Bearospace at UCLA
(LoL)
Leveling on Land
2020 - 2021 NASA Student Launch
Preliminary Design Review (PDR)

University of California, Los Angeles
420 Westwood Plaza
Los Angeles, CA, 90095
2685 Boelter Hall
November 2, 2020

Table of Contents

List of Figures

List of Tables

0. General

0.1 Adult Educators

Cathy Douglas
Interim Dean, Center of Excellence in Engineering and Diversity
cathyd@seas.ucla.edu
(310) 206 - 6493

0.2 Student Leader

Sophia Martinez
Project Manager
ucla.bearospace@gmail.com
(949) 514-1373

0.3 Safety Officer

Karla Bonilla
Safety Officer
bonillakarla0@gmail.com
(310) 962-9803

0.6 NAR/TRA Partner

Rick Maschek
Director, Sugar Shot to Space
ROC (Rocketry Organization of California)
MDARS (Mojave Desert Advanced Rocketry Society)
TRA # 11388
Level 2

1. Summary of PDR Report

Team Name:	Bearospace at UCLA
Mentor:	Rick Maschek TRA #11388 Level 2
Rocket Dimensions:	68 inches long, 6-inch diameter, 18.7 lbs. with motor
Preliminary Motor Choice:	Aerotech K1103X-14
Target Altitude:	3600 feet
Recovery System:	The recovery system will be a dual deployment system consisting of a drogue chute deploying at apogee between the upper body tube and the nosecone and a main chute deploying at 700 feet above ground level (AGL) between the upper body tube and the lower body tube. Black body charges will be used to deploy the chutes.
Payload Title:	Levelling on Land (LoL)
Payload Summary:	Payload consists of a 3 DOF, two platform lander actuated using 3 servo motors that levels a top platform. The lander receives feedback from a gyroscope/accelerometer module to aid in levelling the lander. A single camera takes pictures of the landing site using a motor to periodically rotate the camera. Data and pictures are transmitted to the team for automatic post-processing and image stitching to create a single 360-degree image. The payload is deployed at 500ft AGL using a hinge mechanism with bulkheads. The payload's velocity is reduced using a parachute.

2. Changes Made Since Proposal

2.1. Changes to Launch Vehicle

The most significant changes are the following:

1. The locations of the drogue and main chutes have changed. The drogue chute will still deploy at apogee but will be located between the nosecone and the upper body tube. Before the drogue chute was located between the body tubes
2. The main chute will be located between the upper body tube and the lower body tube instead of its original location between the nosecone and the upper body tube. Also, the main chute will release at 700 feet AGL to decrease the landing kinetic energy of each component

No other major design changes have been made. These changes have been made to accommodate the deployment of the payload at 500 feet AGL.

2.2. Changes to Payload

The payload has changed its stabilization method and deployment mechanism since the proposal.

The payload itself consists of two platforms, one of which makes contact with the landing site and the other is levelled within 5 degrees of vertical. Three servo motors on the bottom base will level out the top platform. A single camera will be rotated on top of the lander to take periodic pictures of the landing site.

The deployment method has changed to use hinges to drop the payload out of the launch vehicle. This design aids the payload from enduring the ejection charges during the launch vehicle’s recovery system events through the use of additional bulkheads.

2.3. Changes to Project Plan

There have been no major changes to the project plan.

3. Vehicle Criteria

3.1 Mission Statement

Bearospace at UCLA will design, construct, test and launch a vehicle capable of reaching an apogee between 3,500 and 5,500 feet, deploying parachutes at major events, and lands safely. The vehicle will deliver a payload specific to that year's competition. Lastly, minimizing cost will be at the forefront during the manufacturing phase while not jeopardizing the structural integrity of the launch vehicle nor violating any vehicle requirements.

3.2 Mission Success Criteria

A successful mission for the launch vehicle will be determined as completion of the following tasks:

1. Reaching within 100 feet of the targeted apogee
2. Deploying the drogue parachute at apogee and the main parachute at 500 feet AGL while landing safely without any visible damage so the vehicle can be flown again
3. Safely harboring the payload throughout the flight without damaging the structure and electronics of the payload so it can successfully carry out the mission
4. Collecting and storing data of the launch vehicle during flight through the avionics components such as temperature, speed, and altitude of the launch vehicle

3.3 Launch Vehicle

Figure 1: Full Rocket Vehicle Layout

Bearospace will present three different designs for our launch vehicle, highlighting the pros and cons of each alternative by going through the variations in each design. Each design will share the same general layout and will mainly vary in dimensioning of the vehicle and its components. Instead of going through each alternative design at a system level, the team will highlight the differences of the systems of each alternative design, since all the designs only vary in dimensioning, ballast amount, and motor choice. The rocket will have three parent components: the nosecone, the upper body tube, and the lower body tube.

Nosecone

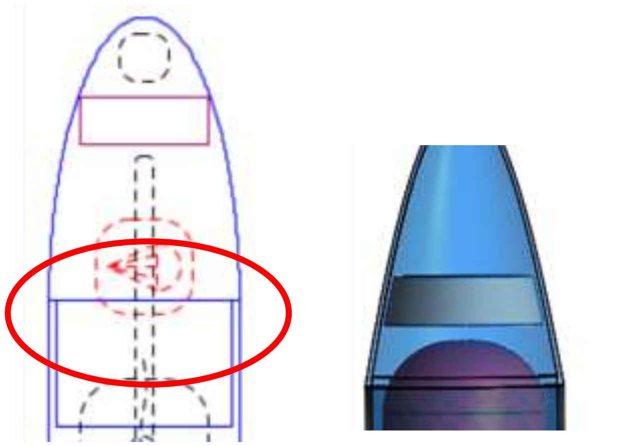


Figure 2: Nosecone Layout

The nosecone will have five different components:

1. The nosecone parent component
2. The bulkhead (made of pinewood), which is used as part of the recovery system to attach the nosecone parent component to the drogue parachute assembly
3. The eyebolt, which attaches the drogue parachute assembly to the bulkhead and the nosecone parent component
4. The quicklime, which attaches the drogue parachute assembly to the eyebolt
5. The nut, which fastens the eyebolt to the bulkhead

All designs will utilize these components. All designs will also utilize the ellipsoid shape due to its very low drag compared to all other shapes. The team also chose the ellipsoid shape since the payloads team has different designs of the payload that vary in size, so an ellipsoid nosecone shape provides an ample amount of space to fit the drogue parachute in case the payload size is very large. The payload will be near the separation point of the drogue chute between the upper body tube and the nosecone. The red circle on the figure above indicates where the separation point occurs as well as the planned placement of a black powder charge. The black powder charge will be used to break shear pins to separate the nosecone and the upper body tube. This will be further discussed in the recovery section. Another black powder charge might be used to push the payload out of the upper body tube which would also be in the red circle in the figure above. This will be explained in the payload section.

Upper Body Tube

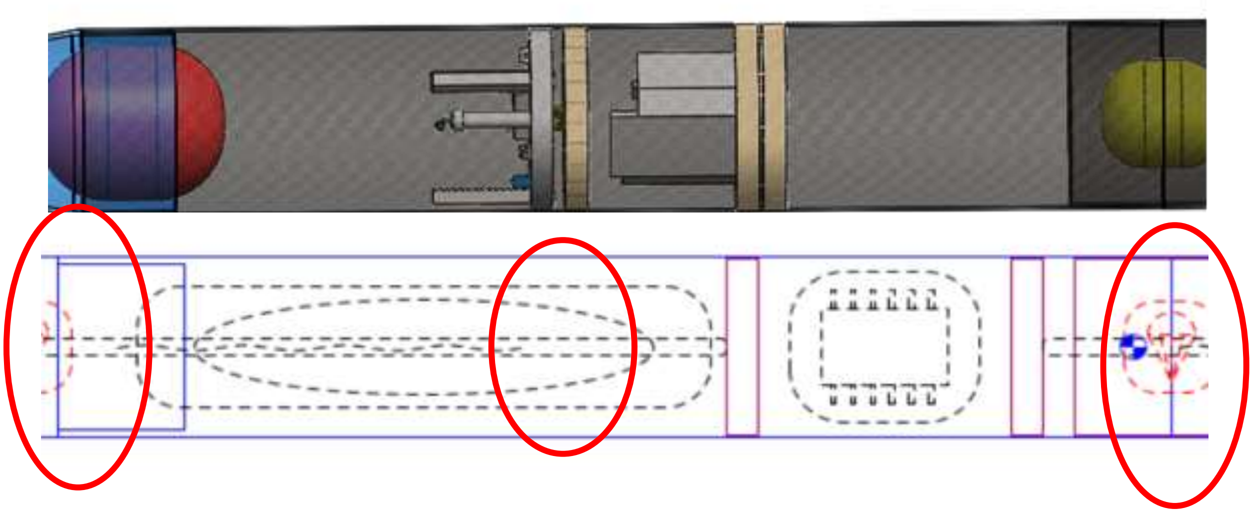


Figure 3: Upper Body Tube Layout

The upper body tube vehicle section will have eight different components:

1. The upper body tube parent component
2. The payload (not shown in the SolidWorks figure above) which will be ejected around 500 feet to complete the competition objective of taking a 360-degree panoramic photo
3. The electronics bay, which records data on the rocket vehicle's flight and triggering the parachute deployments as well as the payload deployment
4. The locking mechanism, which is both the anchor point for the main chute assembly and the access point for the electronics bay.
5. The bulkhead, which is used as an anchor point for the drogue parachute assembly to the upper body tube parent component
6. The eyebolt, which there are two: one for attaching the drogue parachute assembly to the bulkhead, and another for attaching the main chute assembly to the locking mechanism
7. The quicklink, which there are two: one for securing the drogue parachute assembly to the eyebolt attached to the bulkhead, and another for securing the main chute assembly to the eyebolt attached to the locking mechanism
8. The nut, which fastens the eyebolt of the drogue parachute assembly to the bulkhead

The team did not include the payload within the rocket because there are multiple different designs the payload team is considering. All the designs will utilize these components but may vary in location in the launch vehicle such as the payload or electronics bay. The dimensions and material of these various components will be the same for all designs. The red circles in the figure above are potential placements for black powder charges which are needed for the main and drogue chute deployments as well as the payload deployment. The black powder charge for the payload deployment might be different for the team's designs depending on the location of the payload but in general, the black powder charge will be located in the middle red circle.

Lower Body Tube

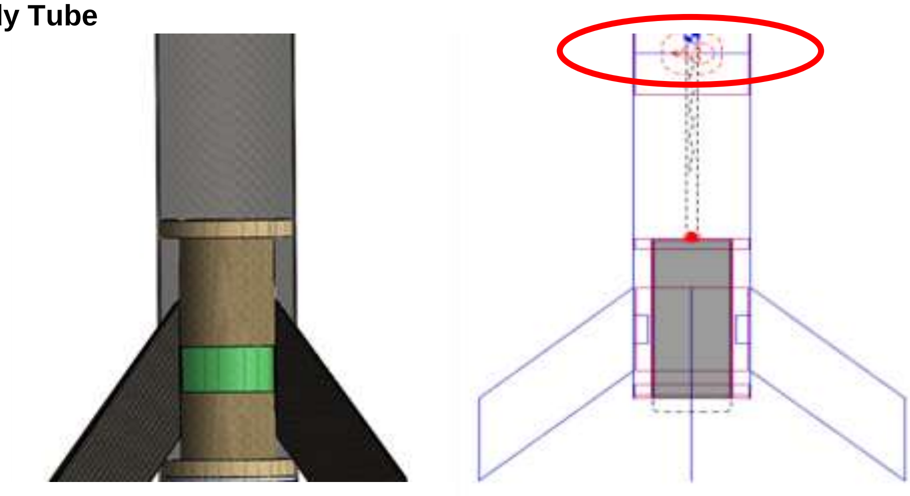


Figure 4: Lower Body Tube Layout

The lower body tube vehicle section will have ten different components:

1. The lower body tube parent component
2. The centering ring, which there are two: the forward is used as an anchor point for the main parachute assembly to the locking mechanism in the upper body tube and as a stabilizing anchor point for securing the phenolic tube and thus the motor to the lower body tube parent component, and the rear which acts solely as another anchor point at the rear of the phenolic tube
3. The eyebolt, which attaches the main parachute assembly to the bulkhead and by extension the lower body tube parent component
4. The quick link, which secures the main parachute assembly to the eyebolt
5. The nut, which fastens the eyebolt to the bulkhead
6. The phenolic tube, which serves as a housing for the motor
7. The motor retainer, which serves as keeping the motor within the rocket during descent
8. The trapezoidal fins, which serve to provide stability to the rocket during flight
9. The fin securement mechanism (FSM), which serves as an anchor point, brace, and alignment device for the trapezoidal fins so that they remain attached and straight during flight and landing
10. The aluminum centering ring, which serves as reinforcement for the centering ring on the bottom since it will experience most of the motor's force

The designs for each rocket will vary the most in this section. The dimensions of each fin set will vary throughout all designs and will be discussed further in each alternate design section. The locations of the centering rings and phenolic tube will vary depending on the length of the motor. Due to the different choices of motors, the fin shape, ballast amount, shock cord length, etc. will all vary and result in different designs. The red circle in the above figure is another placement of a black powder charge so that the main chute can deploy at 700 feet AGL.

3.3.1 Alternative Designs

When creating vehicle designs, on top of general rocket components that must be included, a series of competition and team requirements had to be met. A listing of all of them can be seen below.

Table 1: Competition and Team Requirements

Restriction	Purpose
Vehicle will deliver the payload to an apogee altitude between 3,500 and 5,500 feet AGL	Competition Requirement
Launch vehicle will have a maximum of four independent sections	Competition Requirement
Motor cannot exceed 5,120 Newton-seconds (L-class)	Competition Requirement
Launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit	Competition Requirement
The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit	Competition Requirement
Payload will receive 1.5 feet and 3 lbs. in the upper body tube above the electronics bay, facing the nose cone.	Team Requirement
Upper and lower body tubes will both have an outer diameter of 6”	Team Requirement

When designing the launch vehicle, the biggest obstacles were finding a balance between the required apogee and stability as well as the restrictions on total body length and space allotted for the payload. To design the launch vehicle, the team approximated the payload mass to be 3 lbs. with a length of 1 foot. As a result, the team had to design the rocket around the payload by allotting a space of 1.5 feet in the upper body tube. In case the payload needs more than 1.5 feet, the designs of our rocket covers this potential issue. Estimating the payload mass to be 3 lbs. allows the team to design more towards achieving a higher stability since the payload will most likely have mass less than the estimate. The team will design the rocket to have an apogee above 3,500 feet so if the payload is less than 3 lbs., the apogee will only increase for all designs. This leaves the designs to solely focus on maximizing the stability. The designs will focus on increasing the stability to compensate for the stability loss with a payload mass lower than the estimate.

In terms of motors, since most L class motors are over 20 inches in length, the strategy taken by the team was to research shorter L-class motors or to choose a K or J class motor that would then customize the vehicle to fit it and the payload. Fins and thickness of bulkheads/centering rings would then be altered to meet the stability requirements and simulations would ensure appropriate apogee and rail exit velocity, resulting in multiple alternative designs of a rocket vehicle that differed in only fin design, bulkhead/centering ring thickness, and motor selection.

The stability of the vehicle is dependent on the distribution of mass and area along it. Before construction, distributions are calculated using OpenRocket. This program takes material densities and projected sizes to produce a mass distribution and uses surface area to create an area distribution. The center of gravity and pressure are then calculated using the respective distributions.

Once the centers of mass and pressure are calculated, stability can be calculated using the formula below where x_{cp} the center of pressure, x_{cg} is the center of gravity, and d is the diameter of the launch vehicle, and S is the stability at rest.

$$S = (x_{cp} - x_{cg})/D$$

For all alternative designs, carbon fiber tubing is being used for body and coupler elements due to its lightweight, durable, and heat resistant aspects. This will be purchased from a commercial supplier. Purchasing a body tube also minimizes health risks to the team and increases precision on simulations and real launch.

3.3.1.2 Alternative Design 1

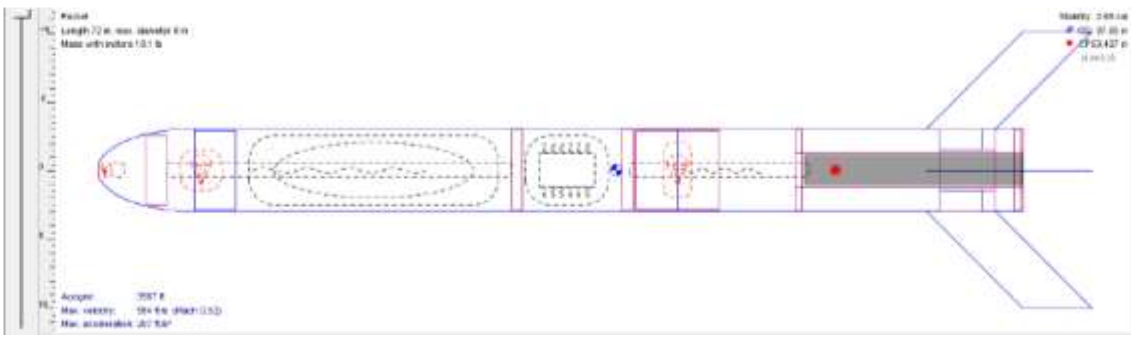


Figure 5*:* Alternative *Design 1*

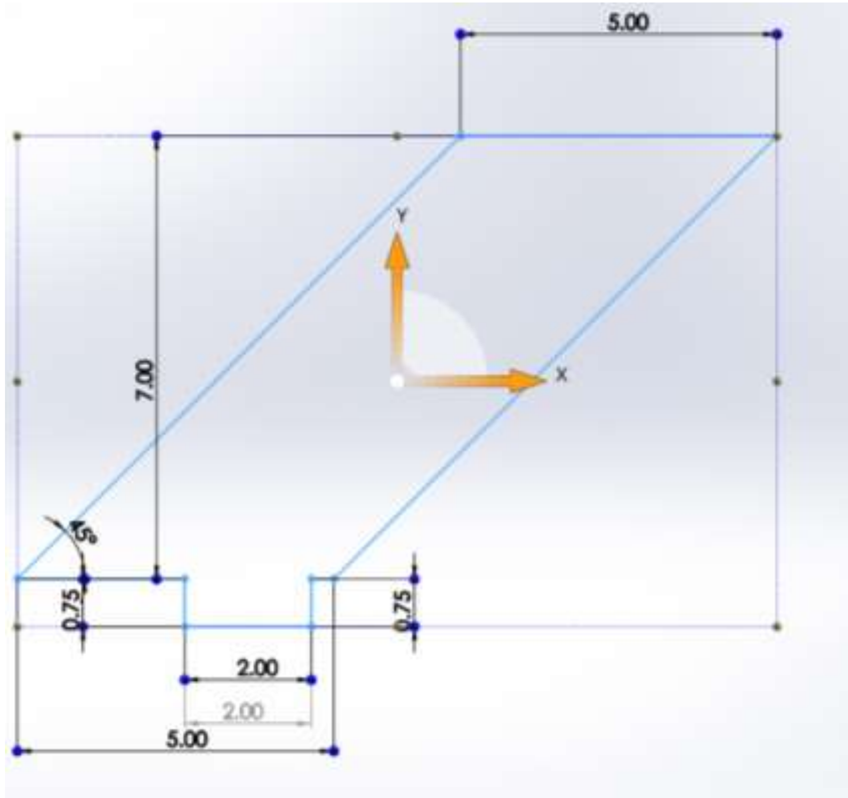


Figure 6*: Alternate Design 1 Fin Layout*

Alternate Design 1 uses the Aerotech K715G motor which can supply a great amount of impulse to achieve the desired apogee window of 3,500-5,500ft. This larger sized motor still allows for flexibility in the precise positioning of the payload or the main chute, as more space remains should the payload or main chute exceed predicted size expectations. The downside of this design is the lower limit of apogee window is barely reached, as the apogee stands at 3,567ft. This is the main reason for the selection of another motor with a greater impulse and design. The sizing of the fins is another slight factor of not selecting this design as the final design; they are relatively large compared to Alternate Design 2 which would thus increase the cost of production and not be feasible to manufacture. The bulkheads in the upper body tube, which are a part of the recovery system, are of increased thickness compared to alternate design 2 capable of withstanding a higher impulse from the deployment of the parachutes. This is one reason to consider this design over Alternate Design 2.

