Purdue University
Project Grissom

PURDUE SEDS

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1. Summary of PDR

1.1. Team Summary

1.1.1. Team Name And Mailing Address

Purdue University Students for the Exploration and Development of Space
107 MacArthur Drive, Room 150 West Lafayette, Indiana 47906

1.1.2. Name Of Mentor, NAR/TRA Number And Certification Level, Contact Information

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1.2. Launch Vehicle Summary

1.2.1. Size and Mass

Our launch vehicle will be 121” tall when assembled and weigh an estimated 27.4 pounds when not loaded with propellant or motor hardware. The rocket will have a nominal outer diameter of 5.15” and be constructed fully out of filament wound composite fiberglass.

1.2.2. Motor Choice

We are currently planning on using an Aerotech Rocketry L1520 Blue Thunder as our means for propulsion. It is a 75mm diameter, 3 grain motor that produces a total impulse of 3,715 newton seconds over the course of a 2.4 second burn time.

1.2.3. Recovery System

The rocket will utilize standard dual deployment recovery methods, including redundant electronics and ejection charges using a Telemetrum and RRC3+ Sport. A 24” drogue parachute will deploy at apogee, followed by a 100” main parachute at an altitude of 700’ above the ground. The shock cord will consist of 1/2” tubular Kevlar with a 7,200 pound rating.

1.2.4. Milestone Review Flysheet

See attached flysheet.

1.3. Payload Summary

1.3.1. Payload Title

The experimental payload that will be flown in this launch vehicle is a “Target Detection System”.

1.3.2. Payload Experiment Summary

Adjacent to the launch site will be three 40ft x 40ft differently colored tarps. The payload flown will be permanently fixed to the launch vehicle. It will record video of the ground and targets during powered flight. This video will be processed by an onboard computer. The onboard computer will serve to identify the tarps and to distinguish them by their respective colors.

2. Changes Made Since Proposal

2.1. Changes Made To Vehicle

In our original proposal, the vehicle was a 6” diameter rocket with 4 fins. We have since shrunk the rocket diameter to 5” diameter and reduce the fin count to 3. It will be made using the same materials (primarily filament wound fiberglass) and techniques mentioned in the proposal, but will not fly on a smaller motor. We saw a decrease in weight and cost, while we saw an increase in stability.

2.2. Changes Made To Payload

The overall design and functionality of the rocket’s payload has stayed mostly unchanged since the initial project proposal, though there have been numerous design decisions made to further flesh out details of the system. The proprietary Raspberry Pi camera module was selected as the imaging device to interface with the Raspberry Pi. Research showed that this camera module would produce sufficient image quality, while providing the most robust means of connecting with the Raspberry Pi. Additionally, the Anker PowerCore 10,000mAh power supply was chosen as the means of providing continuous power to the Raspberry Pi. Research and testing concluded that this power supply provides more than enough charge to keep the Pi running throughout the launch process. It is estimated that the battery will be able to operate the system for over 4 hours of continued use. Finally, in the software development process, the OpenCV computer vision library with Python 3 bindings was chosen as the platform for image processing. This platform has extensive documentation and research, therefore yielding a framework that can be easily adapted to the needs of this project.

2.3. Changes Made To Project Plan

Generally speaking, there have been no major changes to the project plan as a whole. We have met our educational engagement requirements, but will continue to work with local schools and makerspaces to continue to interact with students of all ages. In addition, the team has been working with the Aeronautical and Aerospace Engineering department to open a student account to begin crowdfunding in addition to soliciting donations, sponsorships, and resources from local businesses. Our timeline has been expanded to include launch dates at Indiana Rocketry Association, and will include more in the future.

3. Vehicle Criteria

3.1. Selection, Design, And Rationale Of Launch Vehicle

3.1.1. Mission Statement And Mission Success Criteria

Our mission is to design, build, fly, and a fully reusable, student built rocket capable of carrying a scientific payload to an altitude of one statute mile. For us to consider the flight a success, the vehicle must:

1. Make a stable ascent.
2. Fully deploy both the drogue and main recovery systems at the proper altitudes.
3. Stay completely tethered and have no freefalling sections.
4. Be flyable again without any repairs or alterations.

3.1.2. Current Vehicle Design

3.1.2.1. Lower Airframe

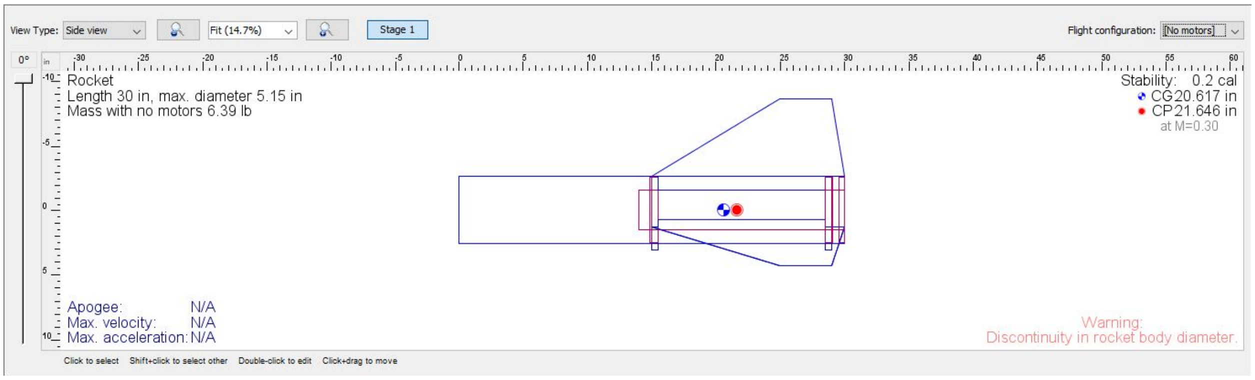
3.1.2.1.1. Design Alternatives With Pros And Cons

While designing the lower airframe, the team initially faced two options: to make no alterations to the lower airframe that was presented in the proposal, or to use a smaller diameter rocket with one less fin. Assuming all material choices are constant, the smaller airframe provided less drag and weight, allowing the team to use a smaller motor. As a result, a smaller rocket would be less expensive to build and fly. By reducing the fin count from three to four fins, the angle between each fin increased from 90° to 120°, giving our camera system a greater unobstructed field of view. On the contrary, a larger rocket is more impressive and less difficult to construct due to increased tolerances and clearances, but is also heavier, more expensive, and has a larger cross section to incur more drag. A larger airframe also gives the team the opportunity to launch larger, heavier payloads in the future should our design for the payload change.

3.1.2.1.2. Leading Choice

After considering all of the drawbacks and benefits of a larger four finned airframe or a smaller three finned airframe, our team elected the latter alternative. As stated, this design choice will save our group weight, drag, and cost while providing the camera system a larger unobstructed field of vision, thus increasing the chance of our mission's success. We also discovered that by reducing the fin count, but not changing the fin profile, the rocket was more stable at launch rail clearance than a larger four finned counterpart. This makes the rocket safer to fly and operate in less than favorable wind conditions.

3.1.2.1.3. Dimensional Drawing



Our lower airframe section will have a 5.15” outer diameter, 5.00” inner diameter, be 30.00” long, and have a fin span of 6.00”. The top 5.00” of the tube will interface with the payload coupler.

3.1.2.1.4. Estimated Mass

As can be seen from the figure above, the estimated weight of the lower airframe of the rocket with the motor mount assembly, thrust plate, rail guides, and fins, is 6.39 pounds. This does not take into account the weight of paint, epoxy adhesive, or metal hardware. We still need to incorporate these objects into the weight figure. Once the section is built, we can obtain a more accurate weight measurement to incorporate into our simulation to better predict altitude and flight parameters.

3.1.2.2. Payload Bay

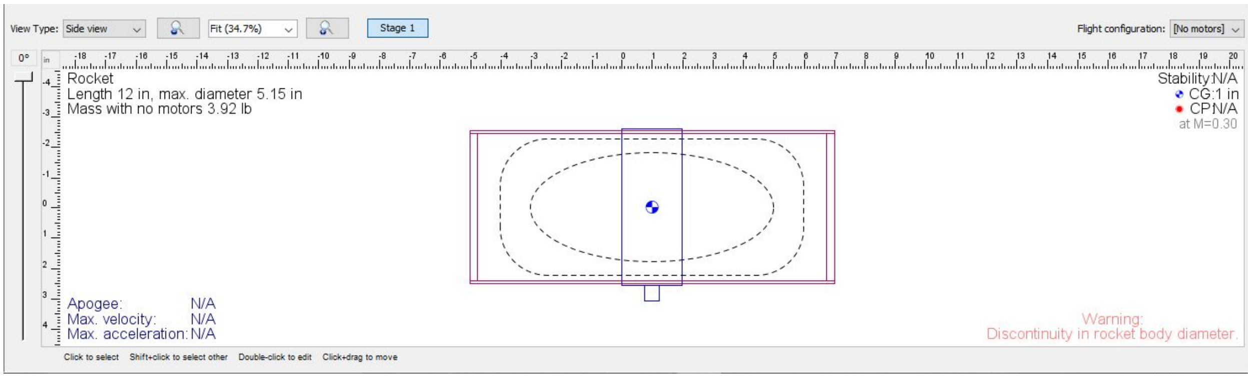
3.1.2.2.1. Design Alternatives With Pros And Cons

Our payload bay construction ultimately only faced two variables, which were the length of the shoulder that would be interfacing with the airframe tubes and whether or not the team felt it was necessary to include a camera band. A coupler with a longer shoulder is more stable and will have less freedom of movement than a short coupler. It would also allow us to carry larger payloads, but would weigh more than the alternative. A camera band, likewise, would add weight to the rocket and require bonding, but would give the camera an area from which it can protrude and not interfere with either the lower or mid airframe section.

3.1.2.2.2. Leading Choice

Our team decided to use a coupler with one caliber of tube interfacing with an airframe on either side. Furthermore, we determined that despite the added complexity, the camera band would make mounting and removal of the cameras easy and worth the effort. As a result, our payload bay is 12.00” long: 5.00” on either end and a 2.00” long camera band. Threaded rods will run through the bulkheads and be secured with nuts and washers, clamping the bulkheads over the ends of the tube and sealing the payload inside from any hot gasses produced during ejection charges.

3.1.2.2.3. Dimensional Drawing



Our payload bay will have an outer diameter of 5.15” at the camera band and 5.00” at the coupler. The inner diameter of the coupler will be 4.815” and will be 12.00” long. The 2.00” camera band will be located at the center of the coupler. 5.00” of both ends of the coupler will interface with airframe sections.

3.1.2.2.4. Estimated Mass

As can be seen from the figure above, the estimated weight of the payload bay of the rocket with the coupler, camera band, bulk plates, rail guide, and payload itself, is 3.92 pounds. This does not take into account the weight of paint, epoxy adhesive, or metal hardware. We still need to incorporate these objects into the weight figure. Once the section is built, we can obtain a more accurate weight measurement to incorporate into our simulation to better predict altitude and flight parameters.

3.1.2.3. Mid Airframe

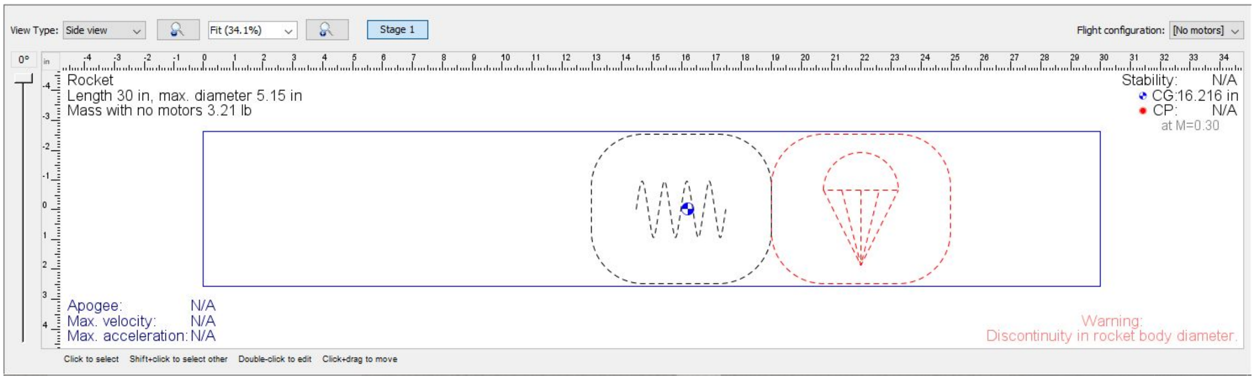
3.1.2.3.1. Design Alternatives With Pros And Cons

The choice our group faced when designing the airframe was to determine the length of the tube necessary for our vehicle. The shorter our airframe was, the lighter our rocket would be, the less volume we would need to pressurize for ejection, and the less expensive our vehicle would become. A shortened tube, though, also moves the center of gravity closer to the end of the rocket and thus reduces stability margins.

3.1.2.3.2. Leading Choice

The team elected to use a standard 30” length of tubing. As a result, we do not need to pay an extra fee to have the tube recut to a custom length and the center of gravity remains as far from the aft of the rocket as possible. This also provides us with ample room to pack our drogue recovery gear in, allowing us to use more of the space for coupler shoulders and to allow for longer couplers in the future if needed.

