being fit with a control system which will listen for an activation signal sent by our team's ground station after receiving permission to do so after confirmation of a safe landing. Once activated, the retention system will autonomously actuate to unfold and orient itself to prepare the UAV for takeoff as well as power it on. After being released from the retention system, the UAV will be piloted to a Future Excursion Area using an FPV camera and GPS for additional guidance and release the beacon using a small linear servo to drop it when appropriate, then fly a reasonable distance away from the area to land and power down to complete the mission.

Section 5.2. Payload diagrams and further specifications

Table 5.2.A. Payload Retention System

Section 5.2.1 Estimated Masses of payload components

Item	Quantity	Individual Mass (g)	Total Mass (g)
Pixhawk Mini	1	141.748	141.748
RotorX Brushless Motors	4	9.09	35.35
Battery	2	7	12

Transceiver	1	6	6
FPV Camera	1	4.5	4.5
Nylon X Filament Roll	2	500	1000
PLA Filament Roll	3	1000	3000
Propellers	4	2.3	9.1
Beacon	1	5	5
Linear Servo	4	56	224

Table 5.2.B. Payload Component Masses

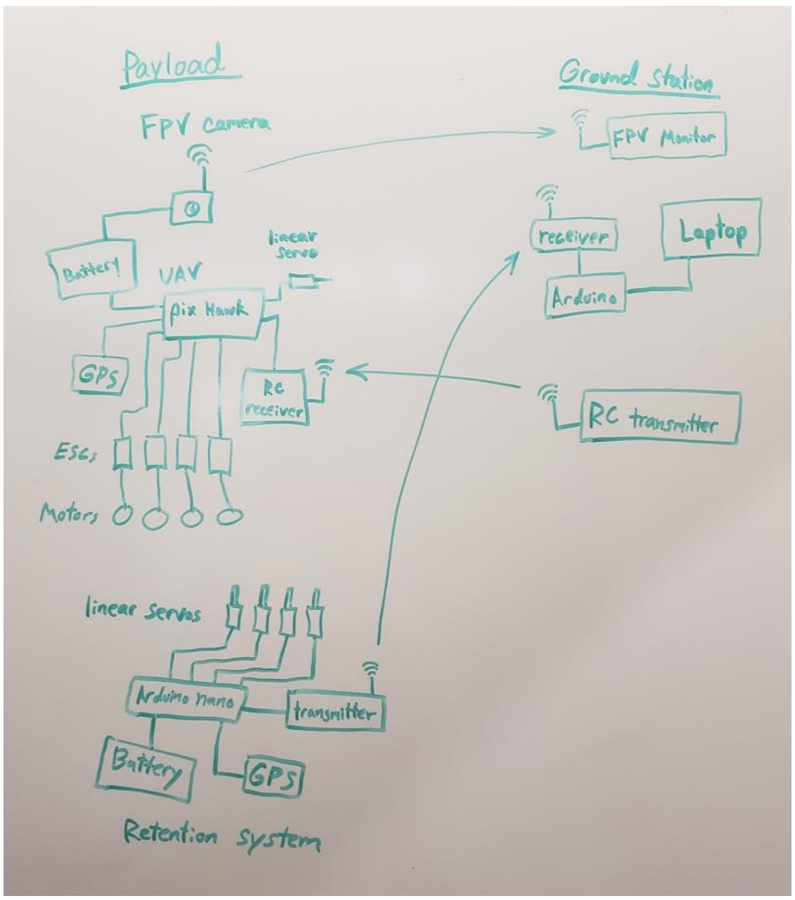


Table 5.2.C. Communication System Diagram

Section 6. Project Plan

This is WPI's first year participating in the NASA Student Launch competition. The team is excited to compete and has prepared as much as possible. The team has already planned out when to go to launches for this year and has come up with a detailed schedule of how deadlines can be met and our mission statement fulfilled in addition to coming up with requirement verification to insure our success. The team has also created a budget of all of the supplies needed to build the whole launch vehicle/payload system and have made sure that funding required for mission success is obtained. The team is dedicated to ensuring our plan will be sustainable and replicable for the years to come.

Section 6.1. Requirements Verification

This section goes into verification plans for the rules set by NASA for the 2018-2019 USLI competition. Our team will abide by all these requirements and work to solve any issues encountered along the way to best fit these conditions.