Table 2: Alternate Design 1

Overall Vehicle Characteristics		**Nose Cone Characteristics**	
Total Vehicle Length (in)	72	Total Length (in)	7.0
Total Weight on Rail (oz)	289.6	Component Weight (oz)	9.104
Static Stability	2.55	Wall Thickness (in)	0.07
Average Thrust-to-Weight Ratio	8.979	Shoulder Length (in)	3.0
Motor	K715G-P	Material	ABS Plastic
Upper Body Tube Characteristics		**Lower Body Tube Characteristics**	
Total Component Length (in)	35	Total Component Length (in)	25
Component Weight (oz)	47.04	Component Weight (oz)	33.6
Wall Thickness (in)	0.07	Wall Thickness (in)	0.07
Material	Carbon Fiber	Material	Carbon Fiber

3.3.1.3 Alternative Design 2

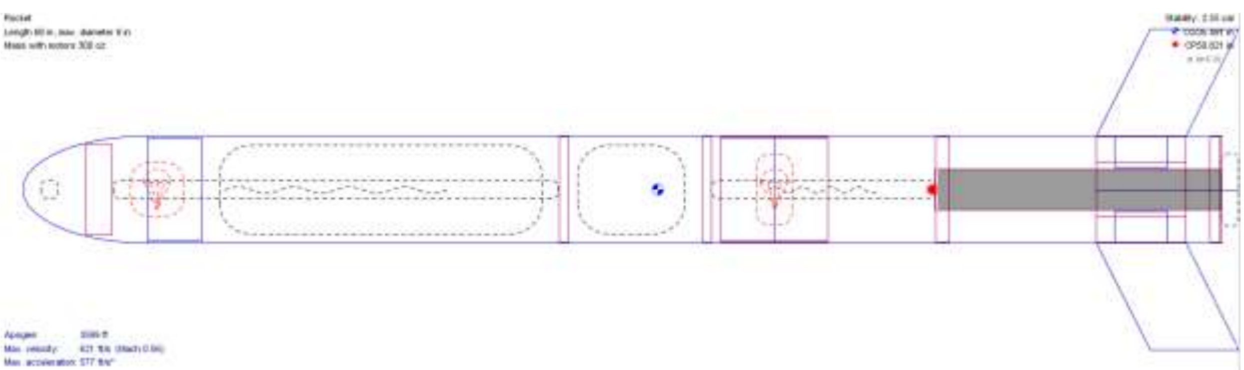


Figure 7: Alternate Design 2

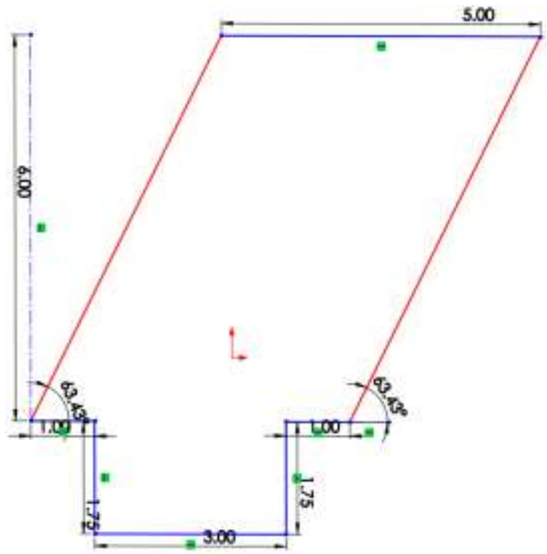


Figure 8: Alternate Design 2 Fin Layout

Alternate design 2 uses the most realistic fin size; the larger fins in the other designs make it difficult to manufacture leading to this design. The Aerotech K1103X-14 motor provides marginally more thrust than needed to reach an apogee between 3,500-5,500 ft at 3,599 ft. The benefit of this design is its high stability at 2.55 calibers which makes it flexible for any adjustments to the payload weight and other external factors. Another downside to this design is that the two bulkheads in the upper body tube are thin, thus they are vulnerable to a high impulse when the separation occurs to release the parachutes. One way to avoid this would be by taping the shock chords together to reduce the shock the bulkheads are struck with; thus, this would expand the time which the impulse is felt and not shatter the bulkheads. While the rocket may struggle to reach the projected apogee, this design prioritizes the stability and manufacturability of the rocket.

Table 3: Alternate Design 2

Overall Vehicle Characteristics		**Nose Cone Characteristics**	
Total Vehicle Length (in)	68	Total Length (in)	7
Total Weight on Rail (oz)	300	Component Weight (oz)	9.07
Static Stability	2.55	Wall Thickness (in)	0.07
Average Thrust-to-Weight Ratio	13.17	Shoulder Length (in)	3
Motor	K1103X-14	Material	PVC
Upper Body Tube Characteristics		**Lower Body Tube Characteristics**	
Total Component Length (in)	35	Total Component Length (in)	25
Component Weight (oz)	129	Component Weight (oz)	70.5
Wall Thickness (in)	0.07	Wall Thickness (in)	0.07
Material	Carbon Fiber	Material	Carbon Fiber

3.3.1.4 Alternative Design 3

This design utilizes the Aerotech K1999N motor which is smaller than the other designs. Due to the small size of the motor, this allows for a lot more flexibility with spacing than the other designs. This design is the most flexible out of all the designs since there is a lot of empty space in the lower body tube that can be used to the team’s advantage. With all that space, the team could increase the sizing of the upper body tube to create more space for the payload if need be. The thickness of the bulkheads can also be further increased, even though they are already thicker than the other two designs with a 1-inch thickness, to withstand a greater impulse from the deployment of the parachutes. Another advantage of this design is the apogee is between the requirement of 3,500 – 5,500 ft at 4,463 ft. This apogee provides the team’s best chance at fulfilling the altitude requirement even with any drastic unforeseen changes that occur during flight. One last advantage of this design is the increased size of the nosecone which allows for more space for the payload and the drogue chute. These are the reasons why this design should be chosen. The downfall of this design are the fins. The fins for this design are too large to reasonably manufacture and will be costly which is the focus of our designs. The fin tabs are also very small compared to the other designs which makes the team question the structural integrity of the fins especially during flight. As a result, this design will not be utilized.

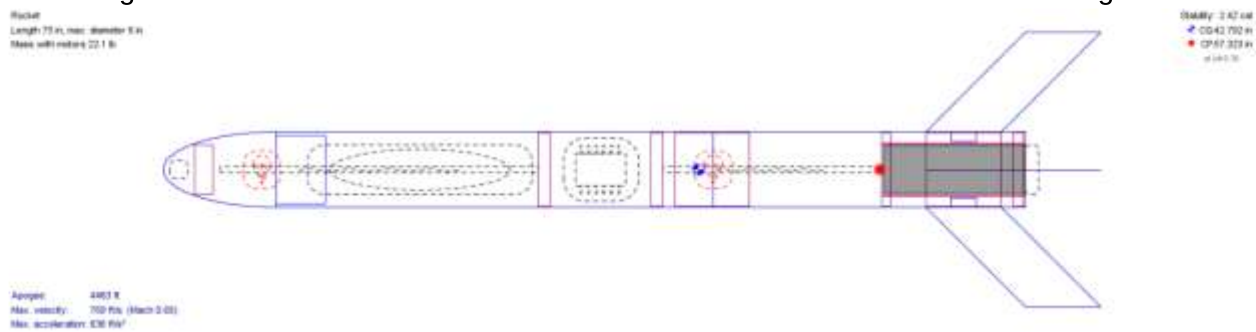


Figure 9: Alternate Design 3

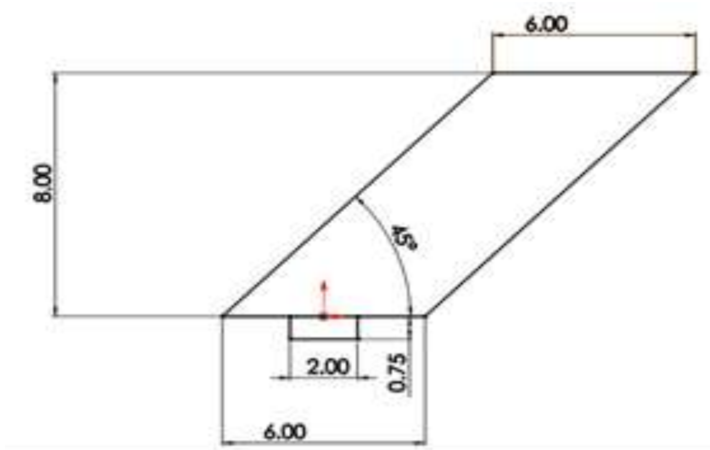


Figure 10: Alternate Design 3 Fin Layout

Table 4: Alternate Design 3

Overall Vehicle Characteristics		**Nose Cone Characteristics**	
Total Vehicle Length (in)	75	Total Length (in)	9.0
Total Weight on Rail (oz)	353.6	Component Weight (oz)	5.568
Static Stability	2.42	Wall Thickness (in)	0.07
Average Thrust-to-Weight Ratio	18.64	Shoulder Length (in)	4.0
Motor	K1999N-P	Material	ABS Plastic
Upper Body Tube Characteristics		**Lower Body Tube Characteristics**	
Total Component Length (in)	35	Total Component Length (in)	25
Component Weight (oz)	47.04	Component Weight (oz)	33.6
Wall Thickness (in)	0.07	Wall Thickness (in)	0.07
Material	Carbon Fiber	Material	Carbon Fiber

3.3.2 Leading Design Choices

The leading design will be Alternate Design 2, primarily due to its reasonable fin size. The reasonable fin size makes manufacturing them feasible and lowers costs which is the focus of our rocket vehicle. The fins are small enough to ensure structural integrity during flight and are only reinforced with the large fin tabs. The fin tabs length can be seen in Figure 8. The benefit of this design is its high stability at 2.55 calibers which makes it flexible for any adjustments to the payload weight and other external factors. While the rocket may struggle to reach the projected apogee, this design prioritizes the stability, manufacturability, and cost of the rocket.

Each subsystem and the components within those subsystems are already covered in the beginning of section 3.3. The only notable differences in this design are the fins, which have been discussed in the alternative design section, and the smaller bulkheads in the upper body tube which have a thickness of 0.5 inches.

See the table below for the estimated masses for each subsystem below of the leading design:

Table 5: Alternate Design 2 Subsystem Masses

Item	**Material**	**Mass (lbs.)**
Rocket Vehicle Subsystem		
Nose Cone	ABS Plastic	0.567

Table 5: Alternate Design 2 Subsystem Masses

Upper Body Tube	Carbon Fiber	2.94
Coupler	Carbon Fiber	0.511
Lower Body Tube	Carbon Fiber	2.1
Fore Centering Ring	Pine Wood	0.33
Fin Securement Mechanism	ABS Plastic	0.25
Trapezoidal Fins	Carbon Fiber	0.942
Aft Centering Ring	Pine Wood	0.22
Capping Centering Ring	6061 Aluminum	0.291
Motor Retainer	Aluminum	0.05
Aerotech K1103X-14	N/A	3.22
Recovery/Avionics Subsystem		
Nose Cone Bulkhead	Pine Wood	0.685
E-Bay Fore Bulkhead	Pine Wood	0.258
E-Bay Locking Mechanism	Pine Wood	0.258
Main Parachute	Ripstop Nylon	0.7
U-bolts	Stainless Steel	0.071
Quicklinks	Stainless Steel	0.069
Shock Cords	Kevlar	0.26
Drogue Chute	Ripstop Nylon	0.318

3.3.3 Motor Alternatives

Motor Alternatives
As mentioned in Section 4.1, there are three candidates for the motor selection that are being considered, given below.

Alternative Design 1 Motor: Aerotech K715G- *not selected*

Alternate Design 1:

This motor requires a greater amount of impulse to push the lower limit of the apogee window far more than what it is now. This is a lightweight motor that permits a higher stability; however, it is slightly heavier than alternate design 2. This motor, however, has a small enough diameter allowing a greater security of the fins through increased size of the fin tabs. Nonetheless, this motor is that is longer than that of alternate design 3, decreasing the amount of space for the main parachute assembly.

Table 6 Alternate Design 1 Motor – K715G Motor Data

AEROTECH 2.13in DMS MOTOR - K715G Specifications

Motor Diameter	2.13in	**Motor Length**	15.8in
Average Thrust	723N	**Max Thrust**	828 N
Burn Time	2.39s	**Total Motor Mass**	3.4lb
Total Impulse	1730Ns	**Propellant Mass**	1.92lb
Thrust to Weight	8.979	**Post-burn Mass**	1.48lb

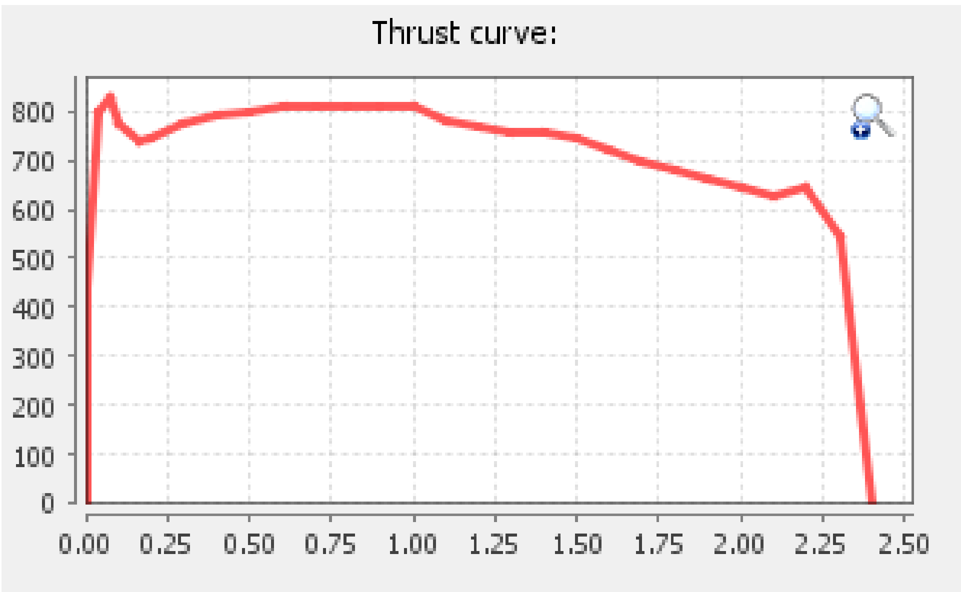


Figure 11: Alternate Design 1 Motor Thrust Curve – K715G

Alternative Design 2 Motor: Aerotech K1103X-14 - *not selected*

Alternative Design 2:

This motor belongs to Alternate design 2. This motor has its drawbacks primarily in that it just barely provides enough impulse to reach the desire apogee of 3500ft. Also, the motor is lighter than that of alternate design 3 which allows for the stability to be higher. Another advantage of this motor is that it has a small diameter which allows for greater security of the fins through increased size of the fin tabs. One disadvantage of this motor is that it is longer than that of alternate design, decreasing the amount of space for the main parachute assembly.

Table 7: Alternate Design 2 Motor – K1103X-14 Motor Data

AEROTECH 2.13in DMS MOTOR - K1103X-14 Specifications

Motor Diameter	2.13in	**Motor Length**	15.8in
Average Thrust	1099 N	**Max Thrust**	1620 N
Burn Time	1.65s	**Total Motor Mass**	3.2 lbs.
Total Impulse	1810Ns	**Propellant Mass**	1.8 lbs.
Thrust to Weight	13.17	**Post-burn Mass**	1.4 lbs.

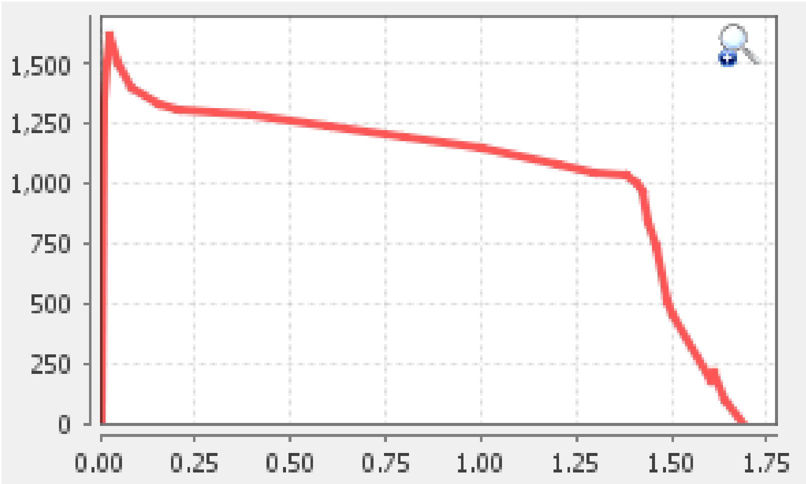


Figure 12: Alternate Design 2 Motor Thrust Curve – K1103X-14

Alternative Design 3 Motor: Aerotech K1999N-P - *not selected*

Alternative Design 3:

This motor belongs to Alternate design 3. This motor has its drawbacks primarily that it is the heaviest out of all the motors with a mass of 6.59 lbs. The motor provides enough impulse to get the rocket to an apogee of 4,464 ft. This motor is also very small with a length of 11.4 inches which provides plenty of extra space. This motor is the smallest in length when compared to the other designs but is the heaviest one which decreases the stability. One drawback of this motor is the diameter since it does not allow for long and thick fin tabs.

Table 8: Alternate Design 3 Motor – K1999N-P Motor Data

AEROTECH 3.86in DMS MOTOR - K1999N-P **Specifications**			
Motor Diameter	3.86 in	**Motor Length**	11.4 in
Average Thrust	1832 N	**Max Thrust**	2002 N
Burn Time	1.38 s	**Total Motor Mass**	6.59 lbs.
Total Impulse	2522 Ns	**Propellant Mass**	2.63 lbs.
Thrust to Weight	18.64	**Post-burn Mass**	3.96 lbs.

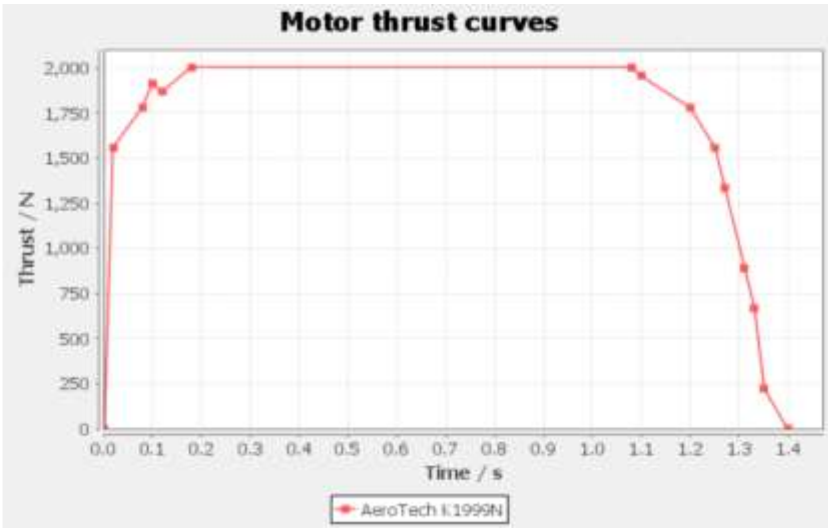
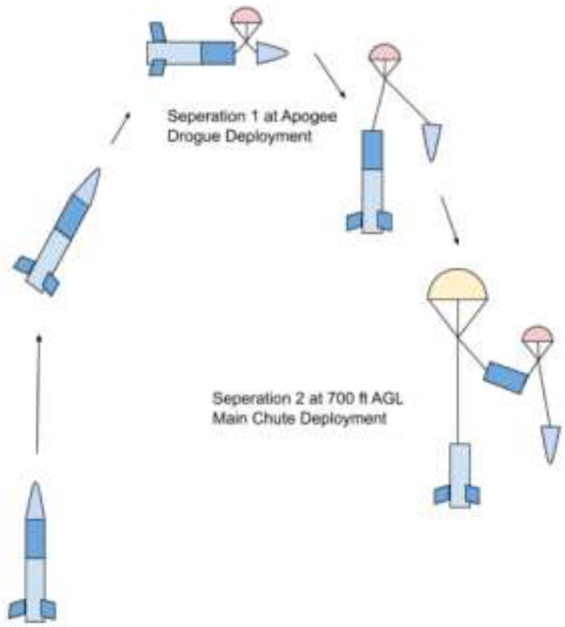


Figure 13: Alternate Design 3 Motor Thrust Curve – K1999N-P

3.4 Recovery Subsystem



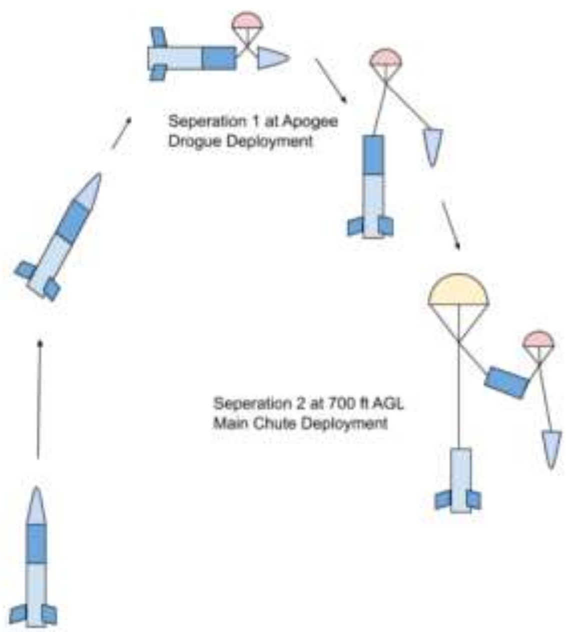


Figure 14: Recovery System Events Diagram

3.4.1 Alternative Designs

When creating alternative recovery designs, the most important aspects are material strength, weight, and cost. The material used for the locking mechanism was either between carbon fiber or epoxied pine. As seen by previous uses, pine is less prone to release of particulates when cut to specific dimensions. Carbon fiber may hold some advantages with an estimated strength to weight ratio of 2457 kN*m/kg while oak (like pine) has a strength to weight ratio of 87 kN*m/kg. The rigidity of carbon fiber is about 20 times stronger than pine.

Since the force exerted on the locking mechanism will be a sudden jolt at high speeds then a suspension with not a large amount of stress pulling the material, rigidity should be optimized and focused on instead of strain of the material. The tensile strength and rigidity of carbon fiber is greater than pine wood, however previous tests have been successful with pine and there must be a decision between strength and efficiency.

Ultimately, the locking mechanism's disk will be made of pine. It is more accessible, cheaper, and lighter than carbon fiber. Carbon fiber's strength is optimal when the force exerted is along the surface. In addition, carbon fiber is brittle and shows no sign of cracks and fatigue as failure of the material is catastrophic. Overall, the force exerted on the mechanism would not even be close to a failure when using carbon fiber or pine. The pine will also be treated with a resin.

Another design consideration we considered was the use of a chute release. This device uses an altimeter to release the parachute at a predetermined altitude. The chute release does not use pyro charges in its deployment method, instead it uses the motor's ejection charge to eject the parachutes. After consideration, the team decided to not include this in our design, as it would be overly expensive and would lead to technical difficulties.

3.4.1.1 Hardware

Looking beyond the expected parachutes and shock cords necessities, a robust system to connect the recovery hardware to the vehicle must be designed. Firstly, the bulkhead material was considered as this would be the main interface between the recovery devices and the vehicle itself. Both pine and carbon fiber were considered.

Figure 7: Bulkheads

While carbon fiber offers more strength, it is more expensive than pine and the particulates it creates in the manufacturing process are much more volatile.