3.1.2.3.3. Dimensional Drawing



The mid airframe will have an outer diameter of 5.15”, and inner diameter of 5.00”, and will be 30” long. 5.00” of both ends of the tube will be used to interface with coupler tubes, leaving 20.00” of usable room for drogue recovery gear.

3.1.2.3.4. Estimated Mass

As can be seen from the figure above, the estimated weight of the mid airframe section of the rocket with the drogue parachute and shock cord, is 3.21 pounds. This does not take into account the weight of paint or fasteners needed to secure the lower end of the tube to the payload bay coupler. We still need to incorporate these objects into the weight figure. Once the section is built, we can obtain a more accurate weight measurement to incorporate into our simulation to better predict altitude and flight parameters.

3.1.2.4. Avionics Bay

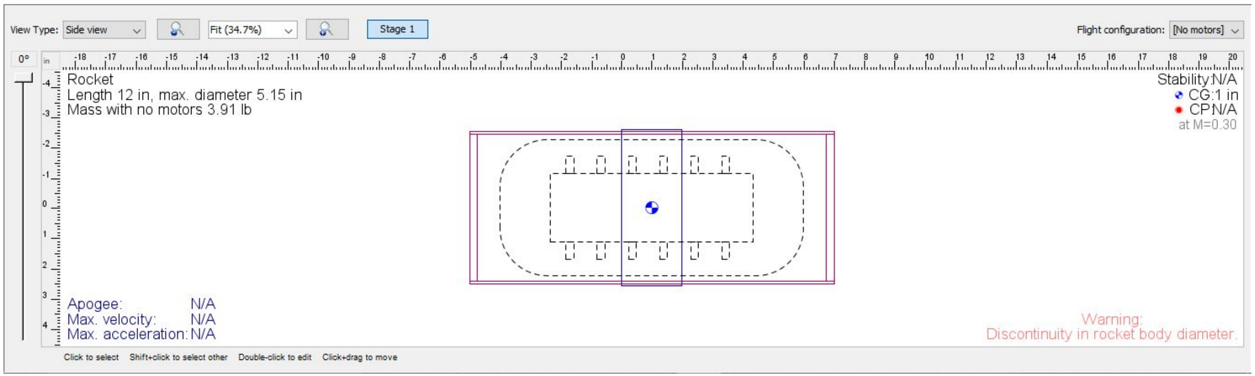
3.1.2.4.1. Design Alternatives With Pros And Cons

Our avionics bay was subject to the same main variables as our payload bay faced, being the length of the coupler tube and the choice of whether or not to include a switch band. The pros and cons were all identical to payload bay design.

3.1.2.4.2. Leading Choice

We decided to design the avionics bay in an identical manner to our payload bay. Our team decided to use a coupler with one caliber of tube interfacing with an airframe on either side. The group determined that despite the added complexity, the switch band would make arming of the altimeters easy and worth the effort. As a result, our payload bay is 12.00” long: 5.00” on either end and a 2.00” long switch band. Threaded rods will run through the bulkheads and be secured with nuts and washers, clamping the bulkheads over the ends of the tube and sealing the avionics inside from any hot gasses produced during ejection charges.

3.1.2.4.3. Dimensional Drawing



Our avionics bay will have an outer diameter of 5.15” at the camera band and 5.00” at the coupler. The inner diameter of the coupler will be 4.815” and will be 12.00” long. The 2.00” camera band will be located at the center of the coupler. 5.00” of both ends of the coupler will interface with airframe sections.

3.1.2.4.4. Estimated Mass

As can be seen from the figure above, the estimated weight of the payload bay of the rocket with the coupler, switch band, bulk plates, and avionics itself, is 3.91 pounds. We still need to incorporate these objects into the weight figure. Once the section is built, we can obtain a more accurate weight measurement to incorporate into our simulation to better predict altitude and flight parameters.

3.1.2.5. Upper Airframe

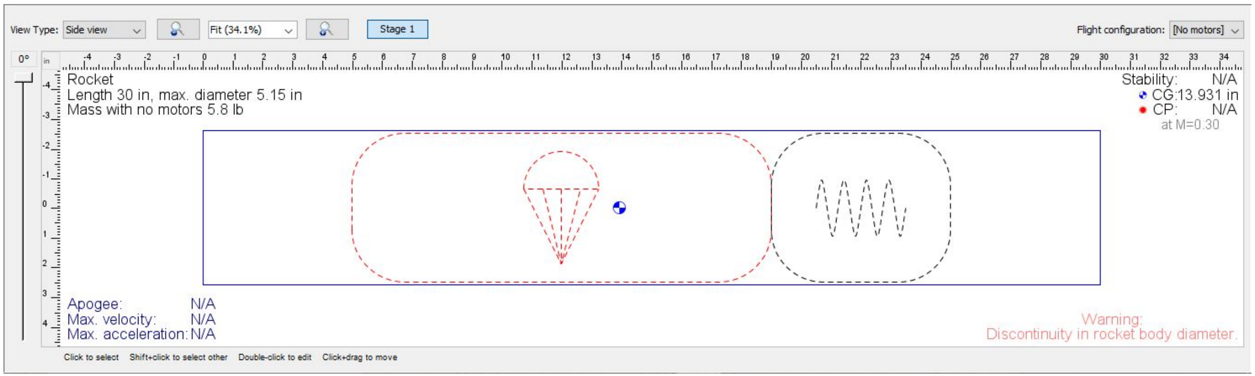
3.1.2.5.1. Design Alternatives With Pros And Cons

The upper airframe faced the same design alternatives as the mid airframe, and thus the same pros and cons. Factors such as weight, cost, volume, and stability were all taken into consideration when choosing the length of the airframe.

3.1.2.5.2. Leading Choice

The team elected to use a standard 30” length of tubing for the same reasons as previously stated for the mid airframe. This length of tube is a standard size and is thus cost efficient and prevents a negative shift of the center of gravity. It also provides us with a tight fit for the main recovery gear, resulting in less volume needing to be pressurized by the main ejection charge for deployment.

3.1.2.5.3. Dimensional Drawing



The mid airframe will have an outer diameter of 5.15”, and inner diameter of 5.00”, and will be 30” long. 5.00” of both ends of the tube will be used to interface with coupler tubes, leaving 20.00” of usable room for main recovery gear.

3.1.2.5.4. Estimated Mass

As can be seen from the figure above, the estimated weight of the mid airframe section of the rocket with the main parachute and shock cord, is 5.8 pounds. This does not take into account the weight of paint or fasteners needed to secure the lower end of the tube to the avionics bay coupler. We still need to incorporate these objects into the weight figure. Once the section is built, we can obtain a more accurate weight measurement to incorporate into our simulation to better predict altitude and flight parameters.

3.1.2.6. Nose Cone

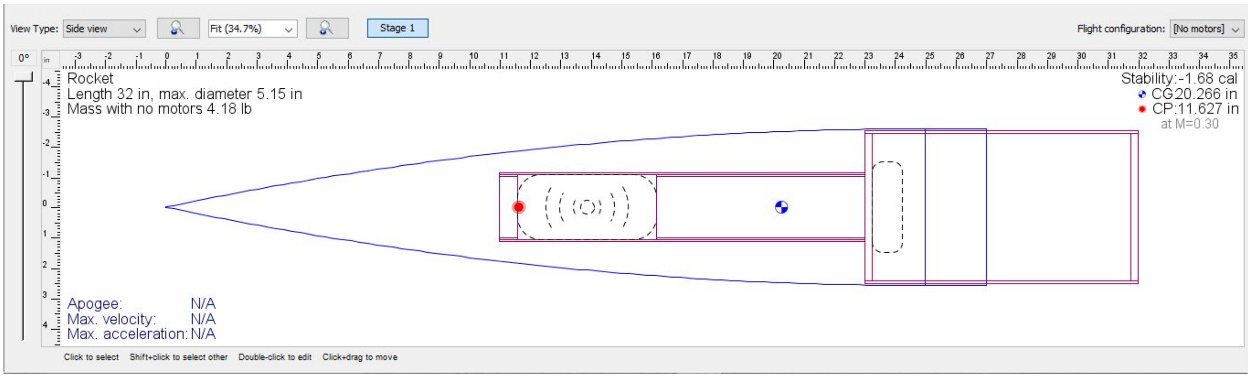
3.1.2.6.1. Design Alternatives With Pros And Cons

The primary concern facing our team with regards to nosecone design was the shape of the nose cone itself. Shorter nosecones would weigh less, but cost the same as a longer nose cone and induces more drag force. Longer nosecones, while heavier, would allow more room for electronics internally, not incur any price increase, and create less drag.

3.1.2.6.2. Leading Choice

Our team decided to use a nose cone with a 5:1 length to diameter ratio with an ogive shape and metal tip. This nose cone reduces drag over those with a lower aspect ratio, and increases the amount of internal space that can be used for mounting additional payloads, electronics, or tracking devices in the future. The metal tip will be secured using a standard bolt and washer, while the coupler will be riveted into place in the base. The coupler will be compressed between two bulkheads held in place by two sections of threaded rod.

3.1.2.6.3. Dimensional Drawing



The nosecone section will be a total of 32.00” long and have a maximum outer diameter of 5.15” at the base of the cone and switch band, and a 5.00” outer diameter at the coupler tube. The nosecone alone is 25” long, and the bottom 2.00” will interface with the nose cone coupler. The switch band is 2.00” long and will be located 2.00” from the top of the coupler tube, leaving 5.00” of coupling exposed to interface with the upper airframe.

3.1.2.6.4. Estimated Mass

As can be seen from the figure above, the estimated weight of the nose cone section of the rocket with the cone, coupler, bulk plates, switch band, and Multitronix Telemetry Pro System, is 4.19 pounds. This does not take into account the weight of paint, epoxy adhesive, or metal hardware. We still need to incorporate these objects into the weight figure. Once the section is built, we can obtain a more accurate weight measurement to incorporate into our simulation to better predict altitude and flight parameters. We have, though, accounted for a ballast placeholder in the coupler tube that currently has no mass in the simulation.

3.1.3. Recovery Subsystem

3.1.3.1. Shock Cord

3.1.3.1.1. Design Alternatives With Pros And Cons

There are several options for us to choose from when determining which shock cord material to utilize in the rocket. For rockets of this size, it is common practice to use either 1” tubular nylon or ½” tubular kevlar. The nylon is cheaper to purchase and more elastic in the event of a premature separation, but it is also bulkier and heavier due to the larger width when compared to the kevlar. Furthermore, it is not fire resistant and does not have as high of a tensile strength as kevlar does. Kevlar is comparatively expensive, but is also fireproof, lighter, and occupies less packing volume within the vehicle. It is also stronger than tubular nylon, but will not stretch to dissipate energy when pulled taunt.

3.1.3.1.2. Leading Choice

We have decided to use a 40’ long section of ½” tubular kevlar as the material for our shock cords in our rocket. As stated previously, they are lightweight, fire resistant, volumetrically efficient, and have a high tensile strength. The tethers we have chosen are rated for 7,200 pounds lifting force, which we believe will be more than adequate for the purpose of this project based on the weight of our rocket. Each end will have a loop sewn into the fabric through which we can pass a quick link for easy attachment to the rocket. In addition, each individual tether, drogue and main, will have a loop sewn ⅓ of the length from the top. This will provide us with an attachment point for the parachute we will be using for recovery.

3.1.3.1.3. Estimated Mass

The estimated mass of the tether, not including the mass of quick links that attach the shock cord to the rocket and parachute, is 0.5 pounds. Once we have obtained the physical component, we will have a more accurate weight measurement that can be updated in our simulation model.

3.1.3.2. Drogue Parachute

3.1.3.2.1. Design Alternatives With Pros And Cons

Several options for drogue recovery were presented with varying methods, sizes, and brands. The team immediately determined that it was not safe to fly without a drogue parachute due to the size and weight of the rocket. It was deemed possible to use a streamer, but streamers provide very little drag and the amount of fabric needed to safely slow and stabilize the rocket during descent would prove too much of a hassle to manage and be too heavy. Ultimately, the team decided to use a traditional parachute that is 24” in diameter. Our group speculates that this will be sufficiently large to slow the rocket to a safe velocity during descent, as well as minimize the risk of individual sections colliding with each other. Furthermore, the team believe that it will provide enough drag to point the camera in such a way that the field of view is still able to recognize the targets we need to identify while free falling.

Once a 24” drogue parachute had been deemed a viable option, the choice had to be made with what brand to use. Our group looked at the Skyangle Cert 3 drogue parachute and the Fruity Chutes Classic Elliptical parachute. The Skyangle parachute has a lower drag coefficient and will result in a faster descent speed and minimal drift distance, but is heavier and bulkier than the Fruity Chute alternative. It was, though, the more economical option. The Fruity Chute could potentially result in an increased drift distance due to the lower descent speed, but would be more stable and have a higher probability of stabilizing the camera to view the targets. It is also lighter and takes less internal volume.

3.1.3.2.2. Leading Choice

Our team ultimately decided to go with the Skyangle Cert 3 Drogue Parachute as a means of drogue recovery. We chose this because although it weighs more, occupies more volume, and has a lower drag coefficient, it is cheaper and more robust. After comparing simulation results using both options, the difference in drogue descent speed was minimal and therefore would not have made a substantial impact. The alternative our team opted for is constructed of zero porosity, 1.9 ounce per square yard, silicone coated balloon cloth. Four shroud lines, each made of ⅝" military spec tubular nylon with a tensile strength of 2,250 pounds. These shroud lines all attach at the bottom to a 1,500 pound rated heavy duty, nickel plated swivel. The parachute has a tested drag coefficient of 1.26 and a surface area of 6.3 square feet. It will be attached to the tether via a ¼" stainless steel quick link that connects through the swivel and a loop in the shock cord.