Section 6.1.1. Handbook Requirements

General Requirements		
NASA Requirements	**How we Plan to Meet Them**	**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.	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	We will include all of the listed requirements for	We will use a Gantt chart and stick to a rigid schedule to make sure that everything is

support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.		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.	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.	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 defined in the STEM Engagement Activity Report, by FRR.	We will participate in multiple outreach event throughout the year.	We will verify that we are completing these task by looking at the Gantt chart 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.	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.	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.	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	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	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.	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.	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 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	We have found a mentor that has all of the prior experience we need.	We will verify this by routinely communication.

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 6.1.1.A. General Requirements

Vehicle Requirements		
NASA Requirements	**How we Plan to Meet Them**	**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 4,704 feet, within the acceptable range.	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 4704ft.	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.	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.	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.	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.	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 repairs or modifications.	We will use materials durable enough to withstand the forces of flight and landing	The Sub-scale and test launches will help to determine whether or not a stronger material needs to be looked into.

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.	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.	The coupler for the ebay 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.	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.	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.	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.	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	We will verify this at our test launches.
2.13. The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).	We will only use the igniter that came with the specific motor and what's supplied at the launch pad to initiate launch.	We will verify this at test launches.
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	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 milestone, regardless of the reason.	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.	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.
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
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
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	N/A	N/A

maximum pressure and flow rate of the tank.		
2.15.3.Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.	N/A	N/A
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	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.	Our current launch vehicle design has a stability of 3.19.

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	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.	Our sub-scale launch vehicle was built early due to limited launches during the winter months in New England. Its launch was on Nov. 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.	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.	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 test.	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 meet this requirement.	The subscale launch vehicle's altimeter will be used to recover flight data	We were able to successfully receive flight data from the raven 3 altimeter located in the electronics bay of the subscale

2.20. All teams will complete demonstration flights as outlined below.	Demonstration flights will be scheduled for the team	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 apogee, main chute at the intended lower altitude, functioning tracking devices, etc.).	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.	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.
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.	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.	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
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.	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	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	N/A	N/A

systems will be active during the full-scale Vehicle Demonstration Flight.		
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	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 fullscale launch vehicle.	We will not make any changes to the launch vehicle or its flight configuration after the CDR submission	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	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	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 Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. This extension is only valid for re-flights, not first-time flights. Teams completing a required re-flight must submit an FRR Addendum by the FRR Addendum deadline.	Demonstration flights will be completed before the FRR	We will take extra care to make sure our launch vehicle and payload are both working in top 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	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, and the retention mechanism must not sustain damage requiring repair.	The payload will be housed in its own retention system that will stay within the launch vehicle for the duration of its flight	We will verify that the payload has stayed contained safely within the payload retention system once it has landed.
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	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
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	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 Demonstration Re-flight	N/A	N/A

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	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
2.21.3. Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.	N/A	N/A

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	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	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
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	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	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	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	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	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	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	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	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	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 necessary to ensure structural integrity of the airframe under the expected operating stresses.	The amount and type of metal will be limited in the design of the launch vehicle. There will be no excessive use of metal.	The only metal components currently incorporated in our launch vehicle design involves quick links, u-bolts, nuts, bolts, screws, and a metal tipped ogive nose cone.

Table 6.1.1.B. Vehicle Requirements

Recovery Systems Requirements		
NASA Requirements	**How we Plan to Meet Them**	**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	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	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

deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.		
3.1.1. The main parachute shall be deployed no lower than 500 feet.	The main parachute will be deployed at 700ft	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	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	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.	While calculating kinetic energy we found that the kinetic energy of the main body is a little high. As we look towards the CDR we will work on solving this issue.

3.4. The recovery system electrical circuits will be completely independent of any payload electrical circuits.	Launch vehicle electrical components will be kept separate from payload electrical components	Launch vehicle electrical components will be housed in its 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	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.	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	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	Shear pins will be placed on both the upper and lower airframes	The launch vehicle will be checked before launching to ensure shear pins are where they need to be.