The team then looked at securement strategies. Bulkheads could be epoxied in or screwed in with screws from the outside of the vehicle. Epoxy offers more assurance of its strength; however accurate application is very difficult and incorrect application could tamper with the payload or other sensitive components.

Attached to the bulkhead is either a unbolt or eyebolt.

Figure 8: U-bolt

Figure 9: Eyebolt

According to McMaster Carr, the eyebolts generally have a higher capacity for large loads as compared to U-bolts. However, U-bolts offer 2 interfaces with the bulkhead while the eyebolts only provide one.

Finally, is the hardware to attach the shock cord to the eye or unbolt. For this, it is planned to utilize a quick link. No other options were considered.

Figure 10: Quicklink

3.4.1.2 Locking Mechanism

The goal of the locking mechanism is to shield critical safety electronics in the avionics bay from hazardous forces during flight while providing easy access to the avionics bay. The locking mechanism simplifies the way electronics are implemented into the launch vehicle.

A concept for this involves a male screw cap that interlocks with a female threaded bulkhead ring. The following image better visualizes this concept.

Figure 11: Threaded Locking Mechanism

Using mating male and female threads as a securing mechanism enable the electronics within the avionics to be easily positioned into the launch vehicle. This also allows the thickness of the locking mechanism to be varied depending on the space within the launch vehicle. However, for both male and female threads to screw on properly without forcing the two pieces together, the parts must be machined with a high degree of precision. Due to the complex geometries of the parts, material options are limited. To achieve the desired precision, the parts would have to be 3D printed using an SLA 3D printer. Traditional FDM printers have a bigger print bed and faster print speeds, but their precision is limited to the nozzle diameter. An FDM printer must be used, but their limited build size may not permit these large parts to be printed.

Another alternative involves a simple slide-and-lock mechanism. This system involves an inner ring which slides into place vertically and then rotates axially to lock into place. The following image illustrates the design.

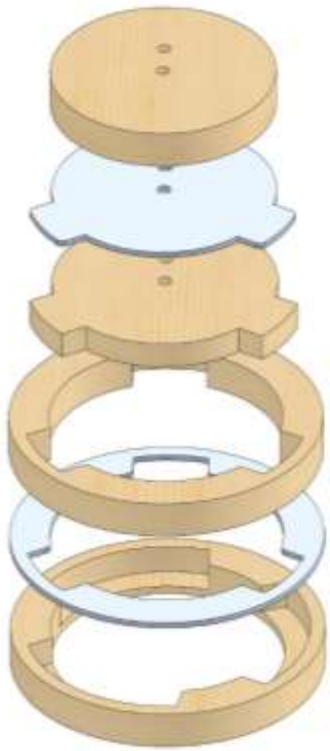


Figure 12: Slide-and-Lock Locking Mechanism

Because the geometry of the assembly is simple, component manufacturing is also simplified. This simple, yet robust design permits a greater variety of materials to be used. Primarily, wood and metals can be CNC'd to specification. A double layered wooden locking mechanism with reinforcing aluminum sheets can be implemented.

Since the inner ring is locked into position through friction fitting, there is a possibility of the locking mechanism rotating out of the locked position and sliding out. The chances of this happening are low, but it must be considered when tolerancing for manufacturing. Another issue is that the tabs must be sufficiently long to withstand forces from black powder charges and parachute deployment. By increasing tab length, the usable circular area for the avionics sled decreases. This design can cause unexpected complications within the avionics system if space is decreased. The avionics system is easier to wire and maneuver if more space is allotted for the avionics system.

3.4.1.3 GPS Tracker

To keep track of the rocket's position, a GPS tracker will be placed inside of the rocket. In past years, the team has noticed that placing the GPS inside of the carbon fiber body tube results in a loss of signal. To prevent this, the GPS will be located inside of the nose cone made from PLA plastic. Due to space limitations, a small GPS tracking device is preferred.

The T3 (Tiny Telematics Tracker) GPS device is capable of tracking through Bluetooth connection with an Android device and is small enough to fit into the nose cone. Its operational range is up to 9 miles, more than the desired range of half a mile. UCLA Bearospace has used this GPS tracker in previous projects, so it can be reused to minimize costs.

The GPS tracker will be placed inside the nose cone to minimize signal loss and ensure proper tracking of the rocket. In past years, the GPS has been placed within carbon fiber body tubes, which reduces signal strength and renders the GPS system useless. The T3 Tiny Telematics Tracker being used is 1" by 2.075" and its 6" antenna is capable of locating the rocket within a 9-mile radius, a distance way greater than the allowable range of the competition.

The operational voltage of the T3 is 3.5 volts to 7.4 volts using a 1S Li-Po battery and the power consumption is about 175 mA. The recommended batteries to be used with the GPS, according to its manual, are 1S LiPo batteries. The GPS can be used with a 2S LiPo battery, however, this battery will dissipate a lot of heat in the process. The benchmarks when using a 750 mA 1S LiPo battery was roughly under 4 hours. So, to reach the minimum 4 hour goal, the battery we are using is a 1200 mAh 3.7V battery, which is the recommended Voltage for the battery to run on while increasing the operational time to 6.86 hours.

A push button for the GPS which will be connected to the LiPo battery for the GPS. Also, a push button will be used as a mechanical method to decrease drag on the rocket and to have an external method of turning the GPS on.

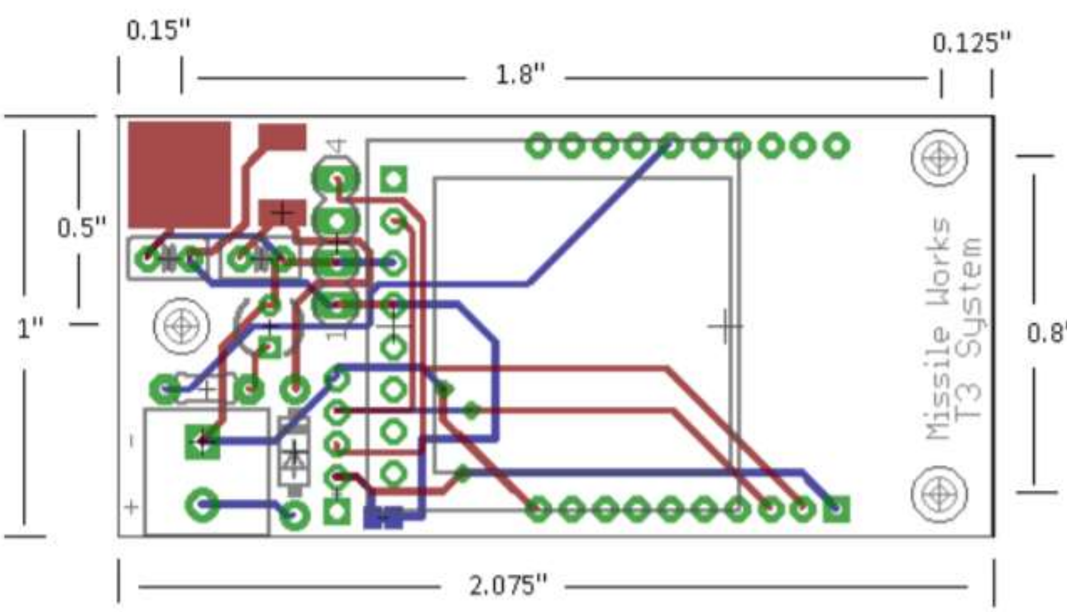


Figure 13: Drawing of Missile Works T3 System

3.4.2 Preliminary Parachute Sizing Analysis

Parachute sizing for each alternative rocket vehicle design is determined by the maximum landing kinetic energy allowed. Per the NASA Student Launch Statement of Work (SOW), the maximum kinetic energy any rocket component can experience is 75 ft-lbf. From this, using the kinetic energy equation, the maximum landing velocity for the heaviest rocket component (as the heaviest component will have the most kinetic energy as can be clearly seen in the kinetic energy equation) can be determined.

Using this equation, the maximum landing velocity of each alternative designs heaviest component is determined.

With this maximum landing velocity, a parachute sizing that lowers the landing velocity to below the minimum is determined. Through simulations through OpenRocket, a 12’ parachute services all alternative designs well enough to lower the landing velocity below their respective maxima.

To reinforce the initial results produced through OpenRocket, simulations were repeated 10 times and the highest landing velocity is taken for additional safety measures, rather than the average. Using the highest landing velocity, the kinetic energy of each mass component. To supplement OpenRocket simulations, calculations were made by hand using the kinetic energy equation and the parachute diameter equation to determine a minimal parachute diameter, which would be rounded up to the nearest even-numbered foot. The corresponding landing velocity to the rounded-up parachute diameter is then used to calculate the landing kinetic energy of each rocket component.

3.4.3 Leading Design Choices

Since Alternate Design 2 is the leading choice, all measurements are relative to that model

3.4.3.1 Hardware

Our launch vehicle will utilize a dual deployment system with the drogue chute deploying at apogee and the main chute deploying at 750 feet above ground level. As seen in the figure below, the drogue chute will be located at separation 1 between the upper body tube and the nose cone, and the main chute will be located at separation 2 between the body tubes. Shear pins will be used in both the nosecone shoulder and the coupler to ensure premature deployment of the chutes does not occur. Four shear pins will be placed 90 degrees from each other around the nosecone shoulder and the coupler. Black powder ejection charges will be in the nosecone shoulder and the coupler. Before any launch, fire clothes will be attached to shroud lines to protect and cover components in the vehicle such as the payload from the ejection charges. At apogee and 750 feet AGL, the black powder ejections charges will be set off, pushing out the shear pins and separating the body tubes as well as the nosecone from the upper body tube as seen in the figure below. The main chute deploying at 750 feet AGL will drastically reduce the ground hit velocity and kinetic energy of all independent sections, making the launch vehicle recoverable and reusable.

Since Pine bulkheads are cheaper and easier to manufacture, pine will be selected over Carbon Fabre in our design. Additionally, U-bolts were chosen over Eyebolts as the retention hardware due to the increased stability and strength U-bolts offer.

3.4.3.2 Locking Mechanism

Since the locking mechanism will endure harsh conditions and serve as a bulkhead, the design of the locking mechanism must be durable and robust. The locking mechanism chosen will be the simple slide-and-lock mechanism because of the success of its ease of manufacturing and prior year's success with this option.

The locking mechanism chosen will be the simple slide-and-lock mechanism. Although its design is clunky and limits usable area for the avionics sled, its robustness and simplicity make it a better selection than the 3D printed threaded locking mechanism. The slide-and-lock's simple geometry allows it to be manufactured with a greater number of materials. In past years, pine has been selected for the locking mechanism and no signs of cracking or deformation are seen on the wood after launch. SLA 3D printers have resins rated with higher strength, but they may not be durable enough for applications within a high-powered rocket. Selecting a durable resin would also incur further testing to see if this material is viable for its application. Pine is simple to CNC mill and is sufficiently strong to endure all forces during flight and parachute deployment. Analysis on pine as the choice material for the locking mechanism will be conducted throughout the project's timeline.

3.4.3.3 Avionics Sled

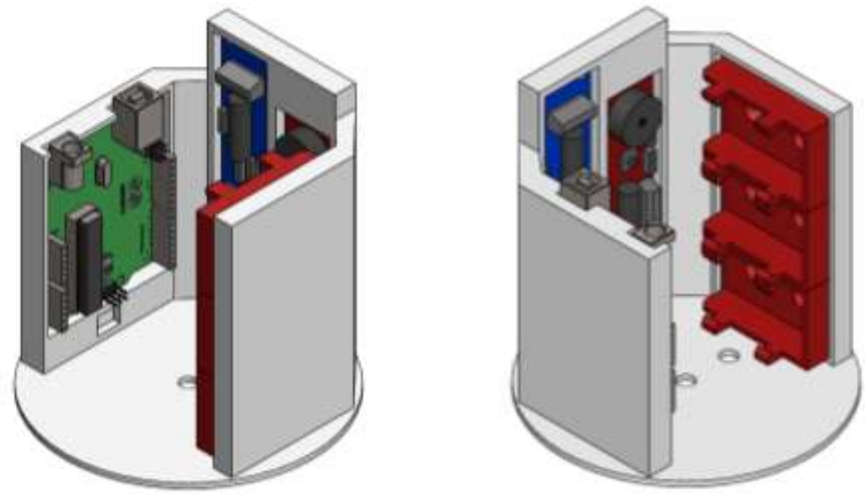


Figure 14: Avionics Sled with Electronics

The avionics sled is an extension of the locking mechanism. It safely and efficiently stores the onboard electronics necessary for deploying the rover, located within the avionics bay of the launch vehicle. The design of the locking mechanism will be the same as the prior year due to its durability and success. The avionics sled will retain three 9V batteries, two commercial altimeters, an Arduino Uno, and a BMP180 barometric pressure sensor. Different to prior years, the electrical components will be attached to the sled using appropriate 4-40 screws which screw into heat set inserts for plastic. This provides a secure attachment while still being easy to remove if necessary, without needing to replace any parts. The avionics sled has a large surface area at its base to provide greater adhesion when epoxied to the inner ring of the locking mechanism.

3.4.4 Redundancy

For safety and success, it is critical that there be redundancy to ensure the deployment of chutes. We are using the Missile Works RRC3 Sports Altimeter and StratoLogger SL100 Altimeter to ensure the rocket deploys when necessary. Both electronics have been used before and have been successful.

3.4.4.5 Switches

Originally the team considered using electronic switches triggered by a button to trigger the startup of the altimeters. However due to the possibility of accidentally being set off, the decision to use turnkey switches was made.

3.5 Mission Performance Predictions

Again, the leading rocket design is Alternate Design 2. Component weights of all subsystems have already been given in Table 3.

3.5.1 Official Target Altitude

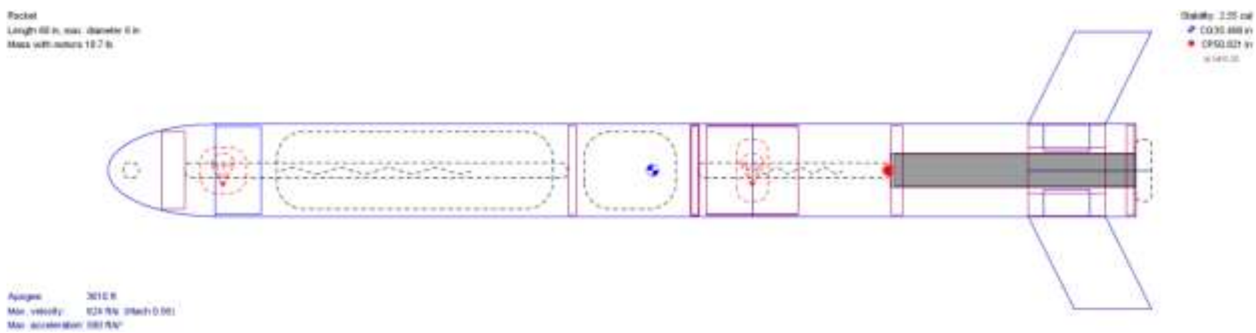


Figure 15: OpenRocket Model of Leading Design

The official target altitude is set to 3600 ft AGL exactly, based off the estimated apogee of the leading rocket vehicle design simulations and probable additional loss in apogee height through other actors such as launch rail friction.

3.5.2 Flight Simulations

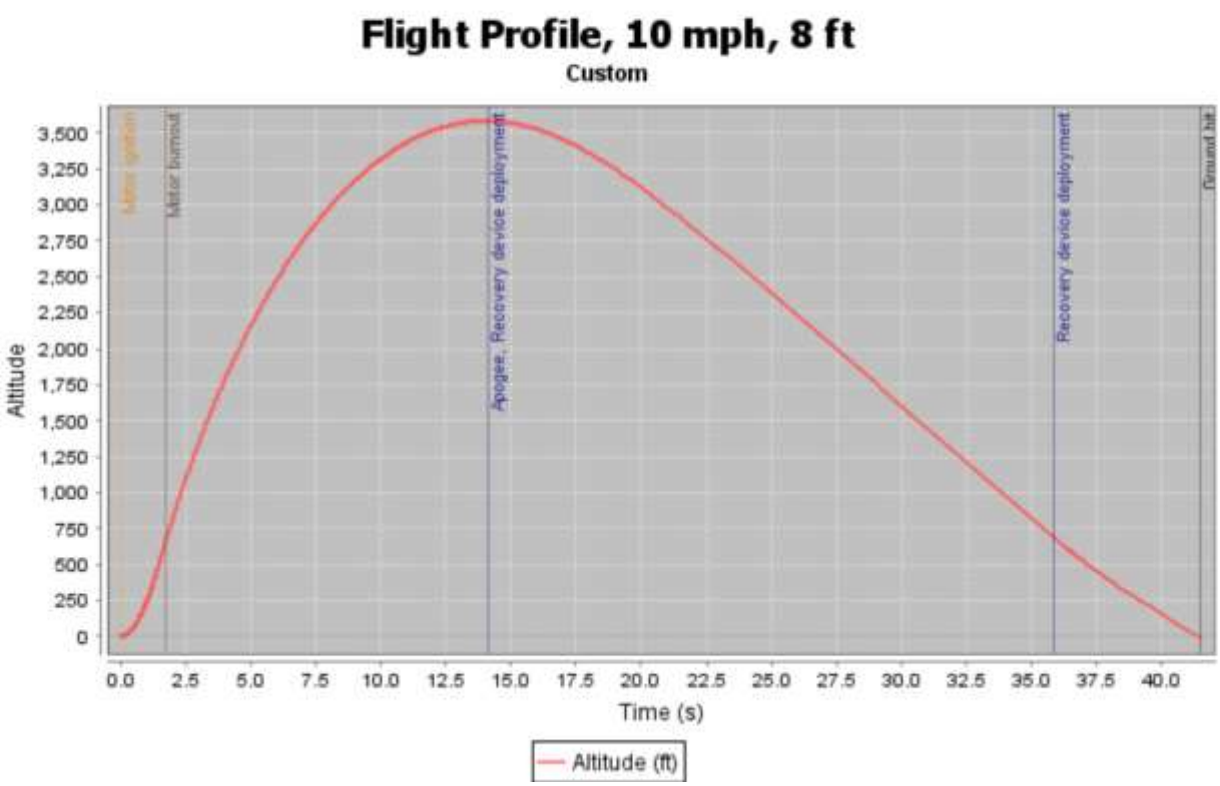


Figure 16: Flight Profile with 10 mph winds, 8 foot launch rod

The flight profile of the leading rocket design is shown above with 10 mph wind speed and off an 8-foot launch rod. The figure above shows the official target apogee of about 3,600 feet.

The motor thrust curve along with the motor data of the Aerotech K1103X-14 is shown below.

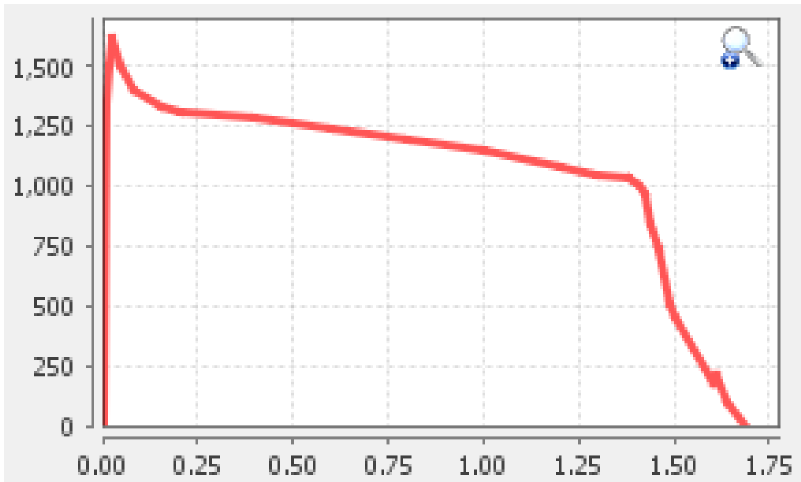


Figure 17: Alternate Design 2 Motor Thrust Curve – K1103X-14

Table 9: Alternate Design 2 Motor – K1103X-14 Motor Data

Motor Diameter	2.13in	**Motor Length**	15.8in
Average Thrust	1099 N	**Max Thrust**	1620 N
Burn Time	1.65s	**Total Motor Mass**	3.2 lbs.
Total Impulse	1810Ns	**Propellant Mass**	1.8 lbs.
Thrust to Weight	13.17	**Post-burn Mass**	1.4 lbs.