3.1.3.2.3. Estimated Mass

The estimated mass of the drogue parachute, not including the mass of quick links that attach the parachute to the shock cord or fireproofing, is 0.375 pounds. Once we have obtained the physical component, we will have a more accurate weight measurement that can be updated in our simulation model.

3.1.3.3. Main Parachute

3.1.3.3.1. Design Alternatives With Pros And Cons

Our team decided to examine the Skyangle Cert 3 XL Parachute and the Fruity Chutes 84" Iris Ultra Compact Parachute. As in the case with the drogue parachute options, the Fruity Chute weighed substantially less and maintained a tighter packing volume than the Skyangle. It was also significantly more expensive than the Skyangle, and had a lower drag coefficient. Both parachutes offered a similar landing velocity and touchdown energy. The primary benefit of using the Skyangle, though, is not the cost savings or landing speed. Because it weighs more and will be located above the center of gravity of the vehicle, it adds positive stability during flight. The Fruity Chute does not have this advantage and while we would still be within stability limits if we chose to use this option, we would have less of a safety factor due to the decreased distance between the center of gravity and center of pressure as a result of the weight difference.

3.1.3.3.2. Leading Choice

Our team ultimately decided to go with the Skyangle Cert 3 XL Parachute as a means of main recovery. We chose this because although it weighs more, and occupies more volume, it has a higher drag coefficient. It is also cheaper and more robust than the Fruity Chute alternative. It is still sized to provide a slow enough landing that no section of the rocket touches down with more than 75 foot pounds of energy, as listed in the requirements. Furthermore, it adds more weight above the center of gravity than the

Fruity Chute, increasing our margin of stability. The option our team opted for is constructed of zero porosity, 1.9 ounce per square yard, silicone coated balloon cloth. Four shroud lines, each made of ⅝" military spec tubular nylon with a tensile strength of 2,250 pounds. These shroud lines all attach at the bottom to a 1,500 pound rated heavy duty, nickel plated swivel. The parachute has a tested drag coefficient of 2.59 and a surface area of 89.0 square feet. It will be attached to the tether via a ¼" stainless steel quick link that connects through the swivel and a loop in the shock cord.

3.1.3.3.3. Estimated Mass

The estimated mass of the main parachute, not including the mass of quick links that attach the parachute to the shock cord or fireproofing, is 3.81 pounds. Once we have obtained the physical component, we will have a more accurate weight measurement that can be updated in our simulation model.

3.1.3.4. Fireproofing

3.1.3.4.1. Design Alternatives With Pros And Cons

Fireproofing recovery components such as parachutes in high power rockets is typically done in one of two ways. One option is to use an phenolic insulating material commonly known as "dog barf" that can conform to whatever space it is pressed into. This material is extremely lightweight, inexpensive, and can be added into vacant spaces within the airframe around the recovery components due to its small particle size. The alternative to this is typical a typical nomex blanket that wraps around the recovery gear and acts as a barrier between the nylon and the hot gases produced from the ejection charge. Unlike the phenolic insulation, this option is reusable while still remaining lightweight and inexpensive, and can be attached directly to the parachutes.

3.1.3.4.2. Leading Choice

Our team decided to use the Nomex blankets as a means of fireproofing our parachutes from the ejection charge gases. They are Relatively inexpensive and lightweight, but the main advantage is that it can be passed over the shock cord and attached directly to the parachute. As a result, we can tightly wrap the parachute inside of the material, as opposed to simply packing insulation around it and risk a gap in the fireproofing. Both the drogue and main parachute will be protected using this method, and both Nomex blankets will be 18"x18" squares.

3.1.3.4.3. Estimated Mass

We estimate that the total mass of both the drogue and main Nomex blankets is approximately 0.25 pounds. Once we have obtained the physical component, we will have a more accurate weight measurement that can be updated in our simulation model.

3.1.3.5. Ejection Charges

3.1.3.5.1. Design Alternatives With Pros And Cons

For the ejection charges, we created a weighted decision matrix (WDM) to determine whether we wanted to use black powder (FFFFg / 4Fg) or a CO_2 ejection device. We used several different criteria to compare the two options. Some of the more important criteria that we were looking at consist of volume, simplicity, reliability, and weight. Beyond this, the cleanliness and style (coolness) had medium and little importances.

Next, we then took the estimated values and calculated values and applied them to the WDM and achieved the finals results with black powder scoring a total of 245 points, whereas the CO_2 received a score of 195. Comparing the two total point values, black powder was the clear choice for our type of ejection charge.

METRIC
HOW WILL MEASURE IF THE CRITERION WAS ADDRESSED?

CRITERIA	Weight/Importance	Overall Estimated Volume	Time to Develop	Reviews	Residue Remaining	Total Weight	Team ranking
Volume	15	X					
Simplicity	15		X				
Reliability	15			X			
Cleanliness	10				X		
Weight	15					X	
Coolness	5						X
	Units	cm^3	hours	1-5	1-5	g	1-5

BENCHMARKING PROCESS (5=Best, 1=Worst)

Overall Estimated Volume	DATA	Score
	>30	1
	>20&<30	2
	15<x<20	3
	>10&<15	4
	<10	5

Residue Remaining	DATA	Score
A lot of Residue	1	1
	2	2
	3	3
	4	4
No Residue	5	5

Time to Develop	DATA	Score
	15	1
	12	2
	9	3
	6	4
	3	5

Total Weight	DATA	Score
	>30	1
	>20&<30	2
	15<x<20	3
	>10&<15	4
	<10	5

Reviews	DATA	Score
	1	1
	2	2
	3	3
	4	4
	5	5

Team ranking	DATA	Score
	1	1
	2	2
	3	3
	4	4
	5	5

	Overall Estimated Volume	Time to Develop	Reviews	Residue Remaining	Total Weight	Team ranking
Black Powder	20.88	5 hours	4	3	3	4
CO2	83.9	12 hours	4	5	1	5

BENCHMARKING (Unweighted) Black Powder	CO2	BENCHMARKING (Weighted) Black Powder	CO2
2	1	30	15
4	2	60	30
4	4	60	60
3	5	30	50
3	1	45	15
4	5	20	25
	WEIGHTED TOTAL -->	245	195

3.1.3.5.2. Leading Choice

From the WDM, talked about in the previous section, we determined that we were going to use black powder as our method of ejection. We will use ejection canister caps in combination with masking tape to contain the black powder. Also from our research we will use FFFFg as the type of black powder.

3.1.3.5.3. Estimated Mass

In order to figure out the overall estimated mass, we first figured out how many grams of black powder that we will need for the ejection to go smoothly. We used the equation C*D^2*L = grams of BP, where D is the diameter of the airframe, L is the length of the recovery section, and C is a constant conversion from PSI. From there we need 10 PSI which corresponds to a value of 0.00399, the diameter is 5.15 in, and the length is 30 in. Once we plug these values into our formula, we get ~3.22± 0.15 grams of FFFFg (4Fg) black powder, per capsule (including backup capsules). Since there will be two capsules on either side, there will be a total of ~12.88 grams of 4Fg black powder used per flight. If we were to use CO2, we would need about 5 times as much CO2 than black powder, ~16 grams, and there would one on either side of the avionics bay, so a total of ~32 grams of CO2.

3.1.3.6. Avionics

3.1.3.6.1. Design Alternatives With Pros And Cons

	Price	GPS Price	Total Price	Mininmum Voltage	Maximum Voltage	Maximum height	Ratio of Max. height to Cost	Area	Barometer or accelerometer	Computer Type	Reviews	Weight	GPS / Telemetry
RRC2	45	150	45	3.5	10	40,000	444.44	1.0545	Barometer	Wind pnly	4	10g	0
RRC3+ Sport	90	150	90	3.5	10	40,000	242.497	1.813	Barometer	Wind only	5	17g	1
Eggtimer TRS	140	0	140	4.5	30	30,000	400	1.95	Barometer	Only Wind	4	25g	2
TeleMetrum	300	0	300	3.7	5	100,000	333.33	0.555	Barometric	Wind, Mac, Linux	4	18.4g	2

Weight/Importance: 15: Must have 10: Good to have 5: Nice to have CRITERIA	Weight/Importance	METRIC HOW WILL MEASURE IF THE CRITERION WAS ADDRESSED?								
		Price	Voltage	Maximum height	Ratio of Max. height to Cost	Area	Computer Type	Reviews	Weight	GPS / Telemetry
Cost	15	X								
Battery / Voltage	10		X							
Altitude	15			X						
Efficiency	15				X					
Size	10					X				
Operating System	5						X			
Reliability	15							X		
Extras	15								X	X
	Units	Dollars	Volt	ft	ratio	in^3	Type	Stars	g	yes/no

Our top four choices for altimeters for our launch vehicle were the Missile Works RRC2, Missile Works RRC3+ Sport, Eggtimer TRS, and the Altus Metrum TeleMetrum. To decide which two altimeter we want to use for the launch vehicle, we created a weighted decision matrix (WDM). In the WDM, we had categories: price, GPS price, total price, minimum and maximum voltage, maximum height, ratio of maximum height to cost, area, barometer or accelerometer, computer type, reviews, weight and whether or not it has GPS/Telemetry. Once we had these categories, we then conducted research on each altimeter to see the data related to them. Next, we made rankings for each category to see which altimeter was better in each category. Then we created weights for each category: a 15 was a must have, 10 was good to have and 5 was nice to have. The categories of price, altitude, efficiency, reliability and extras were weighted with a 15. Battery/voltage and size were weighted with a 10. Operating system was weighted with a 5. After we ranked each altimeter, we multiplied them by the weight and totaled the score for each one. In the end, the order from most points to least was: TeleMetrum, RRC3+ Sport, TRS, RRC2, with their following point values respectively: 362.5, 360, 345, 342.5.

BENCHMARKING PROCESS (5=Best, 1=Worst)

Price	DATA	Score
	201-250	1
	151-200	2
	101-150	3
	51-100	4
	0-50	5

Voltage	DATA	Score
Doesnt comply with 9V		1
		2
		3
		4
Uses 9V	9V	5

Maximum height	DATA	Score
Dosn't meet req.	<5,000ft	1
		2
Around Req.	<7,000ft	3
		4
over req.	>10,000ft	5

Ratio of Max. height to Cost	DATA	Score
Higher the Better	<300	1
		2
	<450	3
		4
	>450	5

Computer Type	DATA	Score
0 systems		1
		2
1 - 2 systems		3
		4
3 systems		5

Reviews	DATA	Score
1 star'	1	1
	2	2
3 stars'	3	3
	4	4
5 stars'	5	5

Weight	DATA	Score
Lighter the better	20-25	1
	15-20	2
	10-15.0	3
	5-10.0	4
	0-5	5

GPS / Telemetry	DATA	Score
doesnt have GPS o	0	1
		2
has either GPS or t	1	3
		4
has both GPS and	2	5

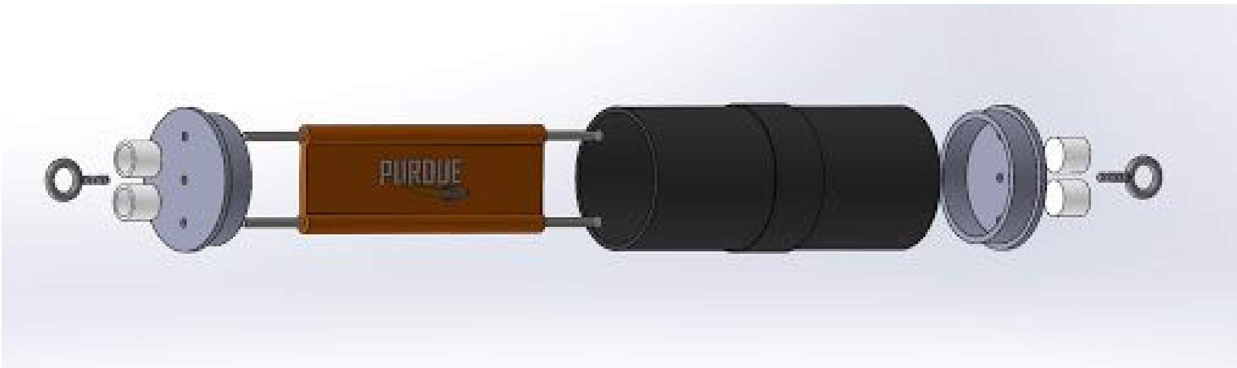
Area	DATA	Score
smaller better	<2	1
		2
	<1.5	3
		4
	<1	5

BENCHMARKING (Unweighted)					BENCHMARKING (Weighted)			
RRC3+ Sport System	RRC2 System	Eggtimer TRS	TeleMetrum		RRC3+ Sport System	RRC2 System	Eggtimer TRS	TeleMetrum
5	2	3	1		75	30	45	15
5	5	5	1		50	50	50	10
5	5	5	5		75	75	75	75
1	3	3	5		15	45	45	75
1	3	1	5		10	30	10	50
3	3	3	5		15	15	15	25
5	4	4	4		75	60	60	60
3	2.5	3	3.5		45	37.5	45	52.5
	WEIGHTED TOTAL -->				360	342.5	345	362.5