drogue 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	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	Using open rock 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 tethered vehicle or any independent section to a ground receiver.	A GPS tracking device will be located on each independent piece of the launch vehicle	The GPS tracking device will be checked before launch to ensure it is transmitting data correctly
3.11.1. Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active	Any untethered piece of the launch vehicle will contain its own GPS tracking device	The nose cone and the rest of the launch vehicle body along with the payload will have

electronic tracking device.		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	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	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 from any other radio frequency transmitting device and/or magnetic wave producing device.	The eBay will be divided into two separate compartments. One will house the altimeters for recovery the other will house the gps tracking device	The altimeters will be checked to ensure there is no interference between it and the gps 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	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	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 devices which may adversely affect the proper operation of the recovery system electronics.	Recovery system electronics will be shielded from other onboard devices	Recovery system devices will be checked to ensure there is no interference due to other devices

Table 6.1.1.C. Recovery System Requirements

Payload Requirements		
NASA Requirements	**How we Plan to Meet Them**	**Verification**
4.2 College/University Division – Each team will choose one experiment option from the following list.	We will select only one experiment option.	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
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

4.3 Deployable Rover / Soil Sample Recovery Requirements	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
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
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
4.3.4 After deployment, the rover will autonomously move at least 10 ft. (in any direction) from the launch vehicle. Once the rover has reached its final destination, it will recover a soil sample.	N/A	N/A

4.3.5 The soil sample will be a minimum of 10 mL.	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
4.3.7. Teams will ensure the rover's batteries are sufficiently protected from impact with the ground.	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
4.4 Deployable Unmanned Aerial Vehicle (UAV) / Beacon Delivery Requirements	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.	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.	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.	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.	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	Our UAV retention system will unpack and prepare the UAV for launch autonomously. After unpacking, the UAV will be teleoperated to deliver the beacon.	After anRDO confirms the landing of our retention system, we will send the signal to autonomously

(FEA). Both autonomous and piloted flight are permissible but all reorientation or unpacking maneuvers must be autonomous.		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
4.4.7 One or more FEA's will be located in the recovery area of the launch field. FEA samples will be provided to teams upon acceptance and prior to PDR	N/A	N/A
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.	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.	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.	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.	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.	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.	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
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	N/A	N/A

Panel, even after a proposal has been awarded.		
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
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
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
4.5.5. Unmanned aerial vehicle (UAV) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAV.	N/A	N/A

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
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

Table 6.1.1.D. Payload Requirements

Safety Requirements		
NASA Requirements	**How we Plan to Meet Them**	**Verification**
5.1. Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	The team will write detailed checklists. They will cover all tasks that are required to launch the launch vehicle safely.	At launch events, the Safety Officer will check off tasks on a 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.	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, subscale launch tests, fullscale launch tests, launch day, recovery activities, and STEM engagement activities.	The safety officer will attend all the events. They will actively advise members on safety matters.	When planning events, the availability of the safety officer will be confirmed in advance.
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.	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.	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	The safety officer will organize the writing of these sections by delegating tasks to specific members and overseeing the sections completion.	The safety officer's sections will be validated by the captain.

analyses, failure modes analyses, and procedures.		
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 to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	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.	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.
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.	The team will only launch rockets at launch events organized by a rocketry club with a FAA waiver.

Table 6.1.1.E. System Requirements

Section 6.1.2. Team Requirements

Vehicle Requirements	
Requirement	**Verification**
1. All materials and components necessary for the launch vehicle success are accounted for before leaving for the launch	A launch vehicle checklist will be used to make sure we have everything
2. Ensure all shock cord lengths are cut to the correct size to avoid tethered pieces from bumping into each other during flight	Shock cord will be cut at a length three times that of the part it is being tied to
3. Ensure that all parachutes, nomex blankets, shock cord, are correctly packed and placed in their corresponding spots in the launch vehicle	Parachutes will be packed using a specific folding method and all parts will be placed according to their locations in the final design of the launch vehicle
4. Ensure Raven 3 altimeter are programed correctly for dual deployment at apogee and at 700 ft	Using a computer we will fun a simulation flight on the altimeter which will confirm its dual deployment values
5. Ensure all other devices in the EBay for collecting data are working and transmitting	A computer will be used to check that the other devices are transmitting data
6. Launch Vehicle is set up on launch pad	This will only be done by a member or mentor that is level two certified
7. Successfully read an apogee at 4704 ft and deploy drogue parachute	This data will be started on the altimeter for verification after the launch
8. Successfully reach an altitude of 700ft and deploy the main parachute, nose	This data will be started on the altimeter for verification after the launch

cone parachute and payload retention system	
9. All parts of the launch vehicle descend successfully such that there is negligible to no damage done to it	Damage will be assessed upon landing however the launch vehicle is designed to withstand all forces it may encounter during flight
10. All parts of the launch vehicle are successfully determined by the GPS recovery system	This data will be accessible from the team computer during the whole course of the launch vehicle's flight