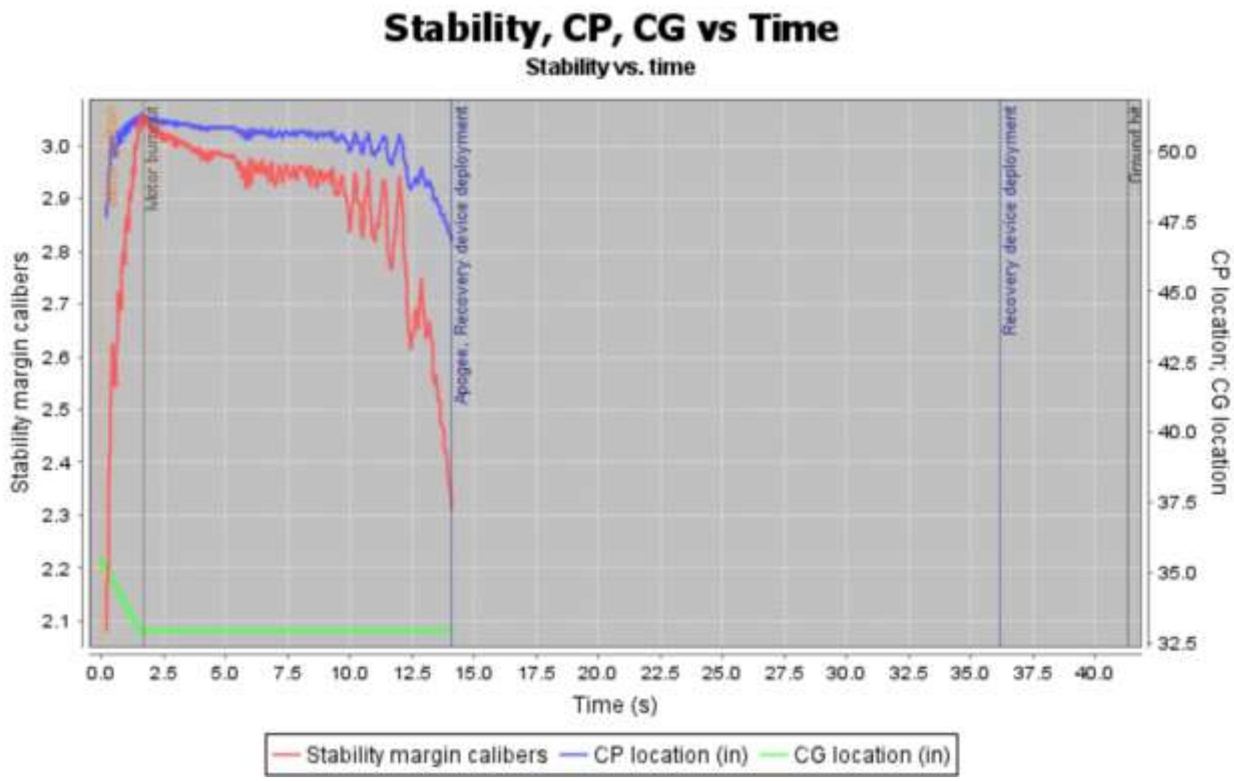


Figure 18: Stability, CP, CG vs Time

The figure above shows the simulated stability, CP location, and CG location during the whole flight. The stability stays well over the minimum value of 2.0. The static locations of CG and CP are shown in the OpenRocket figure under section 3.5.1 with values of 35.498 in and 50.821 in measured from the tip of the nosecone.

The vehicle is robust enough to last through the flight with the expected loads and be recoverable and reusable. This will be proved through testing as the team proceeds to the CDR. As of now, the vehicle will be shown to be recoverable and reusable through the kinetic energy calculations of each section.

3.5.3 Recovery Simulations

Referring to section 3.3.2 and the landing velocities computed using a 12 ft parachute, the kinetic energies of all the tethered rocket vehicle components of the leading rocket vehicle design can be determined.

$$KE_{component} = 0.5 * m_{component} * v_{landing}^2, where\ v_{landing} = 16.4\ ft/s$$
$$m_{nosecone} = 9.07\ oz \rightarrow KE_{nosecone} = 2.37\ ft - lbf$$
$$m_{upperbodytube} = 123.656\ oz \rightarrow KE_{upperbodytube} = 32.28\ ft - lbf$$
$$m_{lowerbodytube} = 74.513\ oz \rightarrow KE_{lowerbodytube} = 19.50\ ft - lbf$$

Note that the highest kinetic energy, that of the upper body tube, is more than 50 percent less than the maximum allowable rocket vehicle component landing kinetic energy, 75 ft-lbf. This provides a measure of contingency in the event of weight gain during the design and manufacturing process, as weight gain contributes to a proportionally higher landing kinetic energy. Further simulations in OpenRocket accounting for 5-10 degree inclinations of the launch rail as well as 0-20 mph wind speeds show that a landing speed of 16.4 ft/s is actually the upper bound to the rocket vehicle landing speed spread, with the lower bound being as low as 14.8 ft/s, meaning a component's kinetic energy, depending only on launch conditions, will always be less than the estimate produced above.

3.5.4 Drift Estimate

Drift is determined through OpenRocket simulations, where drift from apogee to landing is the only lateral distance being considered, if a rocket reaches apogee directly above the launch site. The drift and descent times for each section of the launch vehicle will be nearly the same since the sections of the launch vehicle are tethered together.

Table 10: Drift and Descent Time Estimates

Rail Length (ft)	Wind speed (mph)	Drift (ft)	Descent Time (s)
8	0	0	27.4
8	5	138	27.6
8	10	276	27.6
8	15	410	27.3
8	20	536	26.8

3.5.5 Simulation Verification

The structures team is in the process of writing a code in MATLAB that can verify the calculations stated in this report. This code will be ready in time for the CDR. The team believes OpenRocket to be a very reliable source but will not proceed to the manufacturing stage until simulations are verified. Simulations will be performed in RockSim as well to verify simulations from OpenRocket by the CDR.

4. Payload Criteria

4.1 Payload Objectives

The scientific payload is designed to jettison itself safely and properly from the launch vehicle at an altitude range of 500-1000 ft AGL. The payload will have the ability to descend and land in an upright configuration without obstructing onboard cameras. Once landed, the payload will take data measurements of the initial angle from vertical and correct itself to be within 5° from vertical and transmit this data to the team. It will then take pictures of the landing site using multiple cameras and transmit the pictures to the team to be stitched together to create a singular 360° picture. A successful experiment will complete these tasks autonomously without the need of crewmate intervention to troubleshoot errors.

4.2 Lander Assembly

Two general payload alternatives were considered: a lander system and a UAV. While a UAV would mitigate the issue, a lander would have with entanglement with the parachute during the payload's multiple jettison phases, a UAV would prove too complex to develop and test without the ability to meet in person. A UAV would also require an additional four motors and would need additional motors to level itself after landing, which limits the amount of space for onboard computers. For these reasons, only parachute-based lander systems will be discussed.

4.2.1 Alternate Designs

4.2.1.1 Three Leg Lander

The first payload alternative is a simple solution to accomplish the payload objectives. This lander system involves three legs which retract in a packed configuration within the launch vehicle and electronically deploy once jettisoned.

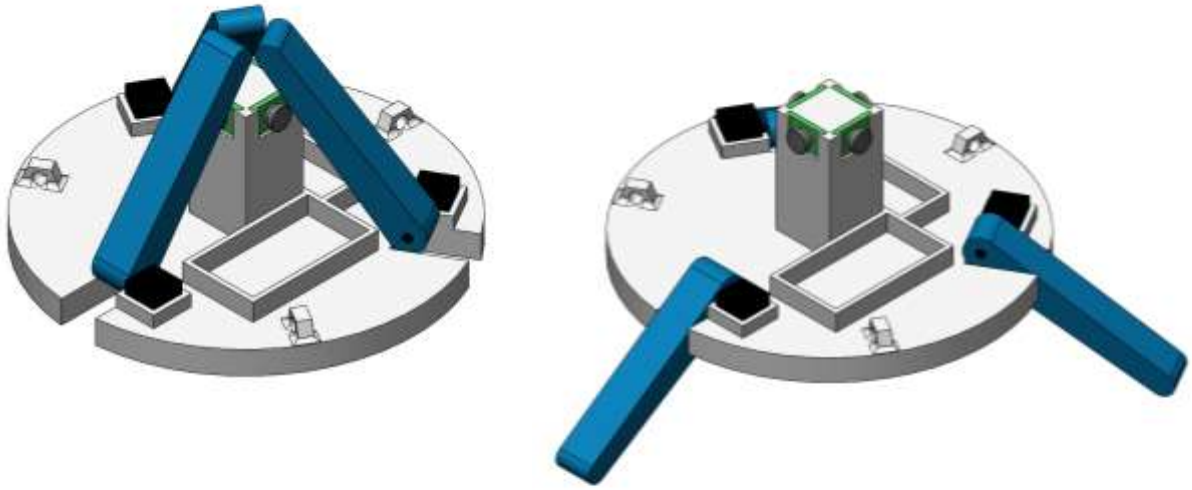


Figure 19: Three Leg Lander Design

The lander features a 5.9” x .4” (diameter x thickness) base with three 3.18” long legs that are actuated using three servo motors. To prevent possible tipping in case of an undesirable landing attitude, a heavy weight is placed within the base to lower the center of the mass. Additionally, the legs will deploy parallel with the base during descent to provide a wider landing area. The large surface area of the lander means multiple compartments can be made for attaching onboard computers and sensors for controlling the lander. Cameras necessary for completing the payload mission are propped on a central column to increase visibility of the landing site and securely attach the cameras to the payload. The central column also houses a gyroscope/accelerometer module to provide feedback to onboard electronics. The lander also features three harness points for attaching a parachute to the payload. The lander’s mechanical simplicity means it is also simple to manufacture as there are fewer moving parts.

One of the biggest concerns with this design is possible entanglement between the parachute and the legs of the lander while the lander is jettisoned in its packed orientation. During descent, the parachute shock cords at the three different harness points may undergo torsion which may cause the shock cords to collide with the legs and prevent them from deploying and operating as intended. Another concern is the minimal contact points of the lander with the ground. Since there are only three contact points with the ground, the lander is not very stable and may tip. A possible solution to this is to attach another leg and motor, but this minimizes space needed for onboard electronics.

4.2.1.2 Three Leg Nose Cone Lander

An important aspect of the payload is its ability to retain itself within the launch vehicle and properly deploy itself when desired. A concern with using a parachute-based lander system is its potential for the parachute to get caught within other components within the launch vehicle or the parachute not catching wind due to packing. Storing the payload within the launch vehicle also introduces the complication of needing to deploy the launch vehicle’s parachutes to expose the payload to the air prior to its deployment. By using the launch vehicle’s nose cone as the body of the payload, deployment of the payload and the launch vehicle's parachutes happen in a single event and eliminates complications of ejecting the payload from within the launch vehicle.

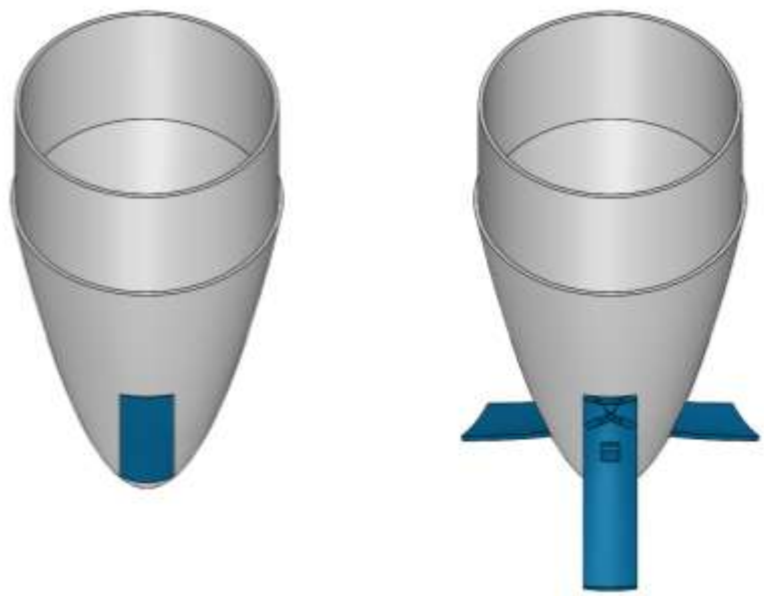


Figure 20: Three Leg Nose Cone Lander Design

This payload design is like the three-leg lander design mentioned before except it is adapted to fit within the launch vehicle's nose cone. The three legs are actuated using three servo motors and are designed to be flush with the nose cone's contour to prevent increased drag during flight. A camera system like the previous design exists within the payload and can take pictures of the landing site using clear 3D printed plastic for the nose cone. A similar central column houses a gyroscope/accelerometer module to provide feedback to onboard electronics. Since the nose cone experiences blast forces due to ejection charges, a locking mechanism bulkhead will be used to fasten the payload to its parachute near the exit of the payload. Using a system like the locking mechanism mentioned previously allows for easy, regular access to the inside of the payload. Using the locking mechanism bulkhead as an attachment point for the parachute also prevents entanglement of the parachute with the legs of the lander.

A major issue of this design is the ability for the camera system to take pictures of the surrounding landing site. While clear 3D printed plastic exists, the opacity of the material does not allow for crisp pictures to be taken. Clear 3D printed plastic also complicates manufacturing as a lot of post processing and experimentation needs to be done to achieve feasible results. Additionally, the design also suffers the same issues as the original three leg lander system such as stability and limited contact points. The legs of the lander must not contact the nose cone while opening, which means an airtight surface is not possible. This messes with the aerodynamics of the launch vehicle and is a potential hazard as it can affect its trajectory.

4.2.1.3 Four DOF Rack and Pinion Lander

To increase traction between the landing surface and payload, a payload with a large base as its point of contact is needed. The previous payload alternatives discussed lacked the traction necessary in the case a slippery surface is encountered. The use of an additional base also provides more space for the payload to house electronics and other motors.

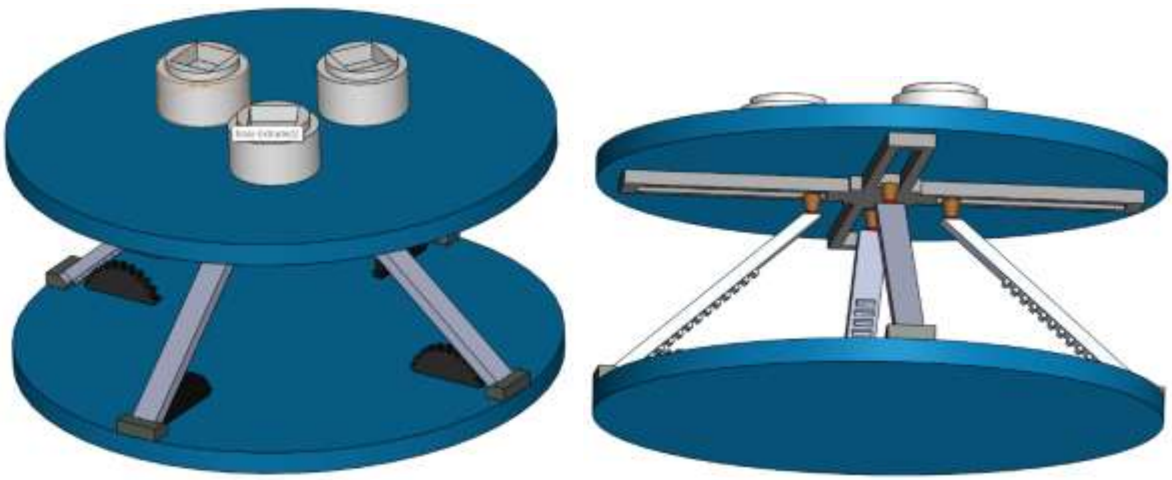


Figure 21: Four DOF Rack and Pinion Lander

This design features two 6” x 0.25’’ base platforms connected by four 2.72’’ legs which are adjusted independently by four motors with matching gears. The legs are connected to the bottom platform using a revolving joint allowing the leg to move from an angled position to a vertical position. They are connected to the top platform using a ball joint and slider which allows for free movement along a horizontal direction. Since the rods move independently of one another, they can each adjust to level the top platform according to the angle between the bottom platform and the ground. There is sufficient room in the center of the bottom platform to also add in weight for stabilization and/or electronics to provide onboard feedback.

One of the main drawbacks to this design is the real-world functionality of the gears to grip onto the teeth of the legs and have the legs truly move freely. Another downside to this design is its bulky stature which can easily lead to instability, thus upon landing the payload could tip over, compromising the payload objective.

4.2.1.4 Three DOF Levelling Plane

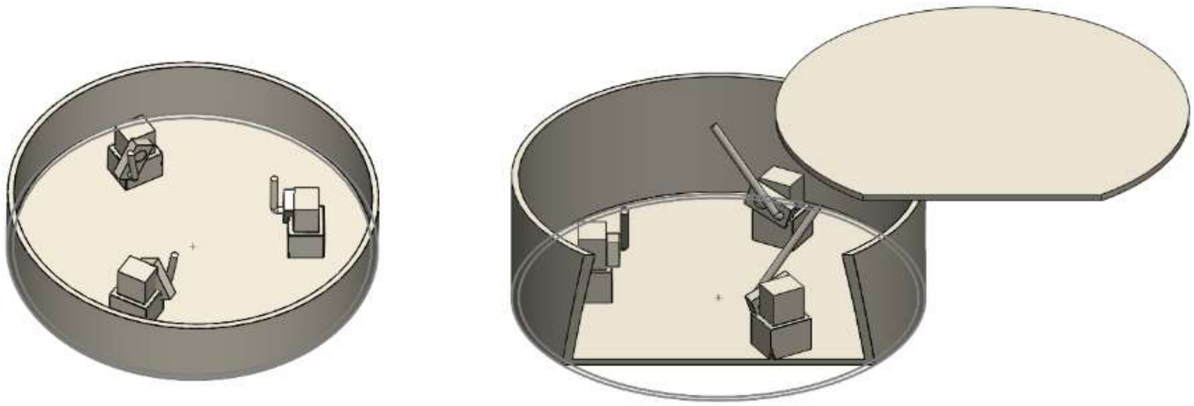


Figure 22: Three DOF Leveling Plane

This design prepares for the hypothetical case in which the payload lands on an uneven surface.

This model is comprised of a circular base with a diameter of 5.9 " and a maximum height of 3". The base of this model is weighted to ensure that the bottom contacts the floor prior to any other part of the payload. This lander makes certain that regardless of the angle the base makes with the floor upon landing, the top remains leveled with the support of three degrees of freedom, each powered by a servo motor. The movement of these degrees of freedom is dependent on a joint attached to the side of the motors and the extension of the arm connected to these joints. The platform on the surface is adjusted by each of the metal arms and allows for the platform to be in a leveled position upon landing.

4.3 Leading Design Choice

The selected payload design is the three DOF levelling plane lander for its increased contact area with the ground, ease of manufacturing, high level of control while stabilizing, and increased space for electronics. This payload design lessens the possibility of the lander’s parachute entangling itself with the payload as it does not use a leg system for stabilizing itself. While the three DOF levelling plane lander has a high center of gravity, weights can easily be placed on the bottom plane to lower its center of gravity.

When compared to the simple three leg lander, the selected payload design is mechanically more complex. However, the three DOF levelling plane design is still rather simple to manufacture and it eliminates potential entanglement with the parachute, which makes this design a clear choice over the three leg lander systems.

The four DOF rack and pinion lander is like the selected lander except it is significantly more complex. The use of gears to drive the rack and pinion leg system and the use of a slider system increase potential for mechanical failure since there are multiple components that must be manufactured and placed with precision. The three DOF lander system uses the motors to directly move the levelling platform which simplifies manufacturing and reduces mechanical failure.

In general, the three DOF lander system design minimizes failure modes while not compromising structural integrity or mechanical ability to complete the payload objective.

4.4 Payload Ejection Methods

The lander ejection assembly is a system designed to safely retain the rover during flight and properly jettison the lander from the launch vehicle within 500ft and 1000ft AGL. The lander ejection assembly must jettison the lander without obstructing its trajectory or tangling with the lander's parachute during deployment. The target altitude for deployment is 550ft AGL to give the selected payload method approximately 50ft until it must be separated from the launch vehicle.

4.4.1 Alternate Designs

4.4.1.1 Rotating Lock (Alejandro)

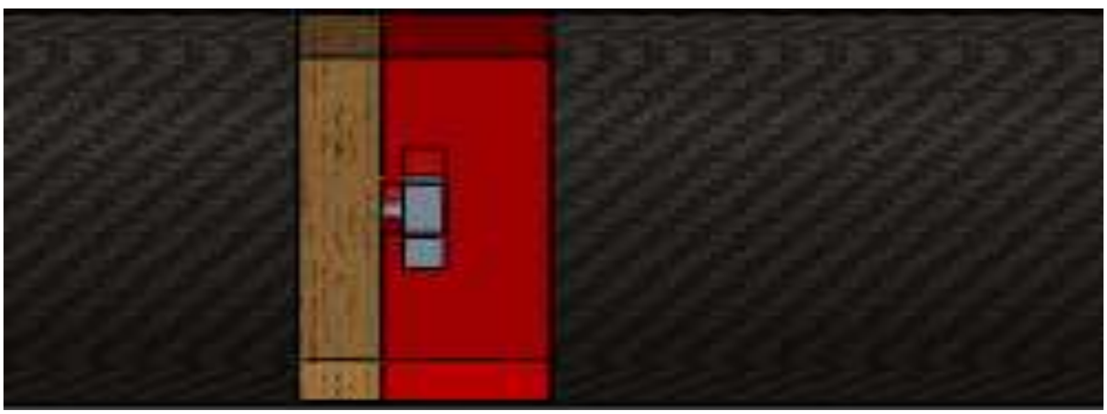


Figure 23: Cross Section of Rotating Lock Ejection Design

This locking mechanism is made to simplify the transition in a uniform way. The payload is made with slots to accommodate the pathway on which the keylike feature holds it in place as well as releases it. The two slots made into the payload easily provide clearance to be released when the keys are rotated to the required orientation. The keys are operated using electronics. The keys rotate from the initial lock position to eventually release the payload at a uniform descent when the target deployment altitude is reached.

This method provides an effective way to ensure that the payload departure is smooth. Although the concept of departure provides a simplistic manner that appears achievable the setback falls within the manufacturing of the design. The slots placed on the bottom of the payload do not allow for a simple cut. To achieve the desired slot an undercut must be made to provide the clearance needed for the keylike feature. This design also is heavily dependent on the electronics that rotate the keys. This provides room for error that can occur during the forceful explosion during the flight process.