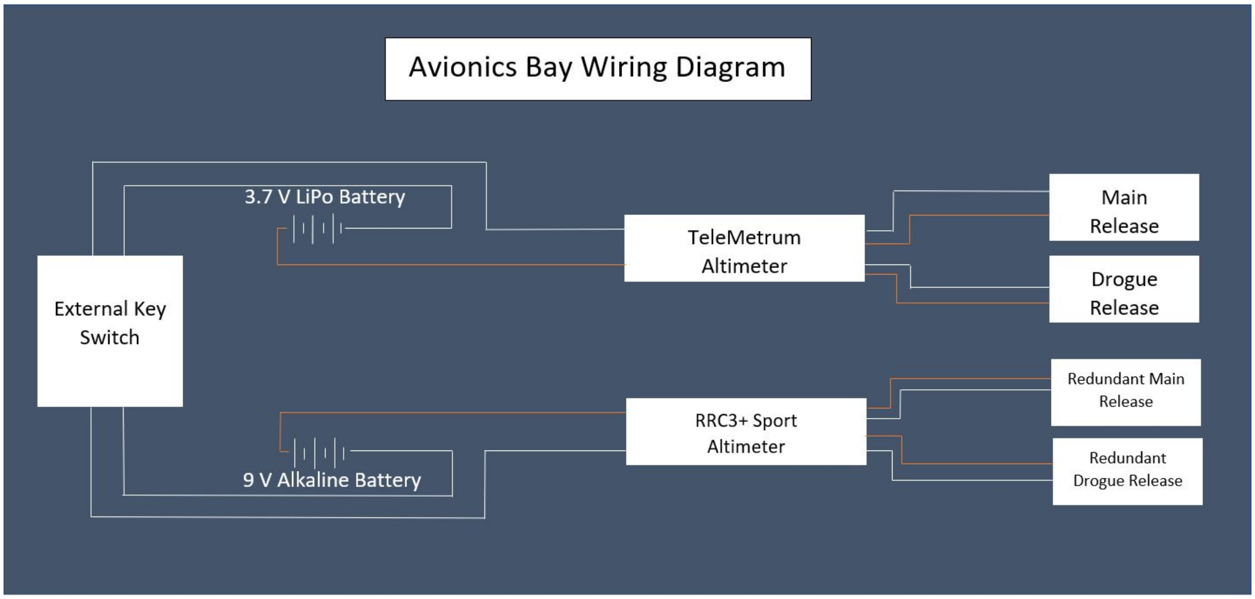
3.1.3.6.2. Leading Choice

The avionics team decided on using the Telemetrum as our primary altimeter and GPS and the RRC3+ Sport as our secondary, redundant altimeter. We decided to choose the RRC3+ Sport as the secondary altimeter due to the fact that we only need one GPS system for the launch vehicle. To ensure the most redundant system, the two different altimeters operate using separate batteries, the Telemetrum uses a 3.7V LiPo battery while the RRC3+ Sport uses a 9V battery. To facilitate the separation of the launch vehicle in order to deploy the drogue and main parachutes, we decided on using black powder charges, as stated in section 3.1.3.5.1.

3.1.3.6.3. Dimensional Drawing



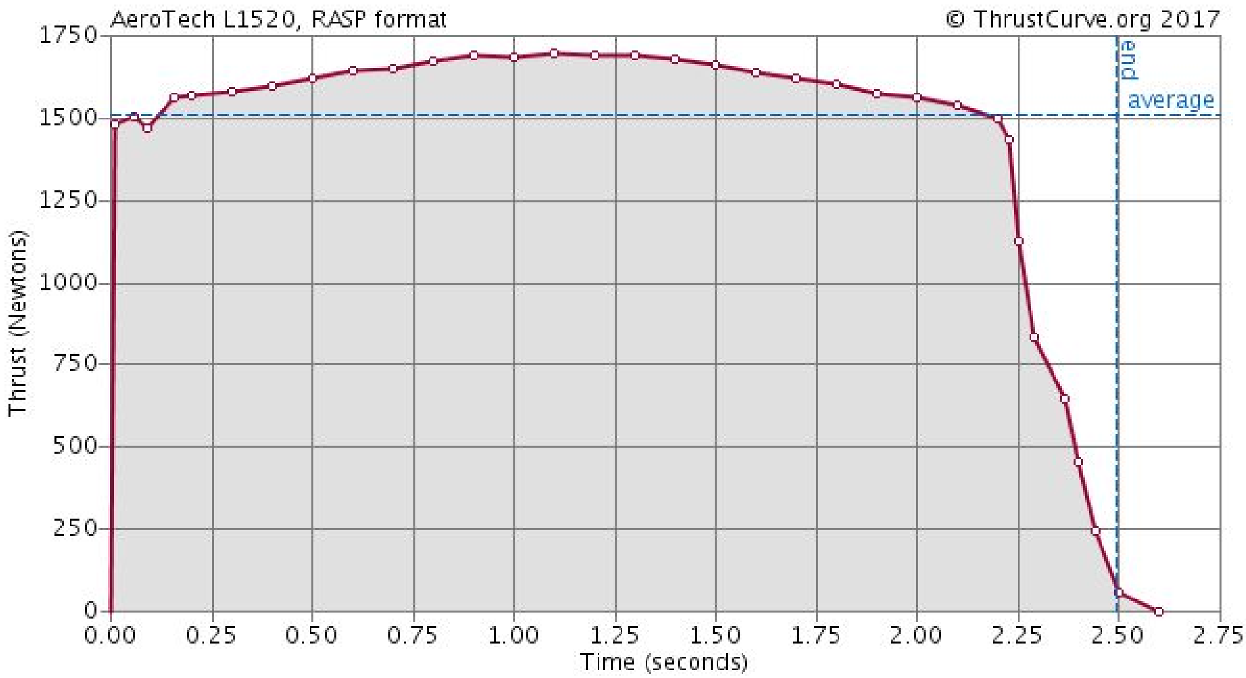
3.1.3.6.4. Wiring Diagram



3.1.3.6.5. Estimated Mass

The estimated mass of our launch vehicle's avionics bay, containing the Telemetrum (18.4g), RRC3+ Sport (17g), 9V Battery (45g), 3.7V LiPo Battery (75g), Key Switch (~90g). This does not include the added weight of the metal hardware, epoxy adhesive, or body of the avionics bay (more info in Avionics Bay) itself. This gives us an estimated weight of 245.4g or roughly ~0.54 pounds. Outside of the launch vehicle we have the TeleDongle (227g) which would be on the ground used as a receiver to communicate with the launch vehicle during flight. We still need to incorporate these objects into the weight figure. Once the entire section is built, we will be able to obtain a more accurate weight measurement to incorporate into our simulation to better predict altitude and flight parameters.

3.1.4. Current Motor Choice



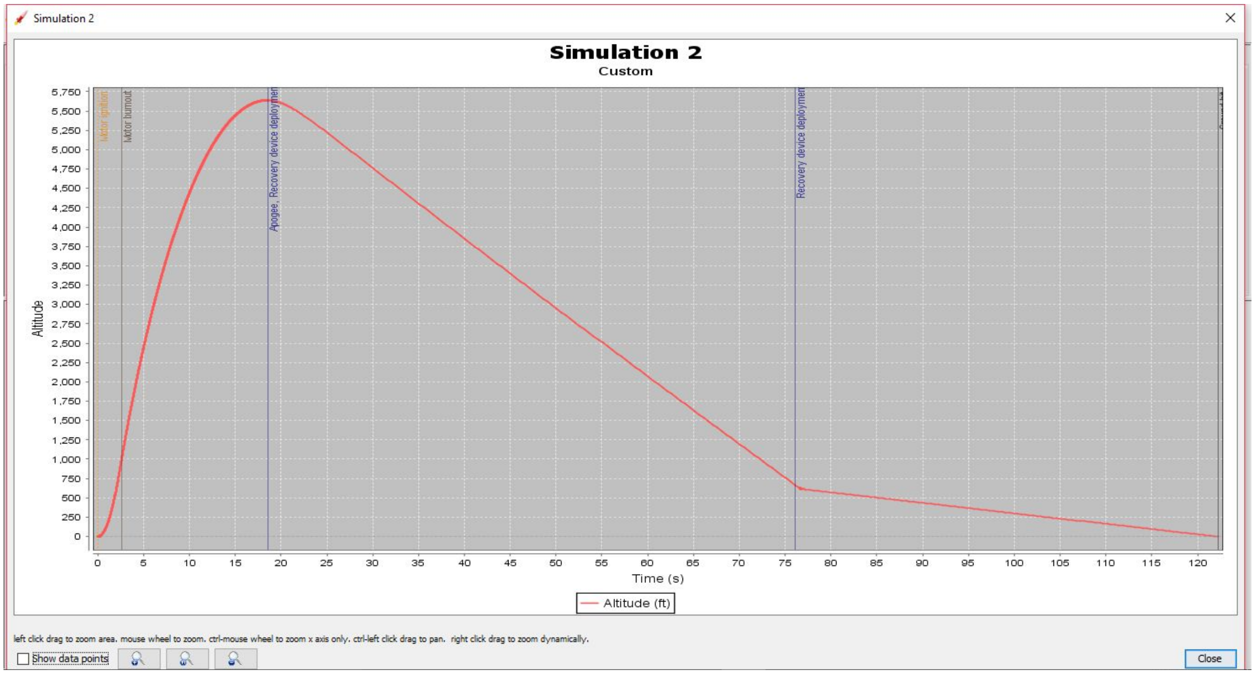
The motor we have chosen to use for the full scale launch is an Aerotech Rocketry L1520 Blue Thunder. This is a 75mm diameter, 3 grain rocket engine that uses the Aerotech Rocketry 75/3840 motor casing and hardware. The L1520 has a total impulse of 3,715 newton seconds, an average thrust of 1,567 newtons, and a maximum thrust of 1,765 newtons. When full loaded the motor has a maximum length of 20.39 inches and a pad weight of 3,651 grams. During the 2.4 second long burn time, the engine will expel 1,854 grams of propellant, leaving 1,797 grams remaining as hardware, propellant casting tubes, and an insulating liner.

At liftoff, the rocket will be propelled to a vertical velocity of 56.9 miles per hour before clearing the twelve foot long one and a half inch launch rail, thus meeting the minimum requirement of 52 feet per second. During the boost phase of the ascent, our vehicle will experience a maximum acceleration of ten times the forge of gravity. After motor burnout, our rocket will coast for an estimated eighteen and a half seconds.

3.1.5. Mission Performance Predictions

3.1.5.1. Altitude Predictions

3.1.5.1.1. Graph Of Altitude Vs. Time



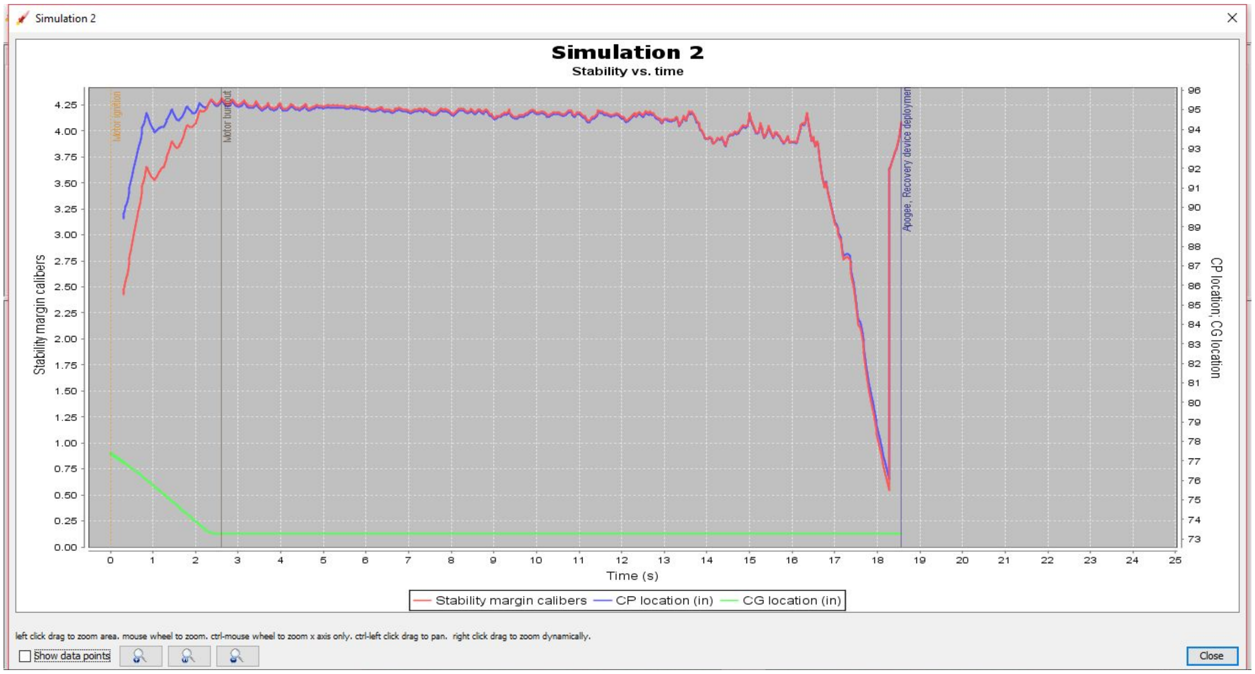
As can be seen from the graph above, our rocket is simulated to reach a maximum altitude of 5,638 feet above ground level. This is 358’ above our target altitude of 5,280 feet above ground level. The team are currently deliberately incorporating this excess altitude into our simulations due to the fact that we do not currently have a physical model to base our computer simulations on. Once our group has constructed our flight vehicle, we will have a more accurate weight measurement for the rocket that can then be entered into the simulation program. Because the rocket is anticipated to weigh more than the simulation shows, as weight is added into the computer model our altitude will decrease.