Table 6.1.2.A. Team Vehicle Requirements

Recovery System Requirements	
Requirement	**Verification**
1. Shock cord lengths are correct	We verify with by using Open Rocket, calculations, and tape measures
2. Parachute sizes are correct	Each parachute will be labeled and color coded
3. Parachutes are wrapped correctly	Parachutes will be wrapped such that they are compact but easily unfold.
4. Confirm GPS device is installed on every tethered or separate pieces of the launch vehicle	GPS devices will be checked to confirm they are on their components, receiving power, and transmitting data before launch
5. Make sure both Paven 3 Altimeters are programmed correctly for apogee along with black powder charges	Using a laptop we can check that the altimeter is flight ready and that the drogue parachute will be released at apogee while the main parachute, nose cone parachute, nose cone, and payload retention system at 700ft

6. UAV is safely secured within the payload retention system	UAV will be inspected before launch to ensure it is installed safely and corrected within the launch vehicle and retention system
7. After the launch vehicle leaves the launch pad its drogue chute deploys successfully at apogee	This data will be received using the Raven 3 altimeter
8. At 700 ft the main parachute, nose cone, nose cone parachute, and payload retention system deploys	This data will be received using the Raven 3 altimeter
9. The launch vehicle lands with all tethered pieces still attached	Shock cord will be cut to the correct lengths and tested to ensure strength
10. All parts of the launch vehicle land successfully with negligible or no damage	Damage will be assessed at the launch pad, however the launch vehicle is designed to withstand the forces it will experience during flight and upon landing with negligible damage
11. All GPS tracking devices transmit accurate data to the computer	This data will be received on a team computer

Table 6.1.2.B. Team Recovery System Requirements

Payload Requirements	
Requirement	**Verification**
1. All materials and components necessary for the payload success are accounted for before leaving for the launch	We will have a checklist with all of our components to verify before departure
2. Ensure all components of the payload are in working order	We will run a systems check to verify everything is working

3. Before fitting the payload into the launch vehicle airframe ensure it is configured for flight	The payload will be checked by multiple members before being loaded in
4. The retention system will be placed into the launch vehicle airframe and remain sturdy and undamaged throughout the flight	The retention system will be designed with structural integrity in mind and secured properly in the launch vehicle
5. The retention system will actuate after landing and receiving permission to orient the UAV upright and power it on	We will thoroughly test the retention system to verify its effectiveness
6. The UAV will take off from the retention system and be remotely piloted to fly to a Future Excursion Area and release the beacon once above	We will have visual feedback from the UAV in order to verify it has taken off and pilot it to the FEA to deliver the beacon
7. The UAV will fly a reasonable distance away from the Future Excursion Area to safely land and power down	We will have visual feedback from the UAV to verify it has flown away from the FEA and landed safely before powering down

Table 6.1.2.C. Team Payload Requirements

Section 6.2. Budgeting and Timeline

Section 6.2.1 Budget

Full Scale and Subscale Launch Vehicle Components

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”x48”	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	Aluminum Motor Casing	1	$107.00	$107.00	Apogee Components	-
Flight Computer	Raven 3 Altimeter	0	$155.00	$0.00	Feather weight Altimeters	Already Owned
Full Scale Battery	Turnigy Graphene 65C Lipo	1	$15.69	$15.69	Hobby King	-
Arming Switch	Full Scale Rocket Arming Switch	1	$9.93	$9.93	Apogee Components	-
Wiring	Wiring	0	$5.00	$0.00	WPI	Already Owned
Main Engine	L730	2	$166.00	$332.00	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	1	$58.50	$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	1	$6.58	$0.00	Home Depot	Already Owned
Gorilla Tape	Gorilla 1-7/8x35yds	1	$8.98	$0.00	Home Depot	Already Owned
Main Tube	2.15”x0.062”x48”	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”x24”	1	$6.25	$6.25	Always Ready Rocketry	Motor Tube
Inner Tube	2.15”x0.062”x8”	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	$5.00	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