4.4.1.2 Latching Switch (Jovi)

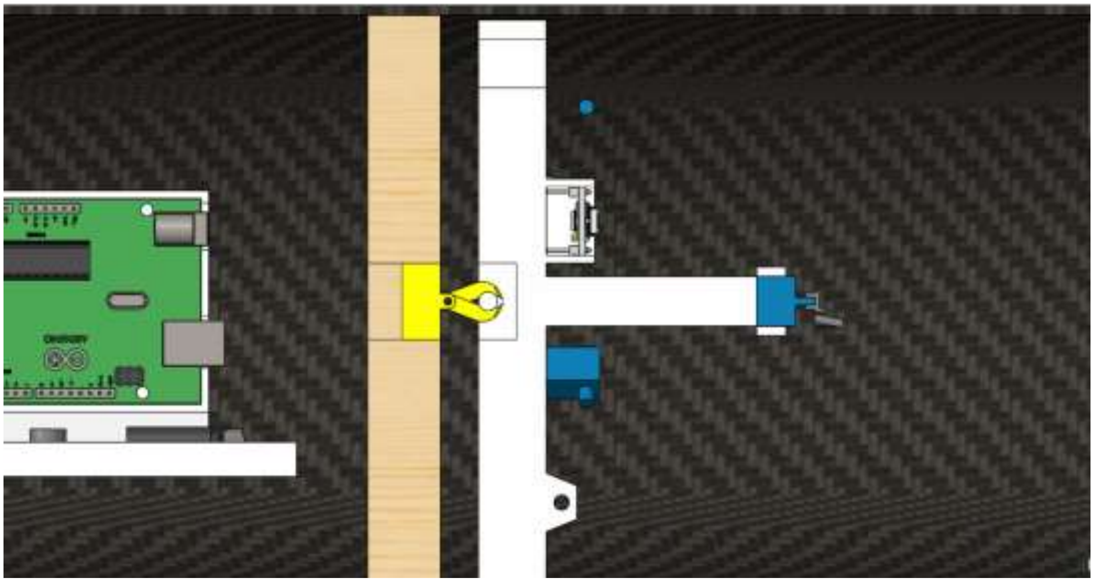


Figure 24: Cross Section of Latching Switch Ejection Design

This deployment method uses a single claw-like latch to secure the payload to the launch vehicle. The bottom of the payload is modified to have a cylindrical rod from which the latch grabs onto. Upon detection of the target deployment altitude, the latch will open using a servo motor and separate the payload from the launch vehicle. This method is mechanically simple and easy to manufacture as there are limited parts that are required.

While this method reduces the number of motors needed for deployment and is mechanically simple, the latching switch suffers from various design flaws. Due to the orientation of the payload, the top of the payload faces towards the exit of the body tube where an ejection charge is located. This is an issue since sensitive electronics are exposed to blast forces, which can cause extensive damage to the payload and critical electronics. Additionally, this method does not guide the payload towards the exit. This means there is a likely chance the payload will collide with the walls of the launch vehicle and potentially get stuck. There is too much in variability in the trajectory of the payload during deployment.

4.4.1.3 Hinge Controlled Dropping Mechanism (Eduardo)

Figure 25: Angled View of Dropping Mechanism

Another alternative design to the ejection assembly involves electronically controlled hinges. It features a bulkhead ring to provide an attachment point for the servo motors that actuate the hinges. When the explosion that opens the rocket occurs, the payload may slide back from the force. The red bulkhead will prevent the payload from moving by shielding it from the blast. A hole has been made in the middle to accommodate for the central column of the rover. Immediately after the explosion, the avionics will send electrical signals through the bulkhead and the two aluminum chassis tubes via wires. These wires are connected to two servo motors, each controlling the movement of the hinges. They will be flush with the body tube, allowing the payload to slide out of the rocket to be jettisoned. A cylindrical tube between the ring bulkhead and red bulkhead will be used to aid in guiding the payload towards the exit.

Drawbacks of this method are its manufacturing complexity and reduced payload diameter. Since the ring bulkhead reduces the diameter the payload must exit through, the payload itself must also have a smaller diameter. This may prove consequential as a reduced area limits the payload's design and electrical selection.

4.4.2 Leading Design Choice

The selected deployment method is the hinged controlled dropping mechanism for its ability to securely retain the payload within the launch vehicle, orient the payload to prevent ejection charges on the payload's electronics, and enable the payload to take a predictable path. While the selected deployment method is the most complex of the proposed alternatives, it is necessary for a successful mission.

Compared to other two deployment mechanisms, the hinge-controlled deployment mechanism excels in being able to shield the payload from ejection charges and control the trajectory of the payload during deployment. The other two methods simply let the payload undergo a free fall without any guidance, which produces varying results depending on the altitude of the rocket at the specific point in time.

4.5 Electronics

4.5.1 Alternate Designs

4.5.1.1 Motors

Motors were considered based on their usefulness to the payload implementation. There are three main areas of implementation that will be considered: deployment of the payload, leveling of the payload, and control of the camera once the payload has landed. The main concern regarding motors is the ability to control them as accurately and precisely as possible, including minute movements.

Several types of motors were taken into consideration. One such consideration was using brushless DC motors, as these were used for last year's payload. These motors have medium, but consistent torque. They are also compact, making them ideal for minimizing space. They have consistent speed control.

Another consideration was using DC servo motors. These motors have high torque, which allows them to be used for precise orientation. They are also energy efficient, although a little on the expensive side. They are slower than DC motors, although speed is not a consideration that is being taken.

A third consideration was using a servo motor with position feedback, specifically a smaller servo motor than the DC servo motors. This servo motor would be ideal for control of the camera, as the camera is very lightweight.

A final consideration was using stepper motors, which function similarly to servo motors. These motors have high torque, although they are executed in fixed steps, which results in less maneuverability. They are also very large and heavy, as well as extremely slow, albeit consistent.

4.5.1.2 Communication

The team considered creating a custom RF receiver whose frequency could be tuned specifically and with original encoding. The model was going to be implemented through an Arduino mini, however the consideration has been scrubbed due to the unnecessary strain in team focus. Though a meaningful educational exercise, writing custom implementations which may not be ready by launch is too much of a risk compared to using already proven methods.

4.5.1.5 Power Supply

Previously the team has used metal hydride batteries, however they have since been decommissioned for the payload and only continue to be used in the sparse power needed for launch necessary electronics like the altimeters. This is because the batteries need to be constantly replaced to fine tune the landers and camera motions.

4.5.2 Leading Design Choices

4.5.2.1 Motors

The actuation of the hinges and the leveling of the payload will be done using servo motors of 120 degrees, as the servo motors can lock, have high torque, and are low power, which is sufficient for the implementation of the payload.

Regarding the rotation of the camera, a smaller servo motor of 360 degrees will be used, as the camera is lightweight, and it must spin 360 degrees. It also has an angular position encoder which will aid in tracking the position of the camera and allowing for more precise and accurate movement.

Overall, the servo motors will offer more control over the payload systems, while allowing for a lighter and more compact design when compared with other motors.

The brushless DC motors were not chosen due to their lack of an encoder for angular position makes them less suited to the precise application and necessary strength to achieve the desired positioning. Additionally, the higher unit cost and power consumption justification for experimentation. Not to mention the fact that the range of motion is not limited to a specific angle, allowing possibility for a situation where the desired position is compromised after landing.
The stepper motors were also not chosen as their large size and weight would outweigh their usefulness to the design.

4.5.2.2 Communication

In terms of communication the rocket will be doing, the video transmitter for the payload selected is the FuriousFPV Stealth 2.4GHz transmitter. The video transmitter will run on 11.1V and 220 mW. This will get sent to a receiver which will then be processed on board. This transmitter was selected because of its long range. The transmitter also has superb video reception, and its compact design will prove useful in conserving space on the payload.

4.5.2.3 Controls

All controls are handled independently by the electronics in the avionics sled. This choice was deliberate because the bulk of complications are in the payload and the rocket itself requires a reliable implementation. Hence the choice for redundancy in altimeters and the separate channels for Bluetooth GPS and RF prevent system wide failures.

Within the payload the electronics are going to being serviced through rigorous application specific testing. The feedback of the legs is going to be measured using an onboard gyroscope and accelerometer to correctly position before permanent landing is established, and then autonomously adjusted until within tolerance. Afterwards the onboard microprocessor will instruct the payload to rotate the camera, while taking a series of photos which will then be transmitted to the team’s computers.

4.5.2.4 Autonomy

The team is currently looking into using convolutional neural networks to implement the necessary image parsing, blending, and compression needed to process our panoramic photo. Not doing so would consume large portions of the weight, budget, and power. Additionally, the team plans to write algorithms to handle the bulk of the self-correction needed to successfully align the payload with the ground.

4.5.2.4 Power Supply

The lander will utilize a lithium polymer battery rated at 11.1 V 3S 4000mAh 50C. This battery will provide sufficient power to each of the electronic parts for approximately 4.1 hours with an expected mission time of 30 minutes. This satisfies the team's goal of designing an electrical system to last four hours to surpass the Student Launch Handbook requirement of a minimum launch pad idle time of two hours. A total of 3660mAh is predicted to be consumed if the lander is under constant operation for 4 hours. As per handbook guidelines this battery will housed separately from the rest of the electronics and be in a red custom housing to indicate its possible fire hazard status.

5. Safety

5.1. Safety Officer

5.1.1. Responsibilities

UCLA's Safety Officer, Karla Bonilla, will work in conjunction with subteam leads, group leads, and team mentors to ensure adequate understanding of safety information and quality communication throughout the project's timeline. In addition, the Safety Officer will oversee the overall safety and launch procedures of the team and will work to fulfill the requirements listed in the SL Handbook (as well Team Derived Requirements delineated in 6.2.2). The team SO is responsible for:

- Keeping track of who has completed training for the team's general lab space and other workspaces on the UCLA campus, to ensure that only qualified and certified members are given tasks involving said workspaces
- Monitoring all team activities with an emphasis on safety during the design and manufacturing stages, as well as any launches during the construction of the vehicle and any vehicle ground testing, sub-scale launch, and full-scale launch.
- Ensuring all disposable PPE (gloves, respirators, etc.) and First Aid supplies are kept in stock and purchased, as necessary.
- Obtaining and holding a full list of Material Safety Data Sheets.
- Reviewing launch vehicle and recovery system assembly.
- Subscale launch test analysis and ensuring safe handling.
- Ensuring full compliance with NAR safety code and all law compliances.
- Assisting in the writing and development of team hazard analysis and mitigations, failure modes, and operational procedures.
- Maintaining contact with and establishing clear communication with all team members

In addition, the Safety Officer will be responsible for making sure all team members obtain the necessary training for all lab spaces and manufacturing locations. The Safety Officer's focus is to ensure the team works in a low-risk, readily available, and fully stocked environment. Any questions regarding policy and procedures may be consulted with the Safety Officer. The standing safety officer is also required to train and cultivate a safety assistant during the manufacturing stage.

5.2. Launch and Safety Checklist

In preparation for our team's subscale launch, we have developed a launch and safety checklist for our vehicle, ranging from pre-departure to post-launch assessments that would be utilized for a high-powered rocket. We will be utilizing this tentative list as a threshold minimum for inspecting our vehicle post-subscale launch and ensuring our launch is as successful and risk-free as possible. The Safety Officer or Project Manager must sign off at the end of each Checklist subsection to ensure proper verification.

If a requirement listed under any of the titled subsections tabled below is not checked, the Safety Officer and/or Project Manager must be notified before proceeding; the SO and/or PM will assess the situation and determine next steps in compliance with written guidelines and laws.

Some steps are delineated with additional red texts following the step needed to be completed to continue with the launch. These red statements elaborate the risks pertaining to significant safety hazards that may result from lack of meticulous inspection. If any issue arises while inspecting the vehicle during the Pre-Launch Checklist, stop proceeding down the checklist and consult the student Safety Officer.

Table 11: Pre-Launch Checklist

Pre-Departure	Completed (✓)?
Required Personnel: Project Manager	
1. All team members accounted for and roll is taken. Safety agreements on hand.	
2. Pre-Launch Checklist has been successfully checked for completion.	
3. Toolbox and equipment securely fastened. Additional parachutes, shock cords, eye bolts, and epoxy are loaded up.	
4. Additional batteries and contingency electronics bay in case of recovery system failure is packed.	
5. Voltmeter secured and boxed. Gloves, eye protection, and respirators on hand.	
6. Launch vehicle and payload packaged for travel.	
	_______________ 6/6 ✓ - Ready to Depart?
Recovery System	**Completed (✓)**
Required Personnel: Structures Lead and Electronics Lead	
1. Electronics bay properly inspected by to ensure wires are secured and components will be static. Potential for premature explosion and fire hazard if components are not secure.	
2. New 9V batteries are installed and tested with voltmeter.	
3. Altimeters are preprogrammed at predetermined chute deployment, fully functional. Double check the altitude settings, as errors in this step can cause recovery failure.	

Table 11: Pre-Launch Checklist

4. Fire clothes are enveloping the chutes and electronics bay. Protecting parachutes from any explosive discharge is imperative to successful recovery system deployment.	
5. Chutes are neatly folded and packed with ample room. If folding is misadjusted & off-procedure, could risk safe vehicle landing.	
6. Both altimeters are connected to both chutes' redundancy. Errors in this step can cause recovery failure.	
7. Bulk heads have been tested against desired force/impulse measurements. Destruction of vehicle impending if internal structural failures. ABORT if failure found post-inspection.	
	_______________ **7/7 ✓ - System Ready?**
Rover Ejection Assembly (Payload)	**Completed (✓)**
Required Personnel: Electronics Lead	
1. Arduino Uno working and implemented in position. If Arduino is damaged, recovery system unable to deploy. ABORT.	
2. BMP 180 (inside) connected, and responses have been confirmed.	
3. Stepper motor and stepper motor driver board properly placed (one inside, one outside) of assembly.	
4. Gyroscope embedded into bulkhead in ejection assembly.	
5. Rover assembly is per design and functional using remote control. If remote control malfunction, the rover will be unable to obtain sample & MISSION FAILURE.	
1. Components fit perfectly to scale and pose no risk to rover deployment.	
	_______________ **7/7 ✓ - Proper Assembly**
Launch Vehicle & Flight Inspection	**Completed (✓)**
1. Electronics bay is properly fit and all components snug/static.	
2. Nose cone is packed with main-chute and shock cords properly attached to eye bolted bulkheads. Nose cone fits snug and friction test was successful.	
3. Chutes fits well within body tubes. Friction test proved successful and shear pin holes have been drilled.	
4. All bulkheads are fully adhered to interior of carbon fiber body tubes. Destruction of vehicle impending if internal structural	

Table 11: Pre-Launch Checklist

failures. ABORT if failure found post-inspection.	
5. Fins are completely attached and as defect-free at adhesion point as possible. Visual confirmation necessary.	
6. All exposed wires are tucked away to the interior. Mechanical switch push button properly flushed to side.	
7. Vehicle is balanced, with center of gravity and center of pressure labeled clearly. Necessary to ensure vehicle retains vertical trajectory.	
8. Inspection fulfilled, and approval received from Range Safety Officer.	
	______________ 8/8 ✓ - Vehicle Assembly
Motor & Igniter Installation	**Completed (✓)**
Required Personnel: Rocketry Mentor	
1. Motor stored in separate container throughout launch day, until needed.	
2. Inspect motor for damage that could result in pertinent flight failures. If damage is identified, ABORT launch.	
3. Insert motor into rocket motor tube and tighten retention ring. Proper installation necessary: can result in major environmental and personnel hazards if installed incorrectly.	
4. Insert igniter into the rocket motor.	
5. Attach leads from igniter to ignition trigger.	
	__________ 5/5 ✓ - Motor and Ignition Set
Launch Procedure	**Completed (✓)**
Launch control turns power off and all prior launches have landed.	
2. Carry rocket assembly to the launch pad.	
3. Vehicle is placed onto launch rail and oriented x degrees off vertical centerline, based on wind speed (within 20 degrees).	
3. All electronics are turned on using mechanical button switch.	
4. Igniter is inserted at bottom of vehicle, pushed, and reaches end of motor, minus 2 inches.	
5. Safety Officer has verified connection to launch control and has given the OK to launch.	
	_____________ 5/5 ✓ - Ready for Launch!
Post-Launch Inspection	**Completed (✓)**

Table 11: Pre-Launch Checklist

PPE Required: Close-Toed Shoes & Long Pants	
1. Range Safety Officer has approved retrieval of launch vehicle.	
2. Locate rocket and attempt safely retrieval. Avoid potentially hazardous areas & proceed accordingly.	
3. Rover successfully ejected from body tube in upright orientation.	
4. Vehicle body is recovered.	
5. Check parachutes and shock cords for damages	
6. Properly dispose of any live black powder charges. WARNING! Risk to personnel if not done properly.	
7. Record altimeter data.	
	____________ **7/7 ✓ - Success!**

In addition, further research has been conducted to strictly comply with all NAR Safety Codes, federal and state laws, and UCLA Machine Shop Safety.

Federal Aviation Regulations 14 CFR

In accordance with Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C: the team will ensure that the rocket is launched and adhered to the general operating limitations. The team will operate the rocket in a manner that is launched, unmanned, on a suborbital trajectory in US territory and does not create a hazard to any persons or property. All team members shall be made aware of this regulation and must agree to comply.

Code of Federal Regulation 27 Part 55

In relation to the handling and use of low explosives (Ammonium Perchlorate Rocket Motors, APCP), Code of Federal Regulation 27 Part 55: Commerce in Explosives, the rocket only uses the motor provided by the competition at the launch site so storing and handling low explosives will not be necessary. All team members shall be made aware of this regulation and must agree to comply.

NFPA 1127

In accordance with fire prevention, set by the NFPA 1127 Code for High Powered Motors, the team will bring both a first aid kit to the launch site and a fire suppression device. Members will follow all guidelines as set by the code. In the event of a misfire, no one from the team will approach the rocket until the safety interlock has been engaged, 60 seconds have elapsed, and the safety officer has given permission for one person to approach and inspect. Team members are to wear proper PPE and have read corresponding MSDS. All team members shall be made aware of this regulation and must agree to comply.

5.3. Hazard Analysis

Close inspection of our tentative project timeline, laboratory, member, and vehicle construction has been done and many hazards that have been observed and/or can be expected have been identified. This list is made in conjunction with past hazard experience and will be assessed on a leveled pattern based on likelihood and impact

5.3.1. Defining Risk Levels

5.3.1.1. Likelihood:

The likelihood of each potential hazard and predetermined risk will be assigned one of three levels. These levels are assigned after analyzing and comparing the risks, estimating the possibility that they would occur.

Table 12: Risk Likelihoods

Description	Qualitative Probability	Quantitative Probability, x
-1- High or Frequent	High probability of occurrence and expected to occur often.	100%> x >67%
-2- Medium or Occasional	Likely to occur and expected to occur half of the time, on average.	67%> x >34%
-3- Low or Remote	Unlikely to somewhat likely to occur. Expected to occur after a large amount of time.	34%> x >0%

5.3.1.2 Impact:

The impact of each potential hazard and predetermined risk will be characterized by one of three levels based on the effects and severity of human injury, equipment damage, effects on project timeline and sustainability, and any potential environmental harm.

Table 13: Risk Impact & Consequence Level

Description	Member and Personnel Safety	Equipment and Facility	Project Plan & Timeline	Environment

Table 13: Risk Impact & Consequence Level

-A- High or Severe	Fatal injury/death. Permanent disability or impairment with serious repercussions.	Elimination and loss of equipment. Irreparable damage and possible dissipation of location.	Immense effect on project lifetime and results on complete halt and/or termination of project.	Irreparable and immense physical damage to the surroundings. Violates codes/laws and regulations.
-B- Medium or Moderate	Fair amount of damage, usually repairable, moderate pain, or adequate illnesses	Significant or notable enough damage to systems, equipment, or facilities.	May result in temporary but notable pause in project timeline and redesign of methods.	Possibly reversible but noteworthy damage. Subject to review based on law compliances.
-C- Low or Minor	Minimal or infinitesimal damage that is repairable and yields little to no repercussions	Small and/or repairable damage to equipment, materials, facilities. Does not compromise any state	Minor to extremely minimal delay in the project plan or timeline. Any delays due to cost or funding.	Infinitesimal and/or repairable damage that follows regulations.

5.3.1.3 Risk Assessment Levels:

Using the definitions and level placements for both the likelihood and impact of predetermined hazards listed above, each potentially identified risk will be assigned an official risk level (shown in color) in the matrix formed below:

Table 14: Risk Assessment Matrix

Likelihood	Severity		
	-A- High	**-B- Medium**	**-C- Low**
-1- High	1A	1B	1C
-2- Medium	2A	2B	2C
-3- Low	3A	3B	3C

Green boxes are deemed low risk with low severity: they are unlikely to occur often or at all, and they may be completely avoidable. They are rare and result in minimal overall effect on the project, personnel, facilities, or environment. Mitigation strategies will and should be implemented if possible, but they are not critical to mission success.

Yellow boxes denote medium risk levels: likely and possessing moderate severity. These risks may or may not be acceptable, and they should be evaluated thoroughly for potential mitigation strategies.

Red boxes denote high risk levels: highly likely and very severe, these risks are potentially catastrophic and need not be risked unless documented approval is given by the project manager, faculty mentor, safety officer, or in extreme cases, the range safety officer. ALL risks categorized as red must be mitigated to a yellow or green level before the vehicle is considered safe enough to be flight ready.

5.3.2. Predetermined Hazard Analysis and Rankings

All risks recognized by team members have been recorded, evaluated, and modified by the team safety officer. Although not all risks have been encountered at the current design and fabrication stage, each risk has been given an expected risk assessment rating both prior to mitigation efforts (BM) and post-mitigation (PM) to better prepare and anticipated hazards.

Table 15: Personnel Hazard Assessment

Personnel Hazard Risk Assessment						
Risk	**Cause**	**Effect**	**BM**	**Mitigation Strategy**	**PM**	**Verification**
Cuts/ lacerations	Improper use of machines/ equipment	Injury & potential medical attention needed	1B	All team members performing potentially hazardous operations will be properly trained. Buddy system implementation for hazardous operations. Always ensure you are working diligently in the lab space and be conscientious of others around you.	1C	Consultation of shop safety guidelines. Immediate attention from team leads and Safety Officer to proceed accordingly.
Exposure to	Improper handling of chemicals	Chemical burns, Epidermal	3B	Latex gloves will be worn	3C	PPE enforcement of latex,

Table 15: Personnel Hazard Assessment

chemicals/ allergens	and known allergens	contamination; Cross contamination; Medical attention		when handling chemicals & known allergens. Proper lab etiquette will be enforced.		chemically resistant gloves
Black powder explosion	Accidental connection to voltage source; static discharge	Epidermal injury/burn; Hearing loss; Ataxic gait	2A	Black powder handlers will only work with small amounts at a time and ground themselves prior. To reduce the gravity of the explosion, small amounts of ejection powders are to be handled at any given time.	3A	Consultation of MSDS before working near or handling powder charges. Members will be adequately trained and certified to handle. Only small amounts are to be handled.
Inhalation of chemical fumes	Improper use/lack of PPE; mishandling of chemicals	Difficulty breathing; potential organ damage	3A	P100 rated respirator masks and filters and goggles will always be worn when working with volatile chemicals & will be handled in well-ventilated rooms,	3C	Required consultation of MSDS prior to use; Respirators and relevant PPE when working with chemical fumes.