Other factors, such as surface finish and the cross sectional airfoil of the fins, are variables that we do not have implicit control over. Our team cannot accurately measure surface smoothness to compare the real and digital models, which will account for some difference in our actual and expected altitudes. In addition, the only choices presented to us when varying the fin’s cross section are “square, rounded, or airfoiled”. There is no direct input for edge thickness or taper length, further limiting our simulations.

All altitude simulations from which the graph above is derived were accomplished using OpenRocket 15.03 using the extended barrowman calculation method and a six degree of freedom runge kutta 4 simulation method. Geodedic calculations were evaluated using spherical approximation, and a 0.02 second time step for simulation calculations was used. Further altitude calculations will be done in RASAero II using similar parameters, and will be discussed later.

3.1.5.2. Stability Margins

3.1.5.2.1. Graph Of CP, CG, And Stability Vs. Time



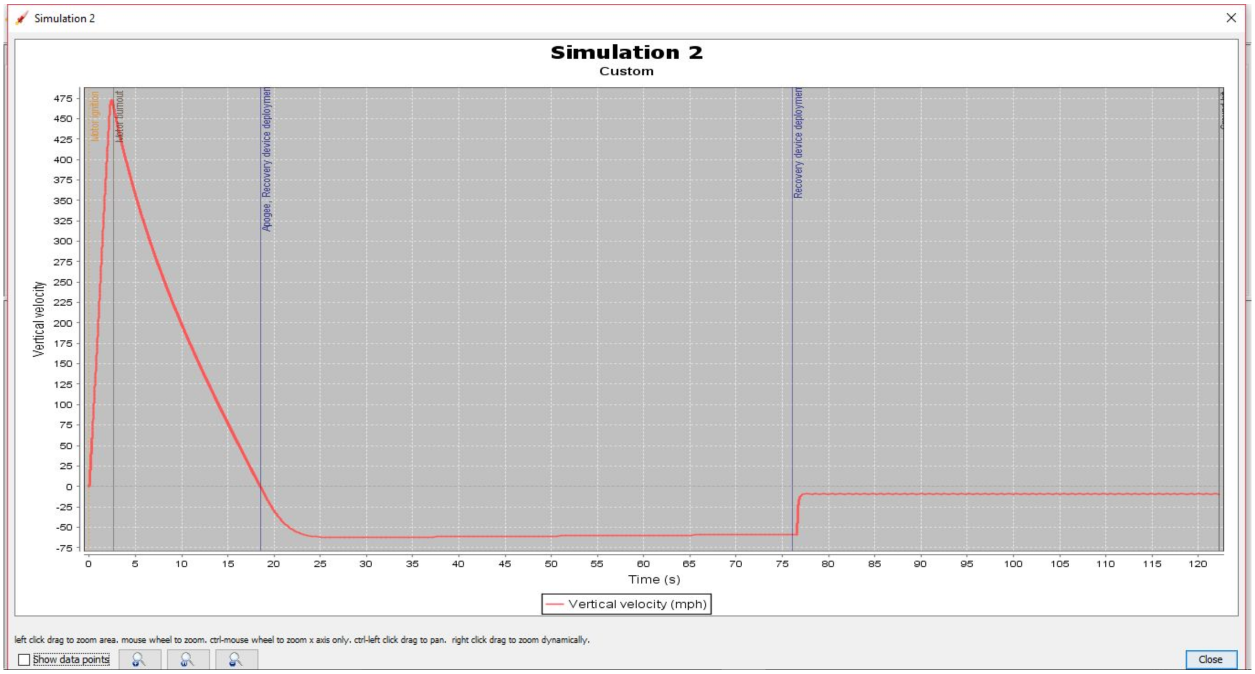
As seen from the graph above, the rocket exits the twelve foot long, one and a half inch launch rail with a minimum stability margin of approximately two and a half calibers, meeting the minimum requirement of two calibers. During the ascent phase, the rocket does not experience a significant drop in stability until it reaches a low enough velocity that the fins cannot maintain aerodynamic stability. At this point, the rocket begins slowing down significantly due to drag and gravity and starts arcing over as it approaches apogee. Despite this, the rocket maintains over four calibers for nearly all of the boost and coast phase.

The center of pressure, a node where the total sum of all pressures acts on the vehicle, starts at a distance of nearly ninety inches from the datum, which is deemed to be the tip of the nose cone. During the entire flight profile, the location of center of pressure closely follows the stability margin calibers when graphed and does not move more than five inches aft of its original location until the rocket has slowed enough to begin arcing. This movement is in itself only one caliber, as the maximum shift is equal to the diameter of the rocket airframe.

The center of gravity, a node where all moments about an axis of rotation equally oppose each other, begins at a distance of approximately seventy eight inches from the datum of the rocket, placing it roughly twelve inches ahead of the center of pressure. During the burn time of the motor, the center of pressure moves forward at a constant rate due to the constant burn rate of the solid propellant. The total shift is nearly four inches, or almost one full caliber.

3.1.5.3. Landing Energy Calculations

3.1.5.3.1. Graph Of Velocity Vs. Time



The figure above illustrates the vertical velocity of the rocket over time. The rocket accelerates quickly during boost and begins decelerate before reaching apogee, where it then deploys a drogue parachute and descends rapidly at an estimated 62.5 miles per hour. At an altitude of seven hundred feet above ground level, the main parachute will deploy to slow the vehicle considerably before touching down at a speed of approximately eight and a half miles per hour. The total landing energy, assuming a burnout mass of 31.5 pounds and impact speed of eight and a half miles per hour, will be 76.081 foot pounds.

3.1.5.3.2. Lower Airframe/Payload/Mid Airframe Landing Energy

The bottom section of the rocket that will be falling independently while remaining tethered to the remainder of the vehicle is expected to weigh 17.6 pounds at touchdown. This will consist of the lower airframe and motor assembly, payload bay, middle airframe, and drogue recovery gear. Assuming the landing velocity is still eight and a half miles per hour, the landing energy for this section will be 42.509 foot pounds.

3.1.5.3.3. Avionics/Upper Airframe Landing Energy

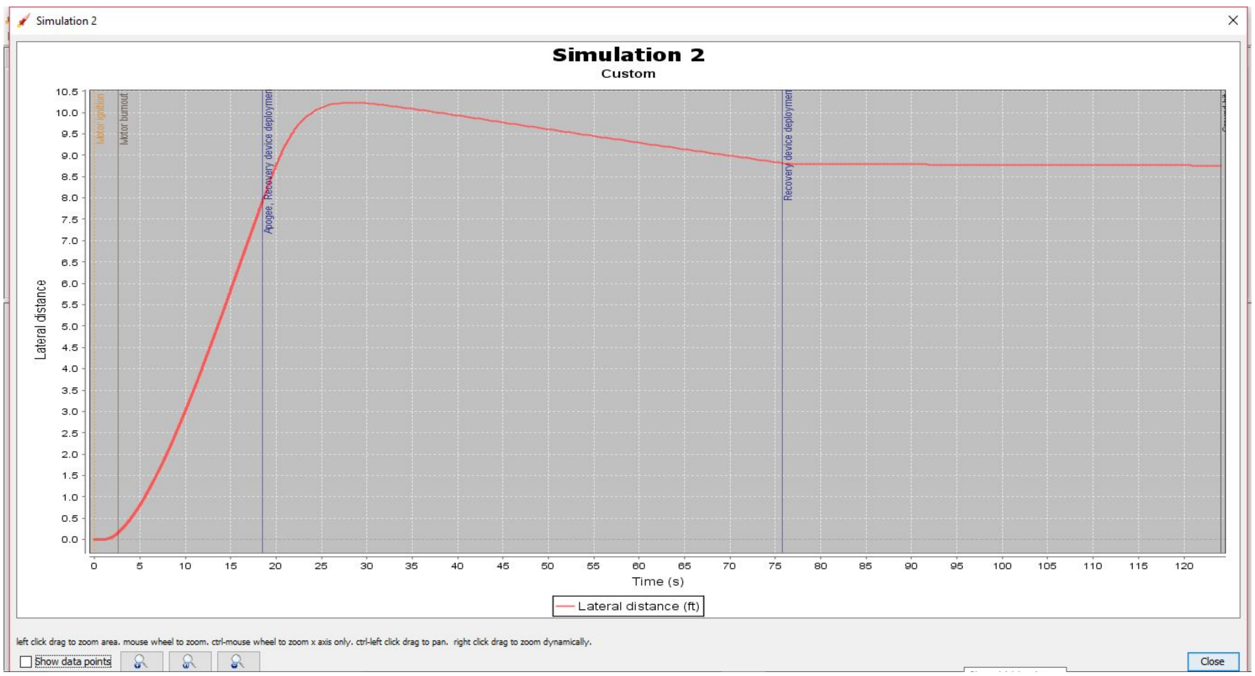
The middle section of the rocket that will be falling independently while remaining tethered to the remainder of the vehicle is expected to weigh 9.71 pounds at touchdown. This will consist of the avionics bay, upper airframe, and main recovery gear. Assuming the landing velocity is still eight and a half miles per hour, the landing energy for this section will be 23.425 foot pounds.

3.1.5.3.4. Nosecone Landing Energy

The nose section of the rocket that will be falling independently while remaining tethered to the remainder of the vehicle is expected to weigh 4.18 pounds at touchdown. This will consist of the nosecone, Multitronix Telemetry Pro, and nose coupler. Assuming the landing velocity is still eight and a half miles per hour, the landing energy for this section will be 10.096 foot pounds.