Table 6.2.1.A. Launch Vehicle Components

Payload Components

Component	Specific Item	Quantity	Price	Total	Vendor	Comments
Processor	Arduino Nano	3	$22.00	$66.00	Arduino	Capsule Processor
Processor	Pix Hawk Mini	1	$134.95	$134.95	Amazon	UAV Processor

LiPo Battery	3.7v 2000mAh	4	$12.50	$62.00	Adafruit	-
ESCs	Lumenier 30A BLHeli_S OPTO	4	$13.00	$54.00	GetFPV	-
Brushless Motor	RotorX RX1404B	4	$15.00	$60.00	GetFPV	-
High Gauge Wire	22AWG colored wire	1	$15.99	$15.99	Amazon	-
Servos	1.8 gram linear servo	2	$12.00	$24.00	Spektrum	-
More Servos	SG90 9g micro servo	1	$18.00	$18.00	Amazon	Pack of 10
Transceiver	NRF24L01	4	$5.00	$20.00	Amazon	-
FPV Camera	FX798T micro FPV camera	1	$30.00	$30.00	GetFPV	-
FPV Monitor	4.3" LM403 LCD FPV Monitor	1	$70.00	$70.00	GetFPV	-
Controller & Receiver	Flysky FS-i6X	1	$54.00	$54.00	Amazon	-
3D Printer Filament	Nylon X	1	$70.00	$70.00	-	-

3D Printer Filament	PLA	2	$30.00	$60.00	-	-
Carbon Fiber	1ftx1ft sheet	1	$27.03	$27.03	Hobby King	-
Propellers	Carbon fiber 5in	4	$4.75	$19.00	Hobby King	1 order is two props, one CW, one CCW
Overhead	Cover for additional components	1	$50.00	$50.00	-	-

Table 6.2.1.B. Payload Components

Logistical Pricing

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	$100.00	MMMSC	-
Hotel Rooms	(4 nights) 2 Double Beds	4	$62.00	$992.00	La Quinta Inn	4870 University Dr NW, Huntsville, AL, 35816 (6.8 miles from the space center)

Flights	Flight Tickets	12	$326	N/A	-	Flights will be paid for by students or sponsors

Table 6.2.1.C. Logistical Pricing

Grand Total	$3,609.92
Total with shipping/tax	$4,031.904

Table 6.2.1.D. Budget Total

Section 6.2.2. Funding

Our USLI team is run under WPI's branch of the AIAA chapter. The majority of the funding for our launch vehicle will come from SGA. They are the main source of funding for undergraduate student organizations at WPI. Last year, a request for funding for the 2018-2019 school year was submitted through the AIAA. Half of the money that was allotted to AIAA for high powered rocketry competitions will go towards our USLI team. If additional funds are required, a request for another round of funding can be submitted to the SGA.

Additional funding requests to cover transportation costs will be made to WPI's Foundation & Corporate Philanthropy Department. The Foundation & Corporate Philanthropy Department coordinates with WPI's Office of Sponsored Programs, Academic & Corporate Engagement departments and more. Teaming with the Philanthropy department will help pair our financial needs with sponsorships whose goals align with that of the WPI USLI team.

Corporate sponsorships are being pursued through outreach to STEM companies. A sponsorship package has been created and the team is in the initial stages of reaching out. All initial communication and information is vetted by the University Advancement department before the conversation is started. The goal of this additional funding is to raise capital for plane tickets to the competition. In addition, it will cover the costs of any unexpected developments in the launch vehicle that are not covered by the SGA, additional outreach costs and other unforeseen USLI needs.