Table 15: Personnel Hazard Assessment

				under a fume-hood when possible.		
Chemical contact with eyes	Improper handling of chemicals	Temporary to Moderately sustained blindness; burning sensation	1B	Proper eye protection will always be worn when handling chemicals. Always ensure chemicals are kept away from face and ensure proper lab etiquette is always enforced.	3B	Required consultation of MSDS; Eye protection PPE is to be used.
Spilled or contact with epoxy resin and/or hardener	Epoxing without informing team members; mistakenly tipping bottles	Epidermal injury, medical attention depending on severity and body contact	3B	Team members will be trained on how to use epoxy and supervised until they are capable. All team members should be informed when working in areas where epoxy is being adhered and worked.	3C	Required consultation of MSDS; An experienced team member will either be performing the epoxy work or supervising it.
Open paint fume inhalation	Improper use of chemicals;	Discomfort; damage to lungs; nausea	1C	P100 rated respirator masks and filters and	3C	Every respirator checked for filter

Table 15: Personnel Hazard Assessment

	lack of PPE			goggles will always be worn when working with paint in conjunction with proper PPE requirements in well-ventilated areas.		cleanliness. Shop safety guidelines are adhered to regarding appropriate fuming location.
Electric shock	Equipment malfunction; electrical power build-up; damaged wires	Electrical component failure; black powder explosion; epidermal injury; limb loss	2A	All wires should be checked for damaged cording before plugging. Refrain from water usage around electronics. Handlers of sensitive equipment will ground themselves to discharge static buildup.	3B	Medical attention should be sought. Depending on the location of shock, equipment may cause fire. Fire extinguisher and lab safety kits on hand.
Prolonged exposure to loud machinery without ear protection	Operation of or enveloping of large machinery	Disorientation; hearing loss; light-headedness	1B	Hearing protection will be worn when handling large machinery or being around equipment that emits consistent,	3C	PPE enforcement of earmuffs and/or ear plugs ONLY when working around or with loud machinery.

Bearospace @UCLA

Table 15: Personnel Hazard Assessment

				loud sound.		
Injury from falling tools/equipment or materials	Incorrect storage or placement; Stock not secured or fastened	Varied injury: depending on height, may require medical attention	2B	All members will wear closed-toed shoes and long pants before being allowed to enter the lab space. All storage will be fastened and secured before leaving the lab space.	3B	Required shop safety guidelines, proper storage, and clean-up. PPE requires clothing covering the full body.
Falls/ stumbling	Loose cords; wires running across floor; horseplay through lab area	Moderate to severe, varying injury	2B	All lab equipment will be placed in its designated storage area when not in use and be used solely where assigned spaces are available. No crowding. Cords are kept at minimal distance from wall plugs and tucked away from walking pathways.	3C	Consultation of shop safety guidelines & proper lab etiquette enforced.

Table 15: Personnel Hazard Assessment

Inhalation of Lead Fumes	Using lead-based solder	Lead known to cause physical and mental health problems when ingested or inhaled; difficulty breathing	2A	If lead based solder is used, it will be done in an environment with a fan to diffuse the fumes away from the user, under fume hoods, while user wears a respirator mask.	3C	PPE enforcement of P100 respirators.
Shop Fire	Chemical cross contamination & equipment overheating; incorrect wiring; explosion	Moderate to Fatal injuries or death; irreparable damage to equipment and lab space	2A	High power circuitry completed with safety officer present; fire extinguishers kept in shop. Always be aware of one's surroundings and be diligent when working in a lab environment	2B	All lab coats are fire resistant. Fire protocol and exit route is included in all lab safety certified courses.
Caught in a machining equipment	Loose clothing; overhanging jewelry; hair draped over face	Serious injury or death	2B	Those performing machining operations will never wear loose fitting clothing or jewelry. All long hair	3B	Reiteration and consultation of shop safety guidelines. Appropriate clothing worn

Table 15: Personnel Hazard Assessment

				must be tied back.		during workdays.
Physical contact with heat sources	Soldering iron; Contact with Machining tools	Varied degree burns	3B	Lab coats are always on hand and are required when working with all heat-producing tools.	3C	PPE requirement of lab coats; all heat producing tools be turned off when not in use.

Note that all materials and equipment are to be stored appropriately, as outlined by the respective guidelines. These hazards are preemptively identified to mitigate and facilitate an elevated degree of understanding for all members regarding safe practices and procedures.

Environmental Concerns & Hazard Analysis

The following table will exhibit any potential risks associated with interactions between the rocket and the environment before, during, and after launch, and vice versa. We will focus on exclusive interactions between the rocket and various environmental & natural phenomena.

Table 16: Environmental Hazard Assessment

Environmental Hazard Risk Assessment: On Environment						
Risk	**Cause**	**Effect**	**BM**	**Mitigation Strategy**	**PM**	**Verification**
Chemical contamination of groundwater	Leakage of battery fluid or excess fuel post landing in natural body of water.	Electrical components leak toxic chemicals into & contaminate the water & wildlife.	3A	Electrical components provided extra separation from environment within body tube; rocket recovered quickly to minimize exposure time; launch site chosen away from bodies of water.	3C	Consultation of launch operations procedure before and after launch. Launch is no-go if body of water within 2500 feet of launch pad.

Table 16: Environmental Hazard Assessment

Injury to wildlife	Animal contact with launch pad/vehicle mount; vehicle impact during flight or landing	Animal injury/death	3A	Mitigation is attempted by establishing launch away from any area near known wildlife grounds.	3B	Ensure complete inspection to launch operations procedure & constant visual of launch pad throughout launch.
Explosion of rocket and/or excess powder charge combustion	Failure of electronic or payload assembly; motor failure	Large scattering of vehicle debris after explosion	3A	All electronic and payload components adequately secured; motor is pre-approved.	3C	Complete design analysis of components to ensure withstanding internal forces.
Recovery system deployment malfunction	Excess powder charges for number of shear pins	Vehicle destruction upon ground impact; debris scattering	1A	Establish extensive recovery system ground tested & ensure appropriate parachute wrapping.	1C	Verify using analysis of expected deployment of parachute time & ejection necessary. Consult launch operation procedures.
Launch pad fire	The launch vehicle harms the environment around it with the flame of the motor ignition	Heat source damage of surrounding land beneath the launch area and detrimental outcomes to plant	3A	Ensure launch area is clear of underbrush or plant vegetation; launch aborted in extremely	3C	Fire extinguisher is on hand & taken to launch site. Consultation of launch operations procedure

Table 16: Environmental Hazard Assessment

		and animal life		dry conditions.		during launch.
Environmental Hazard Risk Assessment: On Rocket						
Risk	**Cause**	**Effect**	**BM**	**Mitigation Strategy**	**PM**	**Verification**
Launch pad fire	Loose wiring or exposure to outside environment; water damage	Electronics for recovery and payload short circuit	3A	Electronics enveloped separate and sealed away from outside exposure	3C	Fire extinguisher is on hand & taken to launch site. Consultation of launch operations procedure during launch.
Shorting wires and explosions; apogee not reached	Rainfall	Hindrance from arrival at apogee and defer the vehicle course. Soggy land may prove impossible for payload to deploy. Possible shorting of wires and electric shock	3A	Depending on individual circumstances, we may decide that it is best for our vehicle not to fly to safely ensure the wellbeing of the launch day attendees.	3C	Team members and leads would consult the RSO and establish ways to proceed
Excess weather rocking	Large wind speeds	Increase drift & unexpected vehicle trajectory; vertical stability complication	2A	Ensure launch vehicle has an ample margin of stability.	2C	Enhanced analysis of vehicle design choice of fins and mass distribution.
Unsafe landing zone; elevated drift	High wind speeds	Increase drift from the launch pad, resulting in unrecovera	3B	If the wind is 20 mph, it is possible that the launch will	3C	Monitor wind levels and await approval from the RSO.

Table 16: Environmental Hazard Assessment

		ble vehicle or land in an area posing additional safety concerns.		be cancelled. Do not launch in wind speeds larger than 20mph.		
Parachute destruction	Excessive wind	Increased vehicle damage due to large horizontal velocity; high drift from pad	3A	If the wind is above 20 mph, it is possible that the launch will be cancelled. Do not launch in wind speeds larger than 20mph.	3C	Monitor wind levels and await approval from the RSO.
Difficulty assembling components in the field	Excess humidity	Distortion of body tube, internal components and/or wooden bulkheads	3A	Weatherproof inner surface of body tube with polyurethane spray	3C	Compliance with fabrication design
Excessive launch rail friction	Misalignment of rail buttons; High temperatures, low humidity	Unexpected vehicle trajectory	3B	Properly align rail buttons; coat rail in DW40/Vaseline	3C	Confirm alignment of rail buttons with design analysis and testing

Launch Vehicle Hazard Analysis

Table 17: Launch Vehicle Hazard Analysis

Launch Vehicle Risk Assessment						
Risk	**Cause**	**Effect**	**BM**	**Mitigation Strategy**	**PM**	**Verification**
Launch pad/ rail failure	Issues concerning the stability	Leads to unpredictable rocket trajectory	3A	Inspect launch pad and rail prior to	3C	Ensure that all personnel are at a

Table 17: Launch Vehicle Hazard Analysis

	of launch pad/ rail			ensure minimum level of stability.		minimum distance from the launch site as established by NAR.
Malfunction in electronics	System failure	May result in failure to deploy/ collect data/ operate as intended	2B	Vigorous testing of separate functions within each part. Electronics Operation Checklist thoroughly completed.	3B	Electronics Operation Checklist thoroughly completed.
Improper deployment of parachute	Failure in electronics. Failure in black powder to separate sections	Will cause damage to launch vehicle as well as payload	2B	Allow time for ground testing of electronics Perform ground tests to ensure enough black powder.	3B	Consult project timeline and operational procedures.
Sections separate prior to indicated altitude of deployment	Structural failure. Failure in electronics, premature activation of black powder	Rocket does not reach apogee and may follow ballistic path	2B	Increased redundancy incorporated into the system. Increased amount of shear pins or creating a more robust coupler.	3C	Consultation of Operation and Pre-Launch Checklist.
Motor retention failure	A drogue chute applies a force great enough to push out motor	The motor may be lost as it detaches completely from the	3A	Ensure centering rings have been well epoxied to inner walls	3C	Ample ground testing to the motor retention system can resist the

Table 17: Launch Vehicle Hazard Analysis

		launch vehicle		of the body tube.		forces place. Consult Operation and Pre-Launch Checklist.
Launch vehicle does not reach minimum velocity before leaving the launch rail	Miscalculation of rocket's mass. Motor failure	Decrease in stability of the launch vehicle; rocket plummets down; possible explosion	3A	Simulations are conducted virtually and physically, checked against one another for redundancy.	3C	Verify with and consult simulations.
Bulkheads do not sustain intended force	Incorrect calculation of forces that bulkheads can support	Intended support provided by bulkheads will no longer secure internal parts. Possible explosion, payload and recovery system damage, and destruction of vehicle	3B	We will ensure the accuracy of calculations using OpenRocket software and test the strength of materials, physically and virtually, used prior to assembly.	3C	Verify that forces encountered by bulkheads can be supported through future flight tests.
GPS tracking malfunction	General malfunction; battery depletion; erroneous code	Unable to locate the launch vehicle in extreme cases	3B	Ensure all batteries fully charged and checked using the voltmeter. GPS rigorously	3C	Consult Operations and Pre-Launch Checklist.

Table 17: Launch Vehicle Hazard Analysis

				tested prior to launch.		

5.4. NAR Safety Code Compliance

NAR/TRA Personnel are launch-vehicle certified members that will be responsible for purchasing, handling, storing, and assembling the rocket's motor, ejection charges, and ignitors. They are to be present at all testing, signing off on all standard operating procedures and overseeing all NAR/TRA safety regulations.

Table 18: NAR Safety Codes and Compliances

Code	Compliance
1. Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.	Team members are only allowed to handle and launch with appropriate certifications: Level 1 certification is required for motor classes H and up, Level 2 is required for motors J and up, and Level 3 will be required for motors M and up. Our team mentor possesses Level 2 clearance certification and will be the sole individual responsible for handling and obtaining the high-power rocket motors used for the launch of our vehicle.
2. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.	Structures team lead and members will be held responsible for ensuring appropriate materials are utilized in the construction of the rocket as outlined in section two above. MSDS research has been elevated, and materials have been compared to ensure adequate selections for the construction of our launch vehicle and payload.
3. Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.	Motors that are purchased are to be exclusively certified and stored safely, as well as only handled by NAR/TRA personnel. Motors will be solely handled and purchased for our high-powered rocket by our team mentor, who possesses Level 2 certification.
4. Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not	The safety officer and team leads will be responsible for proper ignition system installation as outlined in the code. All launch pad procedures have been briefed to team leads and the standing safety officer.

Table 18: NAR Safety Codes and Compliances

installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.	
5. Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.	The team will collectively ensure that in the case of a misfire, the battery is disconnected, and 60 seconds have elapsed before anyone is to approach the rocket. Note that the Range Safety Officer has encompassing final decisions; therefore, alterations may be addressed by the RSO and additional limitations/regulations may be subject to realize.
6. Launch Safety. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.	As stated, the team will follow the appropriate launch safety guidelines set forth at the launch site, by the Range Safety Officer, and at a safe distance away from the launch pad. Rocket stability will be checked. Center of gravity and center of pressure will be presumptively identified and labeled on the launch vehicle. In addition, a hard copy of 2020 NASA Student Launch Handbook and Request for Proposal has been obtained for our records. This allows us to have resources such as the minimum distance table on hand.
7. Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour, I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible	The team will ensure that the stability of the rocket is safe for launch and that all parameters are approved by the Range Safety Officer for proper flight and that the launch field is properly equipped, maintaining safe distances away. All team members have been briefed on and understand the importance of maintaining a safe distance away from the launch pad before the vehicle is set to launch. To safely comply with the standards of the code, we will ensure that our offset vertical degree amount is well within the 20-degree threshold and is dependent on the wind speeds on launch day and time.

Table 18: NAR Safety Codes and Compliances

material if the rocket motor being launched uses titanium sponge in the propellant.	
8. Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high-power rocket motor(s) intended to be ignited at launch.	All leads will collectively ensure the size and design of the rocket satisfies the requirement and will adhere to the constraints set forth. Our predetermined dimensions have all been designed well within the bounds set forth by the code. All possible design options consider the restrictions and allow for marginal freedom to expand pot-design and
9. Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.	The guideline set for all flight safety will be followed in conjunction with directions provided from the Range Safety Officer, who has the final say on all launches.
10. Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).	The team leads and Safety Officer will ensure that the team complies with all regulations regarding the location of the launch site. The launch is to take place in a large, open area with preset parameters that are to be strictly adhered to regarding safe launching. In addition, a hard copy of 2020 NASA Student Launch Handbook and Request for Proposal has been obtained for our records, allowing us to have resources such as the minimum distance table available. The vehicle and payload 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.
11. Launcher Location. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.	The Safety Officer and team leads will ensure that the launch is positioned away from all persons and property. The launcher will strictly adhere to the launcher location parameters and remain at a safe distance away from the launch pad. All team members have read through the 2020 Handbook and recognize the importance of adhering to the minimum personnel distance as outlined by the regulations.

Table 18: NAR Safety Codes and Compliances

12. Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.	All team leads and Safety Officer will ensure the rocket is successfully designed with an excellent recovery system that abides to the guidelines set forth. In addition, our recovery system electronics will not be adversely affected by any other on-board electronic devices during flight. It will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting devices.
13. Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.	The team leads and Safety Officer will collectively ensure that the team safely recovers the rocket by abiding to the preset guidelines. We will collectively wait for approval from the RSO in case of potentially hazardous conditions that may be encountered.

Hazardous Materials

All team members will be required to consult MSDS whenever dealing with unknown or hazardous materials. Hazardous material will be disposed of by coordinating with UCLA's Environmental Health and Safety office, complying with their guidelines and appropriately written procedures. Commonly used materials for the rocket's manufacturing include quick set epoxy, acetone, graphite, and WD-40: all of which will be handled with gloves and respirators. If hazardous materials such as fiberglass or carbon fiber are being cut, it will be done in a well-ventilated area, with all members involved wearing respirators, gloves, goggles, and lab coats. Any additional materials that exhibit large corrosive, flammable, or health indices will be reviewed and precautions will be taken to mitigate potential risks.

6. Project Plan

6.1 Requirement Verification

6.1.1 Competition Requirements

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
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). Teams will submit new work. Excessive use of past work will merit penalties.	Demonstration	Team has been and plans to continue to continue work needed for competition, excluding tasks requiring a mentor.	In Progress
1.2. The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	Demonstration	Finance lead maintains general project plan with milestones, budget, and STEM engagement with assistance from the Project Manager. Individual subteam leads maintain personnel assignments and checklists relevant to their team. Safety Officer maintains risks, mitigations, and checklists throughout project.	In Progress
1.3. Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during certain activities on site at Marshall Space Flight Center.	Demonstration	Foreign National members will be identified by PDR submission.	Complete

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
1.4. The team must identify all team members attending launch week activities by the Critical Design Review (CDR). Team members will include: 1.4.1. Students actively engaged in the project throughout the entire year. 1.4.2. One mentor (see requirement 1.13). 1.4.3. No more than two adult educators.	Demonstration	Selected team member, team mentor, and adult educators attending launch week will be identified by CDR submission	Planned
1.5. The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities. These activities can be conducted in-person or virtually. To satisfy this requirement, all events must occur between project acceptance and the FRR due date. The STEM Engagement Activity Report must be submitted via email within two weeks of the completion of each event. A template of the STEM Engagement Activity Report can be found on pages 36-38.	Demonstration	Bearospace at UCLA will partner with SOLES, NSBE, and AISES at UCLA to aid their STEM outreach efforts.	Planned
1.6. The team will establish a social media presence to inform the public about team activities	Demonstration	A multi-platform media presence will be established and updated by the social media coordinator.	Planned
1.7. Teams will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. If a deliverable is too large to attach to an email, inclusion of a link to download the file will be sufficient. Late submissions of milestone documents will be accepted up to 72 hours after the submission deadline. Late submissions will incur an overall penalty. No milestone documents will be accepted beyond the 72-hour window. Teams that fail to submit milestone documents will be eliminated from the project.	Demonstration	All deliverables will be emailed on time to correct personnel.	In Progress
1.8. All deliverables must be in PDF format.	Demonstration	All deliverables will be in PDF format.	In Progress

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
1.9. In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Demonstration	Table of Contents will be included in all reports	In Progress
1.10. In every report, the team will include the page number at the bottom of the page.	Demonstration	Page Number will be on every page of every report.	In Progress
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. Cellular phones should be used for speakerphone capability only as a last resort.	Demonstration	Equipment necessary for virtual presentations will be acquired before presentation date and properly tested prior to presentation.	In Progress
1.12. All teams attending Launch Week will be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted at the NASA Launch Complex. At launch, 8-foot 1010 rails and 12-foot 1515 rails will be provided. The launch rails will be canted 5 to 10 degrees away from the crowd on Launch Day. The exact cant will depend on Launch Day wind conditions.	Demonstration / Analysis	Launch vehicle will be designed to be compatible with available launch rods and will be utilized at launch. No custom pad will be used. Rail cannot be considered in flight simulations.	In Progress
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 National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to Launch Week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the	Demonstration	A qualified mentor has been identified	Completed

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
team and mentor attend launch week in April.			
1.14 Teams will track and report the number of hours spent working on each milestone.	Demonstration	Hours will be tracked and reported by all members of the team.	In Progress
2.1. The vehicle will deliver the payload to an apogee altitude between 3,500 and 5,500 feet above ground level (AGL). Teams flying below 3,000 feet or above 6,000 feet on Launch Day will receive zero altitude points towards their overall project score and will not be eligible for the Altitude Award.	Analysis, Test, Demonstration	OpenRocket will be utilized to design a launch vehicle that can comply with this requirement. Test launch will be utilized to confirm simulation expectations. Both these actions should prepare the vehicle to meet this requirement on launch day.	In Progress
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.	Analysis, Demonstration	OpenRocket and RockSim will be utilized to predict and declare a target altitude. This altitude will be submitted with the PDR.	Complete
2.3. The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner. The Altitude Award will be given to the team with the smallest difference between their measured apogee and their official target altitude on Launch Day. This altimeter may also be used for deployment purposes (see Requirement 3.4)	Inspection	The vehicle will contain two different commercially available altimeters for redundancy.	In Progress
2.4. 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.	Inspection	Launch vehicle will be designed to be reusable meaning it is designed to be able to withstand flight forces. This will be confirmed on the demonstration flight before launch day by examining any damage to vehicle body and defining no damage as reusable.	In Progress
2.5. The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main	Analysis, Inspection	Launch vehicle will be designed to have 3 independent sections tethered together.	In Progress

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
vehicle or is recovered separately from the main vehicle using its own parachute.			
2.5.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length.	Analysis, Inspection	Shoulders will be 1 body diameter in length.	In Progress
2.5.2. Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	Analysis, Inspection	Nosecone shoulders will be at least ½ body diameter in length.	In Progress
2.6. 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.	Demonstration	Vehicle will be fully completed before launch day and launch readiness checklist will be created to minimize flight preparation time or confusion.	Incomplete
2.7. The launch vehicle and payload 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, although the capability to withstand longer delays is highly encouraged.	Analysis, Test, Demonstration	Electronics will be selected so they can last a minimum 4-hour lifetime. This will be tested at some point before launch. Materials of the launch vehicle will be chosen to remain in launch-ready configuration. This will be tested prior to launch day.	In Progress
2.8. 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.	Demonstration	Motor will be compatible with this ignition system.	In Progress
2.9. 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).	Demonstration	Vehicle will not be designed to need ground systems beyond what is provided.	In Progress
2.10. 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 National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	Analysis, Inspection	Vehicle will be designed to utilize a motor within these specifications and motor will be declared at CDR. Valid motor choice will be confirmed with the NAR/TRA mentor.	In Progress