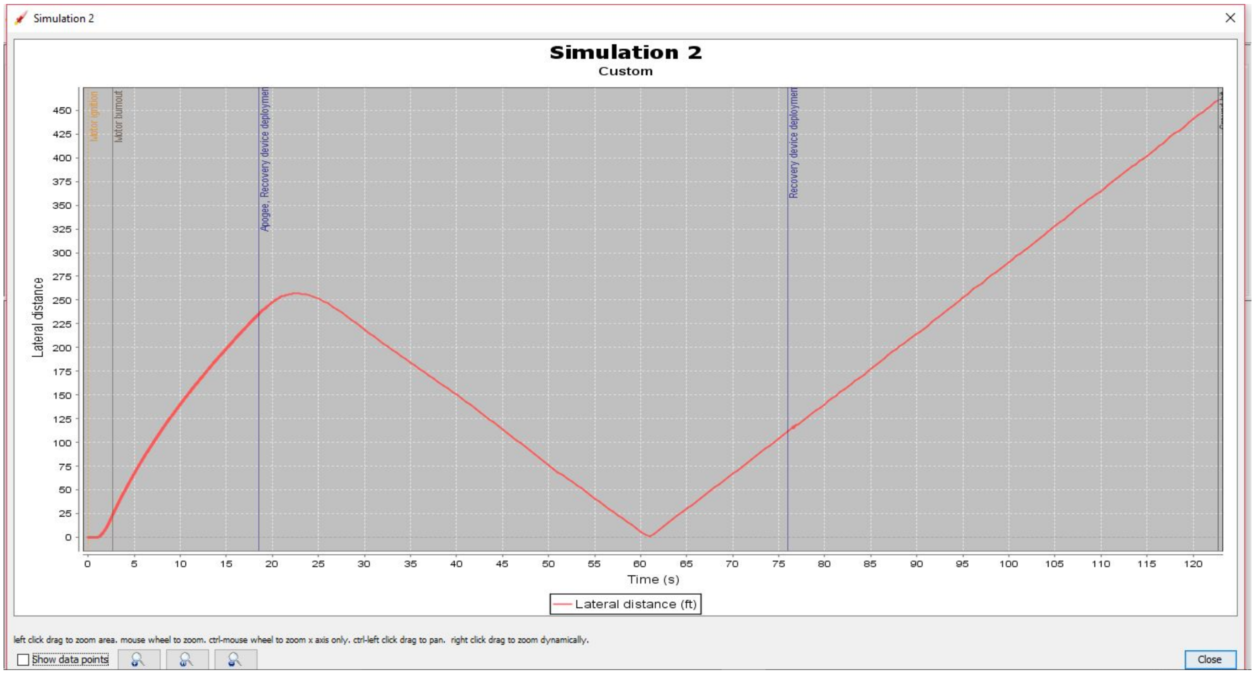
3.1.5.4. Drift Distance Calculations

3.1.5.4.1. 0 MPH Wind



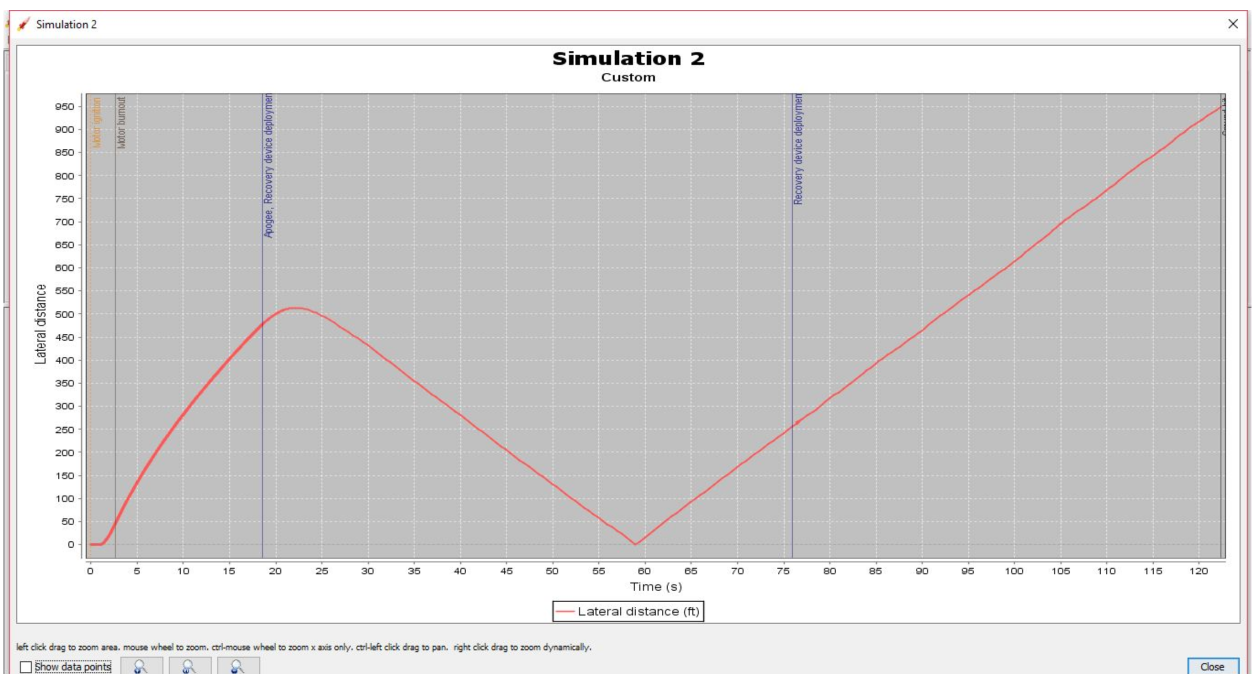
With an average wind speed of zero miles per hour with zero standard deviation and zero percent turbulence intensity, our simulated maximum drift distance during flight is roughly ten feet, with touchdown occurring only eight feet away from the point of origin. As we approach our target altitude of one mile, which is closer than our current altitude, we expect these figures to drop.

3.1.5.4.2. 5 MPH Wind



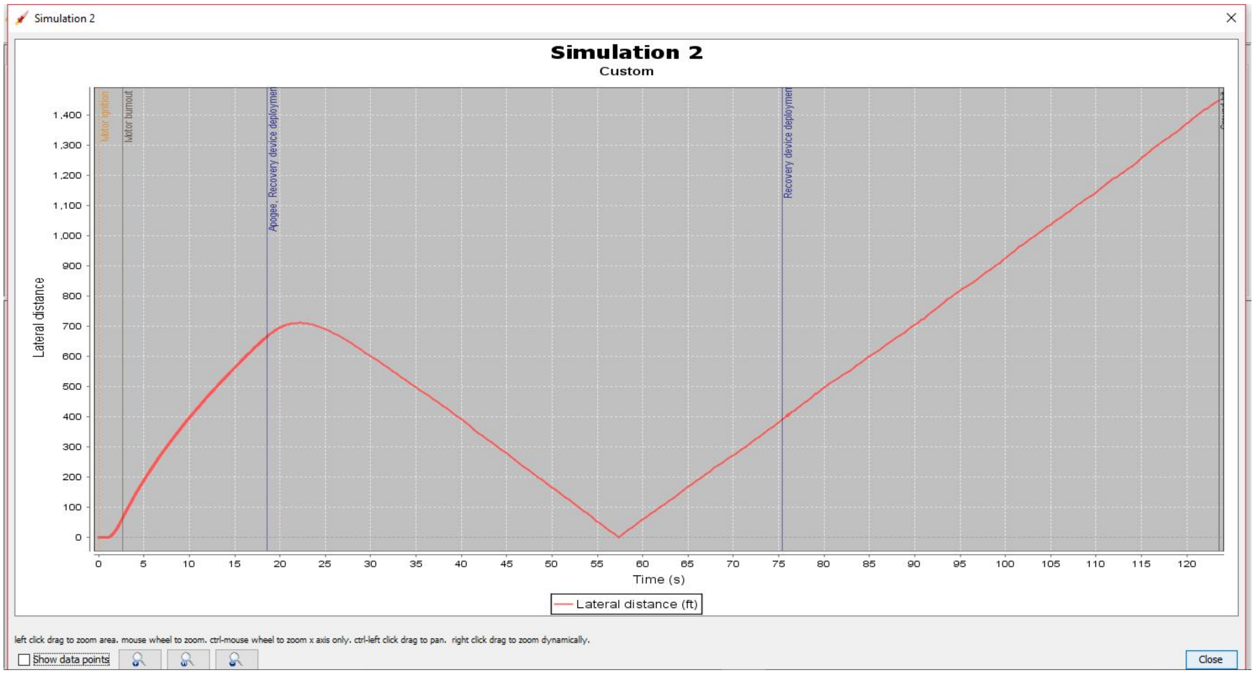
With an average wind speed of five miles per hour with a standard deviation of 0.5 miles per hour and ten percent turbulence intensity, our simulated maximum drift distance during flight is roughly four hundred and twenty five feet, which occurs at touchdown. As we approach our target altitude of one mile, which is closer than our current altitude, we expect these figures to drop.

3.1.5.4.3. 10 MPH Wind



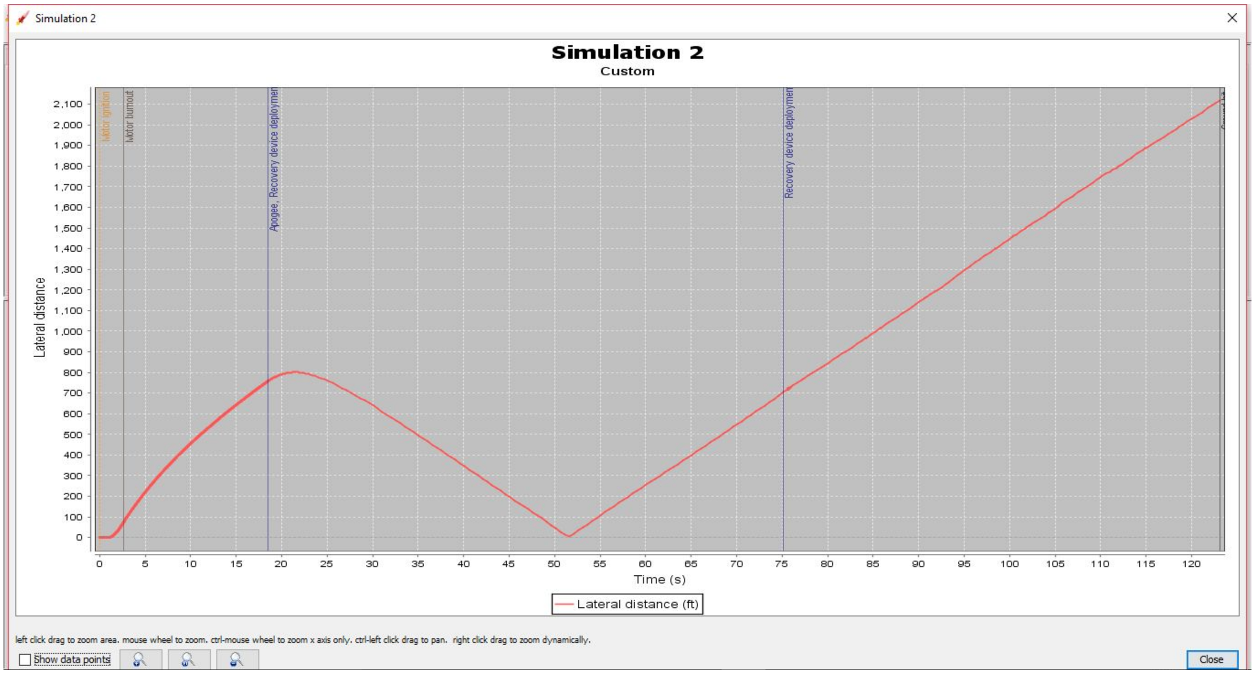
With an average wind speed of ten miles per hour with a standard deviation of 1 mile per hour and ten percent turbulence intensity, our simulated maximum drift distance during flight is roughly nine hundred and fifty feet, which occurs at touchdown. As we approach our target altitude of one mile, which is closer than our current altitude, we expect these figures to drop.

3.1.5.4.4. 15 MPH Wind



With an average wind speed of fifteen miles per hour with a standard deviation of 1.5 miles per hour and ten percent turbulence intensity, our simulated maximum drift distance during flight is roughly one thousand five hundred five feet, which occurs at touchdown. As we approach our target altitude of one mile, which is closer than our current altitude, we expect these figures to drop.

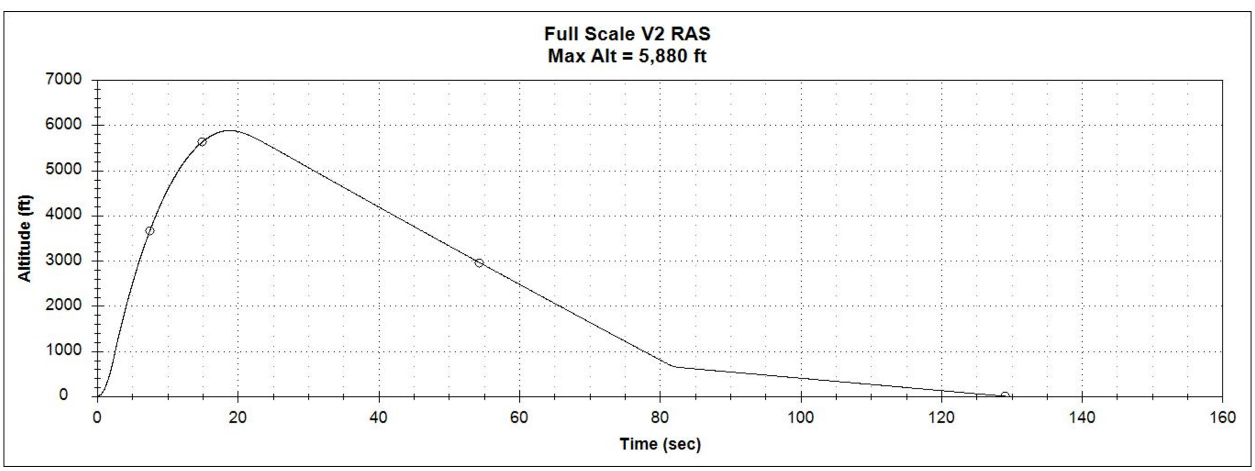
3.1.5.4.5. 20 MPH Wind



With an average wind speed of twenty miles per hour with a standard deviation of 2.0 miles per hour and ten percent turbulence intensity, our simulated maximum drift distance during flight is roughly two thousand one hundred feet, which occurs at touchdown. As we approach our target altitude of one mile, which is closer than our current altitude, we expect these figures to drop.