Section 6.2.3. Timeline

Task	Start	Duration	Aug. 22	Sep. 5	Sep. 19	Oct. 3	Oct. 17	Oct. 31	Nov. 14	Nov. 28	Dec. 12	Dec. 26	Jan. 9	Jan. 23	Feb. 6	Feb. 20	Mar. 6	Mar. 20	Apr. 3	Apr. 17
Request for Proposal	Aug. 23	N/A																		
Team Interest Meeting	Aug. 28	1 Meeting																		
Discussion of the Proposal	Aug. 31	1 Meeting																		
Design Launch Vehicle and Payload	Sep. 5	1 Meeting																		
Write up Proposal	Sep. 7	1 Meeting																		
Revise Proposal	Sep. 11	2 Meetings																		
Design Subscale Launch Vehicle	Sep. 13	1 Meeting																		
Submit Proposal	Sep. 19	N/A																		
Proposal Submission Celebration	Sep. 20	1 Meeting																		
Supply Order	Sep. 21	1 Meeting																		
Begin Working on PDR	Sep. 24	2 Meetings																		
Payload Prototyping Begins	Sep. 25	4 Meetings																		
Create Subscale Rocket	Sep. 26	4 Meetings																		
Finish PDR Rough Draft	Oct 1	2 Meetings																		
Awarded Proposals Announced	Oct. 4	N/A																		
Work on Copprate Sponsorship Package	Oct. 3	3 Meeting																		
Payload Design Testing	Oct. 9	5 Meetings																		
Fall Break	Oct. 12 to Oct. 22	N/A																		
Do Ground Ejection Test for Subscale Rocket	Oct. 19	1 Meeting																		
Launch Subscale Rocket	Oct.20	1 Meeting																		
Revise Rough Draft	Oct. 24	2 Meetings																		
Plan out the flight tickets and hotel rooms	Nov. 1	5 Meetings																		
PDR (report, presentation, and flysheet) Due	Nov. 2	N/A																		
Submit Corporate Sponsorship Package	Nov. 9	1 Meeting																		
Finialize List of Potential Sponsors	Nov. 16	1 Meeting																		
PDR video teleconferences	Nov. 19	1 Meeting																		
Post PDR Review	Nov. 20	1 Meeting																		
Continue Payload Design	Nov. 22	2 Meetings																		
Finalize Launch Vechicle Full Scale Design	Nov. 23	1 Meeting																		
Finalize Payload Design	Nov. 26	1 Meeting																		
Send out Sponsership Letter	Nov. 26	1 Meeting																		
Prepair for First Engament Event	Nov. 26	2 Meetings																		
CDR Q&A	Nov. 27	N/A																		
CDR Rough Draft	Nov. 29	3 Meeting																		
Begin Launch Vechicle Full Scale Build	Nov. 30	3 Meetings																		
Begin Payload Construction	Nov. 30	3 Meetings																		
First Engament Event	December 1	1 Meeting																		
Finalize CDR	Dec.7	2 Meetings																		
Winter Break	Dec. 15 to Jan. 8	N/A																		
Final Colection of Sponsership Money	Jan.1	N/A																		
CDR (report, presentation, and flysheet) Posted on Websi	Jan. 4	N/A																		
Prepair for Second Engament Event	Jan. 6	2 Meetings																		
Second Engament Event	January 12	1 Meeting																		
CDR video teleconference	Jan. 7 to Jan.22	1 Meeting																		
Post CDR review	Jan. 23	1 Meeting																		
Finish Launch Vechicle Full Scale	Jan. 24	2 Meetings																		
Finish Payload	Jan. 24	2 Meetings																		
FRR Q&A	Jan. 25	N/A																		
FRR Rough Draft	Jan. 25	2 Meetings																		
Prepair For Third Engament Event	Jan. 28	2 Meetings																		
Third Engament Event	Feb. 9	1 Meeting																		
Prepair For Fourth Engament Event	Feb. 11	2 Meetings																		
Full Scale ground ejection test	Feb. 15	1 Meeting																		
Fourth Engament Event	Feb. 16	1 Meeting																		
Launch Vechicle Full Scale Launch	Feb. 16	1 Meeting																		
Spring Break	Mar.2 to Mar. 10	N/A																		
Vehicle Demonstration Flight Deadline	Mar. 4	N/A																		
FRR (report, presentation, and flysheet)	Mar. 4	N/A																		
Purchease Tickets and Hotel Rooms	March 6	1 Meeting																		
FRR video teleconference	Mar. 8 to Mar. 21	1 Meeting																		
Prepare for Competition	Mar. 23	3 Meetings																		
Ship Parts to Huntsville Alabama	March 25	1 Meeting																		
Travels to Huntsville, AL	Apr. 3	N/A																		
Launch Readiness Reviews (LRR)	Apr. 3	N/A																		
Launch Day	Apr. 6	N/A																		
Award Ceremony	Apr. 6	N/A																		
Backup Launch Day	Apr. 7	N/A																		
Send Follow up to Sponsors	Apr. 15	N/A																		
Post-Launch Assessment Review (PLAR)	Apr. 26	N/A																		
End of the Year Celebration	Apr. 30	1 Meeting																		

Due dates
Meetings
On Break

Table 6.2.3.A. Gantt Chart