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
2.10.1. Final motor choices will be declared by the Critical Design Review (CDR) milestone.	Demonstration	Motor will be declared at CDR.	Planned
2.10.2. Any motor change after CDR must be approved by the NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment will not be approved. 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.	Inspection	Motor change post-CDR will be approved by NAS RSO if needed.	Not Needed
2.11. The launch vehicle will be limited to a single stage.	Demonstration	Vehicle will be designed to be single stage.	In Progress
2.12. 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).	Analysis, Demonstration	Motor choice will be L-class impulse or lower.	In Progress
2.13. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:	Pressure vessels will not be used		
2.13.1. 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.			
2.13.2. Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and can withstand the maximum pressure and flow rate of the tank.			
2.13.3. The full pedigree of the tank will be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.			
2.14. 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.	Analysis, Test	Vehicle will be designed to have a static stability margin above 2.0 at rail exit point. This will be confirmed using	Completed

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
		simulation software at many different conditions.	
2.15. Any structural protuberance on the rocket will be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	Analysis, Inspection	Vehicle will be designed to meet this criterion. Will be verified post-launch by finding real center of gravity and examination of structural protuberances.	In Progress
2.16. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	Analysis, Test	Vehicle will be designed to have a rail exit velocity above 52 fps. This will be confirmed using simulation software.	In Progress
2.17. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline. Subscale flight data will be reported at the CDR milestone. Subscales are not required to be high power rockets.	Demonstration	Team will fabricate and launch sub-scale vehicle before CDR submission. Subscale flight data will be included on CDR.	Planned
2.17.1. 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.	Analysis, Demonstration	Team will design a subscale vehicle that closely resembles full-scale design. All deviations will be approved by NASA.	Planned
2.17.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude.	Demonstration	Subscale vehicle will carry altimeter to record apogee altitude.	Planned
2.17.3. The subscale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	Demonstration	Subscale will be newly fabricated vehicle.	Planned
2.17.4. Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.	Demonstration.	CDR will include proof of successful subscale flight.	Planned
2.18. All teams will complete demonstration flights as outlined below.	-	-	-
2.18.1. 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	Team will fabricate and launch full-scale rocket to verify its stability, structural integrity, recovery systems, and team's ability to prepare the launch vehicle for flight.	Planned

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
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.). The following criteria must be met during the full-scale demonstration flight:		The full-scale rocket used in the demonstration will also be used on launch day.	
2.18.1.1. The vehicle and recovery system will have functioned as designed.	Demonstration	Vehicle will have recovery system planned for full-scale vehicle and success will be seen during flight.	Planned
2.18.1.2. The full-scale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	Demonstration	Vehicle will be fabricated from scratch.	Planned
2.18.1.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:	-	-	-
2.18.1.3.1. If the payload is not flown, mass simulators will be used to simulate the payload mass.	Demonstration	Either payload or mass closely resembling payload will be flown in full scale vehicle.	Planned
2.18.1.3.2. The mass simulators will be in the same approximate location on the rocket as the missing payload mass.	Analysis, Demonstration	Mass simulations, if used, will be placed so center of masses align with projected payload center of mass as placed in the design of the launch vehicle.	Planned
2.18.1.4. If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.	N/A		
2.18.1.5. Teams shall fly the launch day motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the launch day motor or in other extenuating circumstances.	Demonstration	Declared motor will be flown at vehicle demonstration or a request waiver will be filed.	Planned

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
2.18.1.6. The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the maximum amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.	Demonstration	Full-scale demonstration will be designed to be identical to actual flight, with exception of the payload	Planned
2.18.1.7. After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer (RSO).	Demonstration	No components will be modified post-full-scale demonstration unless approved by NASA RSO.	Planned
2.18.1.8. Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement.	Demonstration	FRR will contain proof of successful flight, including flight data collected.	Planned
2.18.1.9. Vehicle Demonstration flights must be completed by the FRR submission deadline. No exceptions will be made. 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	Vehicle demonstration will be planned to take place well in advance of the FRR and data will be included in the FRR.	Planned
2.18.2. 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. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent and the payload is fully retained until it is deployed (if applicable) as designed. The following criteria must be met during the Payload Demonstration Flight:	Demonstration	Payload demonstration flight will be planned to occur well before the deadline in the case it must be rescheduled due to weather	Planned

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
2.18.2.1. The payload must be fully retained until the intended point of deployment (if applicable), all retention mechanisms must function as designed, and the retention mechanism must not sustain damage requiring repair.	Demonstration, Inspection	Payload will be loaded appropriately into the launch vehicle pre-launch. Post-launch the payload and retention system will be examined for any visible damage.	Planned
2.18.2.2. The payload flown must be the final, active version.	Demonstration	Payload flown will be as discussed in all design reports. Payload will not be flown until fully functional as determined by team leads.	Planned
2.18.2.3. If the above criteria are 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.	-	-	-
2.18.2.4. Payload Demonstration Flights must be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.	Demonstration	Payload flight demonstration will be planned to occur well before the deadline in the case weather causes rescheduling.	Planned
2.19. An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA required Vehicle Demonstration Re-flight after the submission of the FRR Report.	Demonstration	Team will comply if a re-flight is asked for.	Planned
2.19.1. 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 a final competition launch.			
2.19.2. 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 a final competition launch.	Demonstration	Team understands this and plans to complete the payload demonstration appropriately.	Planned
2.19.3. 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	Demonstration	Team will petition for flight of payload if payload demonstration flight is unsuccessful.	Planned

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
RSO or the Review Panel have any safety concerns.			
2.20. 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.	Inspection	Team lead or mentor contact information will be listed easily visible on the vehicle prior to the time at launch.	Planned
2.21. All Lithium Polymer batteries will be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	Demonstration	Lithium Polymer batteries will be harbored within bright red 3D printed plastic enclosures to be distinguished as a fire hazard. They will also be sealed from any explosive sources.	Planned
2.22. Vehicle Prohibitions	-	-	-
2.22.1. The launch vehicle will not utilize forward firing motors.	Analysis, Inspection	Vehicle will not be designed to utilize forward canards.	Complete
2.22.2. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skid mark, MetalStorm, etc.)	Demonstration	Launch vehicle will be designed to only use approved motors.	Complete
2.22.3. The launch vehicle will not utilize hybrid motors.			
2.22.4. The launch vehicle will not utilize a cluster of motors.			
2.22.5. The launch vehicle will not utilize friction fitting for motors.	Demonstration	Motors will not utilize friction fitting and confirmed by mentor	Complete
2.22.6. The launch vehicle will not exceed Mach 1 at any point during flight.	Analysis, Test	Simulation software is used during design of the vehicle to ensure maximum speeds is well below Mach 1. Vehicle demonstration will prove this.	Complete
2.22.7. 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 an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	Analysis, Inspection	Rocket will not carry more than the maximum amount of ballast as determined by its measured pre-launch weight.	Complete

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
2.22.8. Transmissions from onboard transmitters, which are active at any point prior to landing, will not exceed 250 mW of power (per transmitter).	Analysis, Inspection	All transmitters will be selected with a power rating less than 250 mW.	In Progress
2.22.9 Transmitters will not create excessive interference. Teams will utilize unique frequencies, handshake/passcode systems, or other means to mitigate interference caused to or received from other teams.	Test, Demonstration	All transmitters will communicate to the team using frequency hopping to prevent interference with other teams.	In Progress
2.22.10. 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.	Analysis, Inspection	No heavy metal will be included in design of the vehicle. Only a small amount of aluminum, a lightweight metal, is used for the bottom of the vehicle for strength purposes.	Complete
3.1. The full-scale launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee, and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue stage descent is reasonable, as deemed by the RSO.	Analysis, Demonstration	Vehicle will be designed to utilize dual deployment, with drogue deployment occurring at apogee and main deployment occurring at some lower altitude as determined by deployment speed and descension time. This will be demonstrated at launch and full-scale verification flight.	In Progress
3.1.1. The main parachute shall be deployed no lower than 500 feet.	Analysis, Demonstration	Vehicle will be designed to deploy main parachute above 500 ft gal. Redundant altimeters will be used to ensure this. This will be demonstrated at the full-scale launch.	In Progress
3.1.2. The apogee event may contain a delay of no more than 2 seconds.	Analysis, Demonstration	Vehicle will be designed to have to delay at apogee to fulfill this requirement. Redundant altimeters will be used to ensure this.	In Progress
3.1.3. Motor ejection is not a permissible form of primary or secondary deployment.	Analysis, Demonstration	Vehicle will not deploy motor at any point during or post flight. Motor retainer will ensure this.	In Progress

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
3.2. Each team will perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full-scale vehicles.	Demonstration	Team mentor will be present at all demonstration flights and will assist with the completion of all tests. These tests will also be included in pre-launch safety checklists to ensure completion.	In Progress
3.3. Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing.	Analysis, Test, Demonstration	OpenRocket will be utilized to analyze weights of individual tethered sections as well as landing speed to ensure completion of this. Main parachute deployment can be altered to alter speed and kinetic energy at landing. This will be verified during full scale launch.	In Progress
3.4. The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.	Inspection	Two commercial altimeters have been selected. The Missile Works RRC3 and Stratologger SL100	In Progress
3.5. Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.	Demonstration	Each altimeter will be individually powered using 9V alkaline batteries	Planned
3.6. 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.	Test, Inspection	Two small mechanical pushbuttons will be used as arming switches. The pushbuttons will be able to withstand the necessary current and voltage needed to power the altimeters.	In Progress
3.7. Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	Test, Inspection	Pushbuttons will be selected such that when pressed (turned on), the button is no longer protruding from the body of the launch vehicle.	In Progress
3.8. The recovery system electrical circuits will be completely independent of any payload electrical circuits.	Demonstration	All recovery components will be housed in the avionics of the launch vehicle. This is separated from payload electronics using pine wood bulkheads.	Planned

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
3.9. Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	Demonstration	Shear pin placement will be placed in pre-launch procedures to ensure completion.	In Progress
3.10. The recovery area will be limited to a 2,500 ft. radius from the launch pads.	Analysis, Test, Demonstration	Simulation software will be utilized with varying wind conditions to ensure recovery area complies with this restriction. Full scale demonstration will verify simulation.	In Progress
3.11. Descent time will be limited to 90 seconds (apogee to touch down). The jettisoned payload (planetary lander) is not subject to this constraint.	Analysis, Test, Demonstration	Simulation software will be utilized to ensure this. Main parachute deployment time can be altered to comply if needed. This will be verified at full scale demonstration.	In Progress
3.12. 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.	Test, Demonstration	The Missile Works Tiny Telematics Tracker system will be used to transmit the launch vehicle's location from at least a mile radius to the team.	Planned
3.12.1. Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device	Inspection, Demonstration	All rocket components and payload will land tethered with a main tracking device.	Planned
3.12.2. The electronic tracking device(s) will be fully functional during the official flight on Launch Day.	Testing, Inspection	Testing of the GPS system will occur before full-scale launch and connection will be visually verified on launch date.	Planned
3.13. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	Demonstration	All electronics within the avionics bay will not interfere or make use of any connections designated for recovery system electronics.	In Progress
3.13.1. 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.	Demonstration	An avionics bay within the launch vehicle will separate radio telecommunication electronics from recovery system electronics. Other low-powered electronics will be housed within the	Planned

Bearospace @UCLA

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
		avionics bay. Bulkheads will be used to shield the avionics bay from the rest of the vehicle.	
3.13.2. The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.	Test, Demonstration	Recovery system electronics will be housed within the avionics bay which separates all electronics from onboard transmitting devices.	Planned
3.13.3. 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.	Demonstration	Besides wires carrying current between low-amperage electronic devices, no magnetic-field producing devices will be used, so no additional shielding is required.	Planned
3.13.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	Demonstration	Recovery electronics will be adequately shielded within the avionics bay and will be tested for functionality.	In Progress
4.1. High School/Middle School Division – Teams may design their own science or engineering experiment or may choose to complete the College/University Division mission. Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.	N/A		
4.2. College/University Division – Teams will design a planetary landing system to be launched in a high-power rocket. The lander system will be capable of being jettisoned from the rocket during descent, landing in an upright configuration or autonomously up righting after landing. The system will self-level within a five-degree tolerance from vertical. After autonomously up righting and self-leveling, it will take a 360-degree panoramic photo of the landing site and transmit the photo to the team. The method(s)/design(s) utilized to complete the payload mission will be at the teams' discretion and will be permitted so long as	Demonstration	Payload subteam will develop original design to fulfill challenge. Safety officer will analyze any safety or legal concerns. These will be reviewed by NASA RSO.	In Progress

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge.			
4.3. Primary Landing System Mission Requirements	-	-	-
4.3.1. The landing system will be completely jettisoned from the rocket at an altitude between 500 and 1,000 ft. AGL. The landing system will not be subject to the maximum descent time requirement (Requirement 3.11) but must land within the external borders of the launch field. The landing system will not be tethered to the launch vehicle upon landing.	Analysis, Demonstration	Payload will be designed to be retained with all components in the launch vehicle and able to function independent of any additional hardware upon landing. This will be demonstrated at payload demonstration flight.	In Progress
4.3.2. The landing system will land in an upright orientation or will be capable of reorienting itself to an upright configuration after landing. Any system designed to reorient the lander must be completely autonomous.	Demonstration	Payload will be able to identify collection zone and collect sample from it. This will be demonstrated at payload demonstration flight.	In Progress
4.3.3. The landing system will self-level to within a five-degree tolerance from vertical.	Analysis, Test	Payload will be designed to be able to collect and retain more than the minimum of 10mL of sample. This will be verified through testing or collection and retention.	In Progress
4.3.3.1. Any system designed to level the lander must be completely autonomous.	Test, Demonstration	Testing will be done to ensure retention of sample post-collection for the necessary 10ft away from the collection zone.	In Progress
4.3.3.2. The landing system must record the initial angle after landing, relative to vertical, as well as the final angle, after reorientation and self-leveling. This data should be reported in the Post Launch Assessment Report (PLAR).	Demonstration	Safety officer will review all team plans to ensure compliance with all federal rules and regulations.	In Progress
4.3.4. Upon completion or reorientation and self-levelling, the lander will produce a 360-degree panoramic image of the landing site and transmit it to the team.	Analysis, Demonstration	Payload will not be designed to utilize black powder for ejection purposes. Ejection system will be completely mechanical. This will be demonstrated during payload demonstration flight.	In Progress

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
4.3.4.1. The hardware receiving the image must be located within the team's assigned prep area or the designated viewing area.	Test, Demonstration	Retention system will be designed that is robust enough to retain payload during the entire duration of the flight. Retention system integrity will be tested during payload flight demonstration.	In Progress
4.3.4.2. Only transmitters that were onboard the vehicle during launch will be permitted to operate outside of the viewing or prep areas.	Analysis, Demonstration	Retention system will be designed so premature deployment is not possible under flight conditions. This will be verified with simulation software and demonstrated during payload flight demonstration.	In Progress
4.3.4.3. Onboard payload transmitters are limited to 250mW of RF power while onboard the launch vehicle but may operate at a higher RF power after landing on the planetary surface. Transmitters operating at higher power must be approved by NASA during the design process.	Analysis	Retention system will be tested for structural integrity both virtually and physically. It will again be tested during payload flight demonstration.	In Progress
4.3.4.4. The image should be included in your PLAR.	Analysis	Payload subteam as well as safety officer will analyze retention system to find any modes of failure and test that those found are not possible to achieve during flight.	In Progress
4.4. General Payload Requirements	-	-	-
4.4.1. Black Powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Energetics will not be permitted for any surface operations.	Inspection	Develop a payload design that avoids the use of energetics for its deployment from the launch vehicle or any other tasks.	In Progress
4.4.2. Teams must abide by all FAA and NAR rules and regulations.	Inspection	Safety officer will ensure all FAA and NAR rules are followed.	In Progress
4.4.3. Any experiment element that is jettisoned, except for planetary lander experiments, during the recovery phase will	Inspection	Team does not plan on incorporating an additional experimental element other than the planetary lander.	Incomplete

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
receive real-time RSO permission prior to initiating the jettison event.			
4.4.4. Unmanned aircraft system (UAS) 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 UAS.	Inspection, Demonstration	If UAS is incorporated into the design, the team will design deployment mechanism around this requirement.	Incomplete
4.4.5. Teams flying UASs 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).	Inspection, Analysis, Demonstration	If UAS is incorporated into design, safety officer will ensure all FAA rules are followed.	Incomplete
4.4.6. Any UAS weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle		If UAS weighs more than .55 lbs. it will be registered with the FAA through the safety officer and mentor assistance.	Incomplete
5.1. Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any Launch Day operations.	Demonstration	Safety officer works with subteam leads to create a launch and safety checklist used for all launches. This checklist will be included in the FRR.	Planned
5.2. Each team must identify a student safety officer who will be responsible for all items in section 5.3.	Demonstration	A student safety officer has been named and listed in all reports.	Completed
5.3. The role and responsibilities of the safety officer will include, but are not limited to:	Inspection	Student safety officer works alongside all subteam leads during every part of the design and manufacturing process. Safety officer is present during all manufacturing, testing, and launches to ensure proper safety protocol is followed. If safety officer cannot be present, another lead will be briefed by them on possible safety concerns and mitigations. Safety officer also completes safety portions of all reports to demonstrate adequate	-
5.3.1. Monitor team activities with an emphasis on safety during:			-
5.3.1.1. Design of vehicle and payload			In Progress
5.3.1.2. Construction of vehicle and payload components			Planned
5.3.1.3. Assembly of vehicle and payload			Planned
5.3.1.4. Ground testing of vehicle and payload			Planned
5.3.1.5. Subscale launch test(s)			Planned
5.3.1.6. Full-scale launch test(s)			Planned
5.3.1.7. Launch day			Planned

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
5.3.1.8. Recovery activities		understanding of all safety risks and mitigations.	Planned
5.3.1.9. STEM Engagement Activities			Planned
5.3.2. Implement procedures developed by the team for construction, assembly, launch, and recovery activities.	Demonstration	Safety officer will be present during all build days and other major events to ensure planned procedures are followed appropriately. Safety officer will be aware of all procedures created by subteam leads through pre-event briefing.	In Progress
5.3.3. Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.	Demonstration	These tasks are part of the safety officer's description and will be demonstrated on all reports. MSDS sheets are also always readily available in the lab where all members have access to them.	In Progress
5.3.4. Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	Demonstration	Safety officer is responsible for completing these portions of the reports. They have meetings with and work closely with subteam leads to ensure these sections are adequately in depth.	In Progress
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.	Demonstration	Safety officer works with project manager and team mentor to communicate compliance with all rules for all launches. Any problems are addressed if mentor or RSO communicates issue.	Planned
5.5. Teams will abide by all rules set forth by the FAA.	Demonstration	Safety officer has reviewed FAA rules and ensured vehicle complies with all restrictions.	In progress

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
6.1 NASA Launch Complex	-	-	-
6.1.1. Teams must complete and pass the Launch Readiness Review conducted during Launch Week.	Demonstration	Team will follow all NASA Launch Complex protocol if travel to Huntsville is confirmed (TBD).	Planned
6.1.2. The team mentor must be present and oversee rocket preparation and launch activities.			
6.1.3. The scoring altimeter must be presented to the NASA scoring official upon recovery.			
6.1.4. Teams may launch only once. Any launch attempt resulting in the rocket exiting the launch pad, regardless of the success of the flight, will be considered a launch. Additional flights beyond the initial launch, will not be scored and will not be considered for awards.			
6.2 Commercial Spaceport Launch Site	-	-	-
6.2.1. The launch must occur at a NAR or TRA sanctioned and insured club launch. Exceptions may be approved for launch clubs who are not affiliated with NAR or TRA but provide their own insurance, such as the Friends of Amateur Rocketry. Approval for such exceptions must be granted by NASA prior to the launch.	Demonstration	Team will follow NASA regulations if launching from a home site (TBD).	Planned
6.2.2. Teams must submit their rocket and payload to the launch site Range Safety Officer (RSO) prior to flying the rocket. The RSO will inspect the rocket and payload for flightworthiness and determine if the project is approved for flight. The local RSO will have final authority on whether the team's rocket and payload may be flown.			
6.2.3. The team mentor must be present and oversee rocket preparation and launch activities.			
6.2.4. BOTH the team mentor and the Launch Control Officer shall observe the flight and report any off-nominal events during ascent or recovery on the Launch Certification and Observations Report.			

Table 19: Competition Requirements Verifications

Requirement	Method of Verification	Verification Plan	Status
6.2.5. The scoring altimeter must be presented to BOTH the team's mentor and the Range Safety Officer.			
6.2.6. The mentor, the Range Safety Officer, and the Launch Control Officer must ALL complete the applicable section for the Launch Certification and Observations Report. The Launch Certification and Observations Report document will be provided by NASA upon completion of the FRR milestone and must be returned to NASA by the team mentor upon completion of the launch.			
6.2.7. The Range Safety Officer and Launch Control Officer certifying the team's flight shall be impartial observers and must not be affiliated with the team, individual team members, or the team's academic institution.			
6.2.8. teams may launch only once. Any launch attempt resulting in the rocket exiting the launch pad, regardless of the success of the flight, will be considered a launch. Additional flights beyond the initial launch will not be scored and will not be considered for awards.			

6.1.2 Team Requirements

Team requirements can be seen below. Some of the requirements are consistent with years before due to our consistency in minimizing costs as well as establishing general organization footholds.

Table 20: Team Requirements

Number	Team Requirement	Reason for Enforcement
1. General Requirements		
1.1	Team leads will plan and carry out a member retention strategy that is successful in recruiting at least 10 members who continue the project into the next year.	Project must be sustainable from year to year. Being an underrepresented minority team can limit interest from prospective participants. At least 10 experienced members should always be on the team to ensure quality and correct work is representing our school.