3.1.5.5. RASAero Calculations

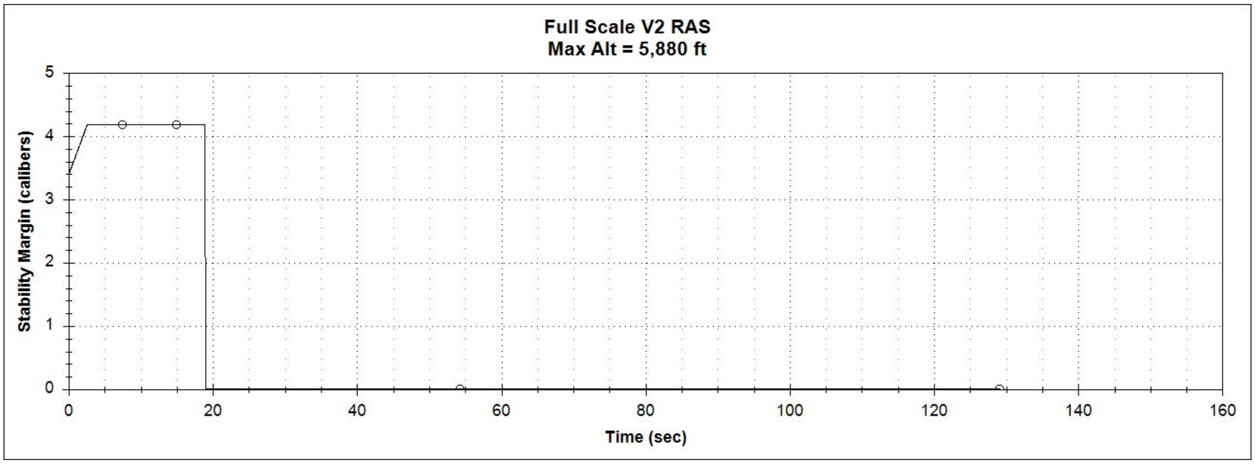
3.1.5.5.1. Altitude Predictions



The graph above, which was produced using RAS Aero II, is a result of running an identical simulation as the team performed with OpenRocket 15.03. All simulation settings were the same, and the vehicle dimensions and metrics were input manually. As a result, the same rocket flying on the same motor is predicted to achieve a maximum altitude of 5,880 feet above ground level. This is an increase of 242’ over the

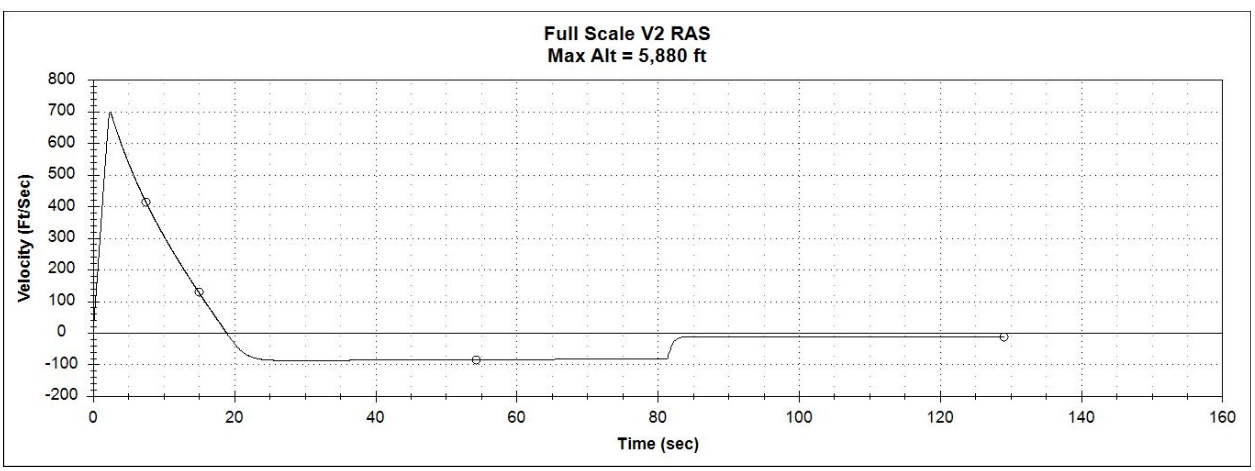
OpenRocket simulations, and a total of 600’ over the target altitude of one mile. While the team does not currently know what caused the difference in the simulation altitude predictions, we will continue to iterate the design in both programs as changes are made and weights are updated. In time, our group expects the difference in the models to decrease and approach the desired altitude of 5,280 feet.

3.1.5.5.2. Stability Margins



The stability margin graph shown above, produced using RASAero II, shows similar results to the stability curve produced in OpenRocket. The static stability is approximately 3.4 calibers, but is higher than the stability at the time of launch rail clearance which is estimated by OpenRocket to be nearly 2.5 calibers. OpenRocket does, however, calculate the static stability to be 3.38 calibers, so these estimates do in fact reinforce each other. Furthermore, RASAero predicts the stability during the coast phase to be approximately 4.2 calibers after expelling all of the propellant mass. This, again, is roughly equal to the stability predicted by OpenRocket.

3.1.5.5.3. Landing Velocity



The graph above was created using RASAero II and depicts the vertical velocity of our vehicle during the flight. Just as in OpenRocket, the terminal velocity during drogue descent is roughly ninety feet per second and terminal velocity during main descent is approximately twelve feet per second. These figures are nearly identical between the two independent simulation platforms.

3.1.5.5.4. Differences Between Calculations

Generally speaking, the two simulation platforms produce nearly identical numbers for altitude, stability, and descent velocity. The altitude predicted from RASAero, which had the highest variance, was still within a five percent margin of error of the OpenRocket estimate. As we mature our computer simulations to match our real world weights and metrics, we predict that the differences between the simulations will decrease. If this is not the case, we will begin simulating the vehicle in a third platform, such as RockSim.

4. Safety

4.1. Safety Officer Information

The Safety Officer for the Purdue SL Team participating in the 2018 competition will be Michael Repella. As Safety Officer, this team member is responsible for the safety and well being of all personnel throughout the course of the competition. This involves ensuring that everybody is constantly aware of the safety plans and emergency procedures, as well as all necessary precautions and personal protective equipment (PPE) required. Once procedures and plans are set by the team, any amendments to them must be authorized by the Safety Officer. Michael will be required to be present at all meetings when fabrication, testing, or assembly is planned to occur. It will also be required of the Safety Officer to have a working knowledge of all facility, equipment, and organizational rules set outside the realm of the team and personnel. This includes adherence to the NAR and TRA high power rocketry safety codes, NFPA 1127, and Federal Aviation Regulations 14 CFR. The Safety Officer will be responsible for the following:

- Creating and maintaining risk analysis matrices to be used throughout the competition
- Creating preflight and postflight checklists to be carried out
- Enforcing all safety plans and procedures set by the team
- Ensuring that all team members are properly trained and supervised to be carrying out their current task
- Ensuring that all team members are wearing appropriate PPE for the task they are conducting
- Ensuring that all team members are following proper operating procedures for using facilities and equipment
- Enforcing all laws and regulations set for the team by authorities and governing bodies
- Attending all build sessions and launches
- Attending all educational opportunities or events where legal minors are expected to be present

4.2. NAR/TRA Personnel Procedures

Victor Barlow, the NAR mentor currently working with the team, will be responsible for the handling and loading of the rocket motors used during launches. He will also be responsible for the purchase, safe storage, and transportation of these motors when necessary. Professor Barlow will be on location whenever the rocket is being launched to serve as Range Safety Officer, will work with the Safety Officer to ensure that all team members follow the NAR High Power Rocket Safety Code during all launches, and will prepare motors and ejection charges during full-scale flights as needed, even though other team members have certification for such tasks.

4.3. Project Risks

The seriousness of a risk will be evaluated by two criteria: the likelihood of an event to occur and the impact of the event should it happen or fail to be prevented.

Likelihood Of Event

Category	Value	Guage
Remote	1	Less than 1% chance of occurrence.
Unlikely	2	Less than 20% chance of occurrence.
Possible	3	Less than 50% chance of occurrence.
Likely	4	Less than 85% chance of occurrence.
Very Likely	5	Greater than 85% chance of occurrence.

Impact of Event

Category	Value	Guage
Negligible	1	Minimal injury, damage to equipment or facility, or environmental effects. Flight continues as normal.
Minor	2	Minor injuries, major reversible damage to equipment or facility, and minor environmental impact. Flight proceeds with caution.
Moderate	3	Moderate injuries, reversible failure, and reversible environmental impact. Flight is put on hold until effects are reversed.
Major	4	Potentially serious injuries, partial failure, and serious reversible environmental effects. Flight is scrubbed or put on hold until system is removed.
Disastrous	5	Potentially life threatening injury, total failure, and serious irreversible environmental damage. Flight is scrubbed or completely destroyed

By cross examining the likelihood of an event with the impact it would have if it occurred, a new table is created that yields a total risk for our safety matrix.

Category	Negligible	Minor	Moderate	Major	Disastrous

Remote	1	2	3	4	5
Unlikely	2	4	6	8	10
Possible	3	6	9	12	15
Likely	4	8	12	16	20
Very Likely	5	10	15	20	25

4.4. Preliminary Personnel Hazard Analysis

Hazard	**Likelihood (Cause)**	**Severity (Effect)**	**Risk**	**Mitigation**
Power Tool Injury	3 (Carelessness)	4 (Possible Hospitalization)	12, Medium	Secure loose hair, clothing, and jewelry; wear appropriate PPE
Dust Inhalation	3 (Airborne Particulate Debris)	3 (Short To Long Term Respiratory Damage)	9, Medium	Wear appropriate PPE or respirator, work in well ventilated area
Eye Irritation	3 (Airborne Particulate Debris)	2 (Temporary Eye Irritation)	6, Low	Wear appropriate PPE or protective eyewear, wash with water
Epoxy Contact	3 (Resin Spill)	3 (Exposure to Irritant)	9, Medium	Wear appropriate PPE such as gloves or lab coats, wash with water
Workplace Fire	1 (Ignition Of Flammable Substance)	5 (Severe Burns, Loss Of Workspace, Irreversible Damage)	5, Low	Have fire suppression systems nearby, prohibit open flames, and store energetic devices in Type 4 magazines
Hearing	2 (Close Proximity	4 (Long Term	8, Medium	Wear appropriate

Damage	To Loud Noises)	Hearing Loss)		PPE such as ear muffs when using power tools
Burns From Motor Exhaust	1 (Proximity To Launch Pad)	3 (Mild To Moderate Burns)	3, Low	Maintain minimum safe launch distances
Injury from Ballistic Trajectory	3 (Recovery System Failure)	5 (Severe Injury, Death)	15, High	Keep all eyes on the rocket and call “heads up” if needed
Premature Ignition	2 (Short Circuit)	2 (Mild Burns)	4, Low	Prepare energetic devices only immediately prior to flight
Launch Pad Fire	2 (Dry Launch Area)	3 (Moderate Burns)	6, Low	Have fire suppression systems nearby and use a protective ground tarp
Recovery Related Injury	2 (Uneven Ground, Poisonous Plants, Fast Moving Water)	4 (Broken Bones, Infections, Drowning, Etc.)	8, Medium	Do not attempt to recover from atypically dangerous areas
Power Lines	2 (Rocket Becomes Entangled In Lines)	5 (Death Via Electrocution)	10, Medium	Call the power company and stand clear until proper personnel arrive

4.5. Preliminary Failure Mode And Effects Analysis

Hazard	**Likelihood (Cause)**	**Severity (Effect)**	**Risk**	**Mitigation**
Failure To Launch	2 (Lack of continuity)	1 (Recycle launch pad)	2, Minimal	Check for continuity prior to

				attempted launch
CATO	1 (Motor defect, assembly error)	5 (Partial or total destruction of vehicle)	5, Low	Inspect motor prior to assembly and closely follow assembly instructions
Instability	1 (Stability margin of less than 1.00)	5 (Potentially dangerous flight path and loss of vehicle)	5, Low	Measure physical center of gravity and compare to calculated center of pressure
Motor Expulsion	1 (Improper retention methods)	5 (Risk of recovery failure and low apogee)	5, Low	Use positive retention method to secure motor
Premature Ejection	1 (Altimeter programming, poor venting)	5 (Zippering)	5, Low	Check altimeter settings prior to flight and use appropriate vent holes
Loss of Fins	1 (Poor construction or improper materials used)	5 (Partial or total destruction of vehicle)	5, Low	Use appropriate materials and high powered building techniques
Ejection Charge Failure	4 (Not enough power, electrical failure)	5 (Ballistic trajectory, destruction of vehicle)	20, High	Ground test charge sizes at least once before flight
Altimeter Failure	3 (Loss of connection or improper programming)	5 (Ballistic trajectory, destruction of vehicle)	15, High	Secure all components to their mounts and check settings
Payload Failure	3 (Electrical failure, program error, dead battery)	4 (Disqualified, objectives not met)	12, Medium	Test payload prior to flight, check batteries and connections
Heat	2 (Insufficient	4 (Excessive	8, Medium	Use appropriate

Damaged Recovery System	protection from ejection charge)	landing velocity)		protection methods, such as Kevlar blankets
Broken Fastener	1 (Excessive force)	5 (Ballistic trajectory)	5, Low	Use fasteners with a breaking strength safety factor of 2
Destruction Due To Drag Forces	1 (Poor construction or improper materials used)	5 (Partial or total destruction of vehicle)	5, Low	Use appropriate materials and high powered building techniques
Airframe Zipper	2 (Excessive deployment velocity)	5 (Partial destruction of vehicle)	10	Properly time ejection charges and use an appropriately long tether
GPS Lock Failure	2 (Interference or dead battery)	5 (Loss of vehicle)	10	Ensure proper GPS lock and battery charge before flight
Excessive Landing Speed	3 (Parachute damage or entanglement, improper load)	5 (Partial or total destruction of vehicle)	15, High	Properly size, pack, and protect parachute

4.6. Environmental Concerns

Hazard	Likelihood (Cause)	Severity (Effect)	Risk	Mitigation
Drag	2 (High air pressure, low temperature and humidity	4 (Premature drag separation)	8, Medium	Use appropriate amount of shear pins and vent holes
Landscape	3 (Trees, brush, water, power lines, wildlife)	5 (Inability to recover rocket)	15, High	Angle rocket into wind as necessary to reduce drift

Humidity	3 (Climate, poor forecast)	1 (Rust on metallic components)	3, Low	Use as little metal as possible, store indoors
Winds	3 (Poor forecast)	4 (Inability to launch, excessive drift)	12, Medium	Angle into wind as necessary and abort if wind exceeds 20 mph
Temp.	3 (Poor forecast)	3 (Heat related injury)	9, Medium	Ensure team is protected against the sun and stays hydrated
Pollution From Exhaust	5 (Combustion of APCP motors)	1 (Small amounts of greenhouse gasses emitted)	5, Low	None
Pollution From Vehicle	2 (Loss of components from vehicle)	4 (Materials degrade extremely slowly)	8, Medium	Properly fasten all components