Table 20: Team Requirements

1.2	Industry relations must be established and at least $5,000 must be received in donations to the team from corporate sponsors.	While the team in the past has sustained itself on grants through UCLA, this funding source is not consistent in amount granted or in timely delivery; it is also usually meant for newly established organizations. As the team continues to expand, constant funding sources must be established as well as connections to industry which our members may find useful for the purposes of career development.
1.3	Virtual social events will be planned and carried out by team leads to encourage membership and team bonding throughout the year.	New member communication with team leads is often lacking due to the level of technicality of the team. Social events where new recruits and leads were both present would help increase communication and retention.
1.4	Online presence must be established.	The position of "webmaster" was created, and a team of three people applied and were selected to create a website to present the team and the projects we have worked on. Leads meet with the webmasters to check the progress of the website as well as offer formatting tips.
2. Vehicle Requirements		
2.1	Upper and lower body tubes will be a cumulative sum of 5' in length.	Our team plans on purchasing a body tube, where a 6" diameter and 5' length body tube costs roughly $600. By limiting the purchase to just one of these, our team is saving a considerable amount of funds.
2.3	Fins must have a rectangular leading edge.	Fins are generally cut out of flat sheets of material into a shape determined by the stability of the vehicle. By defining them as rectangular, it eliminates any error that may come through trying to reshape the leading edge into an airfoil or some other shape. Furthermore, the material chosen often creates volatile particulates during cutting and this would minimize any health threats to team members.
2.5	There will be no structural protuberance on the outer frame of the rocket excluding fins and launch lugs.	It is very hard to accurately measure drag on a complex object. By confining any possible protuberances such as wiring or cameras to within the rocket, the drag estimate will be more precise. Also, the subscale model will give more insight to the actual model results since scaling factors of constant objects will not have to be accounted for.

Table 20: Team Requirements

2.6	There will be no vessel harbored in the vehicle for the specific purpose of containing a gas or liquid with pressure significantly above ambient pressure.	Equipment needed to accurately record pressure within the vessel would be costly. Also, failure of the vessel in any way could result in significant damage to the launch vehicle which could cause failure of the recovery system during flight or derailment of the vehicle from the original launch path.
3. Recovery System Requirements		
3.1	No recovery hardware or parachutes will be planned to deploy if the vehicle is traveling faster than 56 ft/s	Parachutes deploying at too high of a speed could result in failure of the retainment hardware or parachute material itself. Delay in altimeters for any reason can cause a complete failure of deployment if the vehicle is descending at too fast a rate.
3.2	Parachutes will have high-visibility coloring for easy visual tracking.	In the case of GPS failure for any reason, visual tracking is the only method of estimating the landing site of the vehicle. By utilizing high-visibility parachutes, visual tracking will be easier regardless of weather conditions.
3.3	Recovery hardware and load-bearing interfaces will be able to take loads expected during flight with a safety margin of 4 for physical testing.	When failure testing, it is better to be conservative in estimating to ensure failure will not occur. A 1.5 safety margin will be added to loading calculations to ensure that no element of the recovery hardware will fail upon deployment. This includes both hardware and any interfaces including screw links, nuts, and any epoxied surfaces.
3.4	All static interfaces must be reinforced with epoxy or screws.	Reinforcing interfaces with epoxy or screws when possible allows for greater load-bearing capabilities so they will be less likely to fail during deployment.
3.5	Altimeter redundancy must be used using two altimeters from two different brands.	Using altimeters from different manufacturers decreases the chance that both will fail due to the same reason if there is a problem during flight. Using different altimeters will verify the accuracy of data acquired by comparing them to each other.
4. Payload Experiment Requirements		
4.1	Payload will use a parachute during its descent.	Using a UAV as the desired descent method will prove too difficult and time consuming. This is exacerbated by the fact that the team is working remotely so communication is hindered.
4.2	Payload will use no more than 4 cameras to complete mission objective.	Using more than 4 cameras is unnecessary since most compact cameras have a viewing angle of 120 degrees. Increasing the number of cameras also means more pins are needed to wire all cameras. Preferably, only one camera would be used and rotated to take pictures.

Table 20: Team Requirements

4.3	Payload will release parachute upon landing.	Releasing the parachute after landing is necessary so the parachute does not interfere with the levelling stage of the payload.
4.4	Payload will use no more than 6 motors for levelling	Using more than 6 motors for levelling is unnecessary since each motor requires multiple pins to wire. Using less motors achieves electrical simplicity and allows for more space for computing electronics to be placed within the payload.

6.2 Budget

Table 21: Bearospace 2020-2021 Budget

Grand Total					**$12,854**
	Expense	**Vendor**	**Projected Units**	**Projected Unit Price**	**Projected Total Price**
Structures	***Totals:***				$2,259
	Contingency			10%	$205
	Body Tube	Public Missiles	1	$450	$450
	Rocket Kit	Apogee Components	1	$265	$265
	Subscale Motor	Apogee Components	1	$72	$72
	L-910 C-Star Motors	Cesaroni Technologies	3	$268	$804
	Coupler	Public Missiles	1	$94	$94
	Fiberglass Sheet	McMaster-Carr	1	$17	$17
	Pine Wood Stock	Anawalt Lumber	4	$12	$48
	75mm Motor Casing	Off We Go Rocketry	1	$144	$144
	Motor Retainer	Apogee Components	1	$76	$76
	Phenolic Tube	Apogee Components	1	$15	$15
	RocketPoxy	Apogee Components	1	$49	$49
	RockSim License	Apogee Components	1	$20	$20
Electrical / Payload	***Totals:***				$462
	Contingency			10%	$42
	Soldering Spool	Adafruit	5	$8	$40
	RRC3 Sport Altimeter	Missile Works	1	$70	$70

Table 21: Bearospace 2020-2021 Budget

	Radiolink 2.4GHz Transmitter	Amazon	1	$54	$54
	Furious FPV 2.4GHz TRX	GetFPV.com	1	$55	$55
	BosCam 2.4GHz VRX	DronesVision	1	$18	$18
	OpenPilot CC3D Evo Flight Controller	Amazon	1	$23	$23
	Racestar BR2212 Brushless DC Motor	Amazon	4	$8	$31
	Micro High Torque Servo	Adafruit	1	$12	$12
	PCB	Amazon	1	$9	$9
	25A 4-in-1 ESC w/ Brake	Amazon	4	$9	$36
	120 Degree NTSC Mini Camera	GetFPV.com	1	$8	$8
	11.1V 3S 4000mAh LiPo	SMC Racing	1	$44	$44
	2.4GHz SMA Antenna (RHCP)	Amazon	2	$30	$60
Recovery	***Totals:***				$226
	Contingency			10%	$21
	Steel Eyebolts	McMaster-Carr	4	$3	$11
	Shear Pins	Apogee Components	1	$4	$4
	Main Parachute	Rocketman Enterprises	1	$120	$120
	Shock Chord	Apogee Components	1	$50	$50
	Fire Cloth	Apogee Components	2	$10	$20
Safety	***Totals:***				$336
	Contingency			10%	$31
	Particle Mask filters		3	$16	$48
	Particle Mask		3	$55	$165
	Gloves (100 pack)	Fisher Scientific	3	$31	$92
Travel	***Totals:***				$9,570
	Contingency			10%	$870
	Lodging	Hotel	4	$500	$2,000
	Uber to LAX	Uber	4	$30	$120
	Car Rental	Enterprise	4	$575	$2,300
	Gas	Gas Stations	4	$50	$200

Table 21: Bearospace 2020-2021 Budget

	Plane Tickets (Round Trip)	Southwest Airlines	18	$220	$3,960
	Uber to UCLA	Uber	4	$30	$120

6.3 Funding

In the previous academic year, UCLA Bearospace had successfully obtained upwards of $2000 dollars in multiple UCLA grants for use in purchasing materials and travel expenses. This upcoming year, funding plan will be twofold: continuing to pursue grants and donations from UCLA organizations and entities, as well as pursuing donations from corporate sponsors.

Firstly, team managers will apply to grants which the team has won in the past. Last year, the UCLA Engineering Alumni Association (EAA) awarded UCLA Bearospace roughly $1200 for purchasing rocket materials. In addition, UCLA Student Organizations, Leadership and Engagement (SOLE) office released the UCLA Leadership Development Fund recently, a grant for covering travel expenses to conferences that promote student leadership development, to which the team successfully applied and won $1875 for travel expenses. Managers plan on applying to this grant again with AISES at UCLA's help. Aside from these two, team managers plan on exploring more opportunities by partnering more closely with UCLA SOLE representatives that have an extensive and positive contributive relationship with AISES at UCLA.

Secondly, the team will pursue corporate donations for UCLA Bearospace. At AISES at UCLA's Industry Advisory Board (IAB) meeting this summer, UCLA Bearospace representatives had the opportunity to meet corporate representatives from Lockheed Martin, Boeing, Northrop Grumman, and others. After this event, we were contacted by Aerospace Corporation to meet and form a funding opportunity during the fiscal year. Team managers were able to create a comprehensive fundraising plan and budget to provide prospective companies in hopes of obtaining corporate donations, and in so doing, establish the beginnings of a working relationship between UCLA Bearospace and corporate sponsors that will continue to provide funding for UCLA Bearospace into the future.

6.4 Timeline

6.4.1 Project Timeline

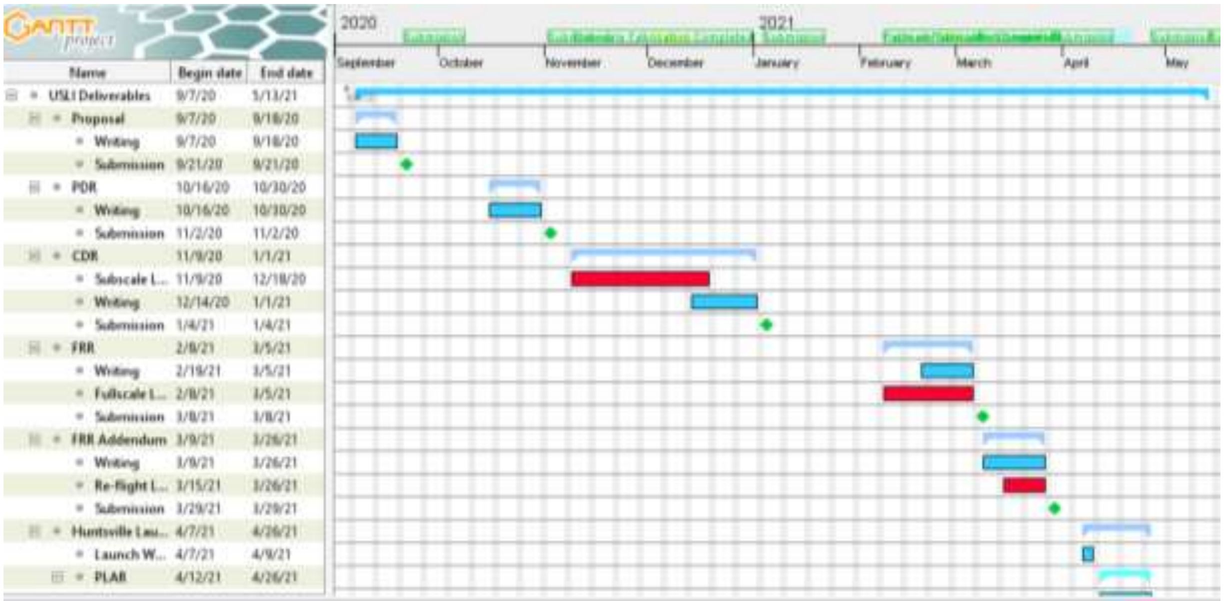


Figure 26: Gantt Chart

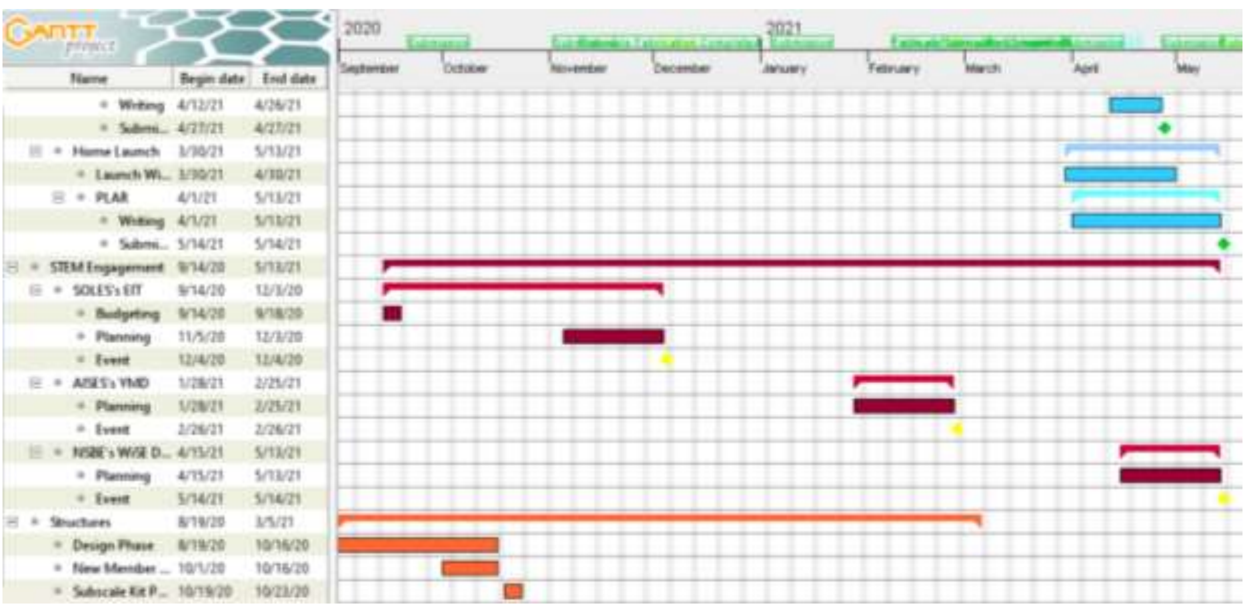


Figure 27: Gantt Chart

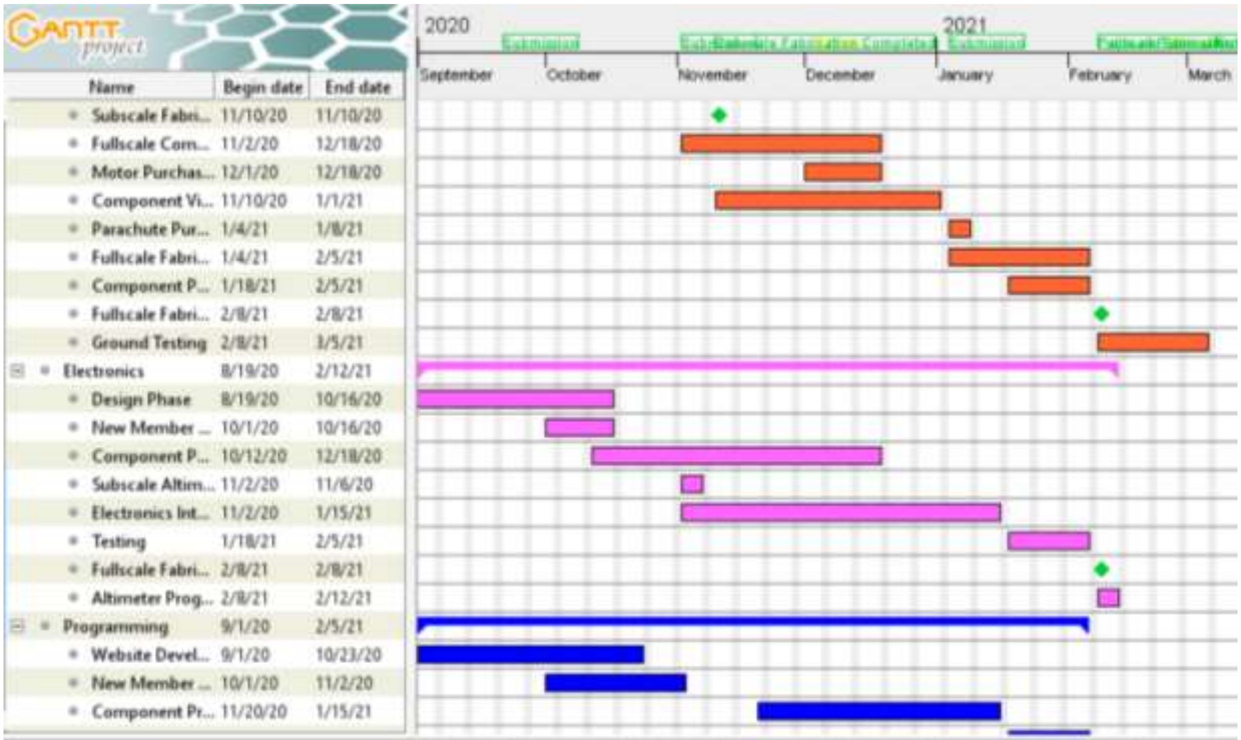


Figure 28: Gantt Chart

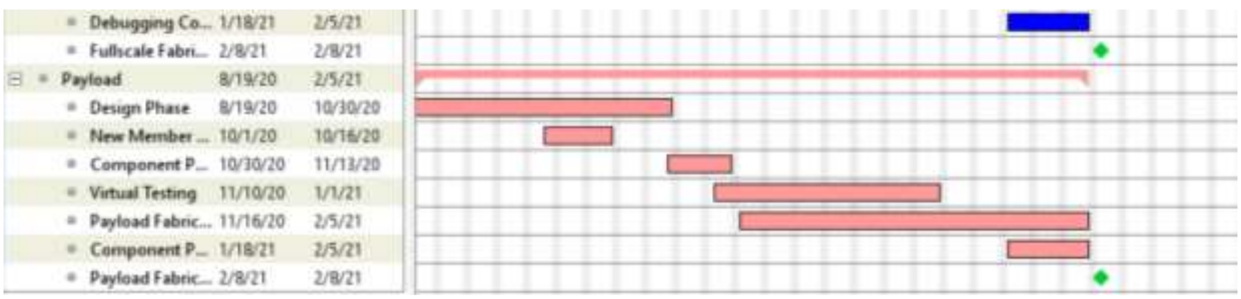


Figure 29: Gantt Chart

For ease of viewing a listing of dates has also been provided below so that both timelines and dates are visible.

Name	Begin date	End date
USLI Deliverables	9/7/20	5/13/21
Proposal	9/7/20	9/18/20
Writing	9/7/20	9/18/20
Submission	9/21/20	9/21/20
PDR	10/16/20	10/30/20
Writing	10/16/20	10/30/20
Submission	11/2/20	11/2/20
CDR	11/9/20	1/1/21
Subscale Launch Window	11/9/20	12/18/20
Writing	12/14/20	1/1/21
Submission	1/4/21	1/4/21
FRR	2/8/21	3/5/21
Writing	2/19/21	3/5/21
Fullscale Launch Window	2/8/21	3/5/21
Submission	3/8/21	3/8/21
FRR Addendum	3/9/21	3/26/21
Writing	3/9/21	3/26/21
Re-flight Launch Window	3/15/21	3/26/21
Submission	3/29/21	3/29/21
Huntsville Launch	4/7/21	4/26/21
Launch Week	4/7/21	4/9/21
PLAR	4/12/21	4/26/21
Writing	4/12/21	4/26/21
Submission	4/27/21	4/27/21
Home Launch	3/30/21	5/13/21
Launch Window	3/30/21	4/30/21
PLAR	4/1/21	5/13/21
Writing	4/1/21	5/13/21
Submission	5/14/21	5/14/21
STEM Engagement	9/14/20	5/13/21
SOLES's EIT	9/14/20	12/3/20
Budgeting	9/14/20	9/18/20
Planning	11/5/20	12/3/20
Event	12/4/20	12/4/20
AISES's YMD	1/28/21	2/25/21
Planning	1/28/21	2/25/21
Event	2/26/21	2/26/21
NSBE's WiSE Day	4/15/21	5/13/21
Planning	4/15/21	5/13/21
Event	5/14/21	5/14/21
Structures	8/19/20	3/5/21
Design Phase	8/19/20	10/16/20

Figure 30: Gantt Chart Dates

Name	Begin date	End date
New Member Training	10/1/20	10/16/20
Subscale Kit Purchase	10/19/20	10/23/20
Subscale Fabrication	10/26/20	11/9/20
Subscale Fabrication Completed	11/10/20	11/10/20
Fullscale Component Purchases	11/2/20	12/18/20
Motor Purchases	12/1/20	12/18/20
Component Virtual Testing	11/10/20	1/1/21
Parachute Purchasing	1/4/21	1/8/21
Fullscale Fabrication	1/4/21	2/5/21
Component Physical Testing	1/18/21	2/5/21
Fullscale Fabrication Completed	2/8/21	2/8/21
Ground Testing	2/8/21	3/5/21
Electronics	8/19/20	2/12/21
Design Phase	8/19/20	10/16/20
New Member Training	10/1/20	10/16/20
Component Purchases	10/12/20	12/18/20
Subscale Altimeter Programming	11/2/20	11/6/20
Electronics Integration and Wiring	11/2/20	1/15/21
Testing	1/18/21	2/5/21
Fullscale Fabrication Completed	2/8/21	2/8/21
Altimeter Programming	2/8/21	2/12/21
Programming	9/1/20	2/5/21
Website Development	9/1/20	10/23/20
New Member Training	10/1/20	11/2/20
Component Programming	11/20/20	1/15/21
Debugging Code	1/18/21	2/5/21
Fullscale Fabrication Completed	2/8/21	2/8/21
Payload	8/19/20	2/5/21
Design Phase	8/19/20	10/30/20
New Member Training	10/1/20	10/16/20
Component Purchases	10/30/20	11/13/20
Virtual Testing	11/10/20	1/1/21
Payload Fabrication	11/16/20	2/5/21
Component Physical Testing	1/18/21	2/5/21
Payload Fabrication Completed	2/8/21	2/8/21

Figure 31:Gantt Chart Dates