4.7. Checklists

4.7.1. Pre-Launch Checklist

General Safety

- ❏ Ensure that at least two people are using this checklist to prep for launch
- ❏ Ensure that a trained Range Safety Officer is present
- ❏ Have first aid equipment and at least one phone available for use nearby
- ❏ Designate a “rapid response” person or persons to be the one(s) to perform duties such as administering first aid in the case of an emergency
- ❏ Designate spotters to keep track of the rocket’s descent and to point out its location as it falls
- ❏ Have adequate fire suppression equipment available for use nearby
- ❏ A fire blanket has been placed under the pad if conditions at launch are dry enough to require it

General Rocket Construction (To be done after prepping avionics and reloads)

- ❏ Ensure computer simulations have already been run of the rocket in its current construction state before launch to analyze both normal and ballistic scenarios
- ❏ Check that all fins and lugs are secure and aligned
- ❏ Check that the body tube is in good condition

- ❏ Check that the motor and ejection system are in good condition, are functional, and are securely installed
    - ❏ Ensure the proper motor and ejection have been selected for the desired flight profile and that they are certified by NAR, Tripoli, or CAR
    - ❏ Check the reload motor for proper build-up, paying special attention to the O-rings
    - ❏ Ensure the ejection charge is properly installed, and is the proper amount according to the table at the end of this checklist (Figure 2)
    - ❏ Check that the motor mount is secure, is in good condition, and will not deflect motor thrust
- ❏ Check that the recovery system is in good condition, is functional, is securely installed, and is strong enough to withstand recovery loads
    - ❏ Check that shock cords are securely attached and are not cracked, burned, or frayed
    - ❏ Check that shroud lines are not burned or tangled
    - ❏ Check that all hardware, such as snap swivels and screw eyes, is in good condition and secure
    - ❏ Check that parachute protection is installed properly and is in good condition
- ❏ Check that the electronics bay is in good condition, is functional, and is securely installed
    - ❏ Have each altimeter checked the **night before** the flight
    - ❏ Ensure the altimeters are properly installed
    - ❏ Check that the avionics are initially disarmed and that an “Arm before flight” reminder is in use
    - ❏ Check that the electronics bay is properly vented and that wires do not cover any ports
    - ❏ Check that the drogue and main wiring are in good condition
    - ❏ Check that all electronics bay hardware and electrical connections are secured against acceleration forces
    - ❏ If appropriate, check the settings of the mach lock-out / mach delay
    - ❏ Ensure the battery or batteries being used are charged and in operational condition, and secure battery positions with masking tape
    - ❏ Check that the ejection charges are properly set up
    - ❏ Close and secure the electronics bay

Flight Check

- ❏ Check the nose cone and any stage or payload couplers for a secure and proper fit

- ❏ Check that the motor is securely installed
- ❏ Check for continuity, resistance, and cracks or flaws in the pyrogen of the igniters; all igniters must touch the propellant, have adequate electrical current flowing to them, and have no shorts
- ❏ If clustering, ensure thrust symmetry
- ❏ Check that staging delay is less than one second
- ❏ Ensure that the center of gravity and center of pressure are in their expected positions
- ❏ Perform manufacturer's checking instructions on the avionics
- ❏ Check that shear pins are installed for main parachute compartment
- ❏ Ensure drogue ejection will not cause main to deploy

Pad Distance

- ❏ Only the minimum number of personnel are at the pad to prep for launch
- ❏ All team personnel and spectators are a safe distance from the pad based upon a minimum distance table; use the table at the end of this checklist (Figure 1)
- ❏ Ensure barriers are in place to keep spectators away from the launch area

Pad Installation

- ❏ Ensure the launch controller is disarmed prior to installing the rocket onto the pad
- ❏ Ensure the launch pad is stable and is an adequate size for the rocket being used
- ❏ Ensure that enough electrical current will reach the igniters of the rocket
- ❏ Verify that the igniter clips are clean and the leads are secured to the pad
- ❏ Verify that the rocket moves smoothly on the launch rail; clean the rail and rocket as necessary
- ❏ Ensure that the igniter clips are clean and secure them to the pad; install igniter into motor
- ❏ Connect launch leads to motor igniter
- ❏ Arm the avionics system once the rocket is on the pad
    - ❏ Ensure that the Raspberry Pi systems are all turned on!

Flight Trajectory

- ❏ Ensure the launch and the flight will not be angled towards any spectators
- ❏ Double check that the rocket will not fly higher than its permitted clearance waiver; know the expected performance of the model
- ❏ Check cloud bases and winds and make sure the skies around the launch area are clear

- ❏ If needed, use a wind speed indicator to avoid launching during extremely windy intervals
- ❏ Ensure there are no obstructions or hazards in the launch area

Beginning the Launch

- ❏ Shortly before the countdown, give a loud announcement that the rocket will be launched; if applicable to the situation, use a PA system
- ❏ Ensure that all spectators are aware of the launch and that parents are in close contact with all children
- ❏ When launching, give a loud countdown of “5, 4, 3, 2, 1, launch!”

4.7.2. Launch Checklist

- ❏ Ensure that at least two people are using this checklist to observe the launch
- ❏ Ensure the stability of the model is being monitored
- ❏ Ensure that the recovery system is successfully deployed.
- ❏ Carry out a safe recovery of the model
- ❏ If radio control is used for flight functions (e.g. recovery), check that the operating frequency is in the 27, 50, 53, or 72 megahertz bands. Use of 75 megahertz for flight functions is not permitted.
- ❏ Ensure rocket trajectory is being tracked during flight. Be aware of tilt or drift from mass/aerodynamic imbalance, wind, or other sources. **Do not turn off the altimeters.**
- ❏ Ensure crosswind positioning of spectators and vehicles
- ❏ Ensure that the launch pad is being monitored after takeoff in case any dangers arise at the pad
- ❏ Ensure all passerby and spectators are aware of the launch
- ❏ Call a loud “Heads up!” (If needed, sound an air horn) in the case of any rockets approaching the prep area or spectators; all who see the incoming rocket should point at it as it descends.
- ❏ Monitor the flight path, using binoculars if necessary
- ❏ Make sure whoever is responsible for recovery is kept fully aware of the status of the rocket (failed to launch, nominal in-flight, mid air failure, returning for recovery, etc.)
- ❏ Communicate launch progress effectively to NASA officials, if needed

In the case of a misfire:

- ❏ Wait a minimum of one minute
- ❏ Disarm launch controller and avionics
- ❏ Remove failed igniter and motor if needed

4.7.3. Post-Launch Checklist

- ❏ Ensure that at least two people are using this checklist after launch
- ❏ Double check that there are no hazards which have gone unnoticed during the launch before approaching the launch pad or the rocket for clean-up.
  - ❏ If there are hazards, notify emergency personnel
- ❏ Let NASA officials verify the results of the launch, if necessary
- ❏ Double check that all necessary data from the avionics bay has been retrieved
  - ❏ If so, disarm the avionics
- ❏ Disarm the launch controller
- ❏ Place cap on launch rods, if necessary
- ❏ Take down the launch pad, if necessary
- ❏ Retrieve the main rocket body and all components which may have landed separately
  - ❏ Check them for any failed ejection charges
  - ❏ If there are failed ejection charges, safe all ejection circuits and remove any non-discharged pyrotechnics

4.8. Plan for Compliance with Laws

The project team will follow regulations listed in NFPA 1127 and CFR 27 Part 55 and will store all motors, black powder, and other flammable materials in a Type 4 Magazine. These materials will only be removed immediately prior to flight. All launches will be conducted in an area with an active FAA waiver that extends beyond 5,623 feet, the projected altitude of the launch vehicle. All team members present at these launches will closely follow the NAR High Power Rocket Safety Code and the safety agreement in section 4.10, which both encourage lawful rocketry.

4.9. Plan to Purchase, Store, Transport, and Use Hazardous Materials

Hazardous materials which will be used on this project include: black powder, ammonium perchlorate composite propellant, pre-made rocket motor igniters, and potentially compressed carbon dioxide. Hazardous materials will be stored off-site, within the Zucrow Labs research facilities adjacent to the Purdue University Airport. Certain members of the team working on project Goddard currently hold a Low Explosives User Permit (LEUP), and these are the members who will handle the acquisition, transportation, and storage of the hazardous materials involved in this project. All team members will be given a briefing on the plan to properly purchase, store, transport, and use hazardous materials by the safety officer. This safety brief will provide knowledge of and access to Material Safety Data Sheets (MSDS) for all potentially hazardous substances which will be used on the project and will ensure the use of proper PPE when handling hazardous materials.

4.10. Team Safety Statement

All team members must sign the following safety statement:

As a member of Purdue SEDS Rocket Team, I agree to:

1. Adhere to any and all relevant local, state, and federal laws and regulations.
2. Adhere to the NAR High Power Rocket Safety Code.
3. Comply with all instructions given to me by the Safety Officer and by the Range Safety Officer.
4. Wear appropriate personal protective equipment whenever constructing or operating the launch vehicle.
5. Understand the hazards of each material or machine I plan to use or operate.
6. Never misuse the materials or equipment I will work with in this project for any reason.
7. Acknowledge that the Range Safety Officer will inspect the launch vehicle prior to all flights.
8. Acknowledge that the Range Safety Officer reserves the right to approve or deny the flight of the launch vehicle for any relevant reason.
9. Acknowledge that my team will not be allowed to fly if we do not comply with each of the aforementioned safety regulations.

My signature confirms that I have read and understood the aforementioned agreements. I recognize that any violation of these agreements may result in being unable to participate in Project Grissom or the NASA SL program.

Name____
Signature______________________________________ Date______________

5. Payload Criteria

5.1. Selection, Design, And Rationale Of Payload

Given the three options for payload missions, this team will launch a payload containing a target detection system. The system will identify three 40’ x 40’ colored targets on the ground in real time on board the rocket during flight. The design will consist of a recording device protruding from the side of the rocket aimed at the ground. This footage will then be processed by an onboard computer. The computer will identify the three tarps and distinguish between the tarps based on color. This computer will be powered by a commercially available rechargeable battery supply.

To ensure success, this payload will be comprised of a full redundancy system. There will be two cameras, two batteries, and two on board computers operating completely independently. The rationality behind this design sacrifices extra weight in return of an insurance plan. It was decided that this payload will remain fixed to the launch vehicle and not be deployed at apogee to minimize the complexity of the system. At this point in the design phase there is still the concern that the rocket will be rotating to quickly during powered flight and that the video will be to blurry for processing. This issue will be addressed during the subscale flight. If the resultant video using the current design is unable to be processed, the alternative design plan is to create a deployable payload that will capture video during descent when aerodynamic forces are less extreme.

5.1.1. Mission Statement And Mission Success Criteria

5.1.1.1. Payload Mission statement:

Design an onboard system which identifies three various tarps located on the ground and distinguishes between the tarps according to color.

5.1.1.2. The mission success will be evaluated according to how well it address the following criteria:

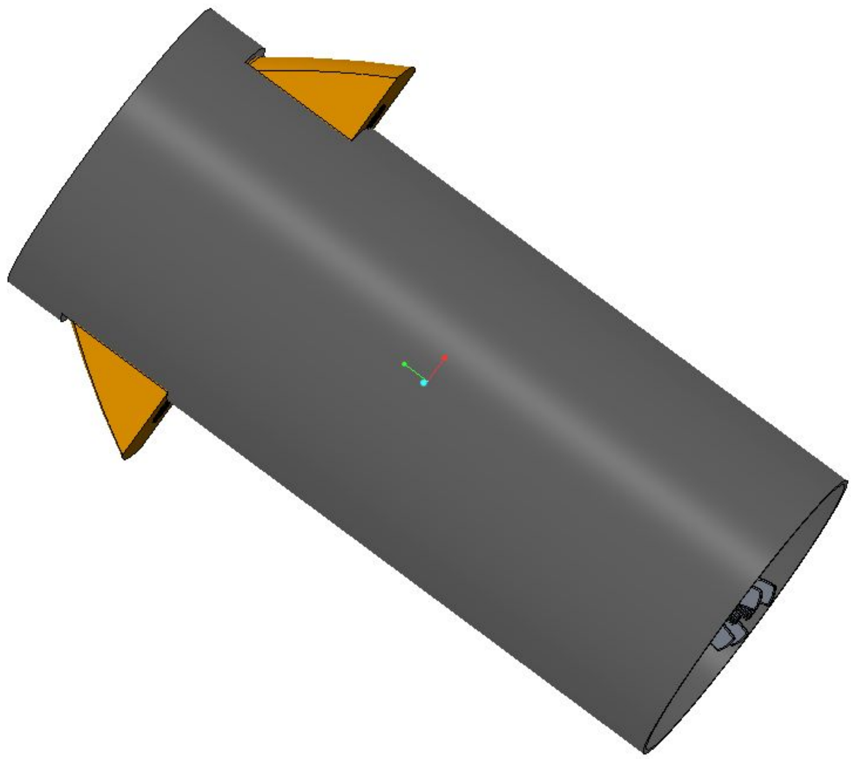
- The payload bay must be located in a section independent from the recovery bay
- The payload must fit within a tube that is 12 inches in length and 4.815 inches in diameter
- The payload must have a power supply independent from the one used in recovery
- The payload must weigh less than or equal to 2 pounds
- The drag produced by the video recording device must be minimized
- The payload must be operable for at least 2 hours

5.1.2. Payload Design

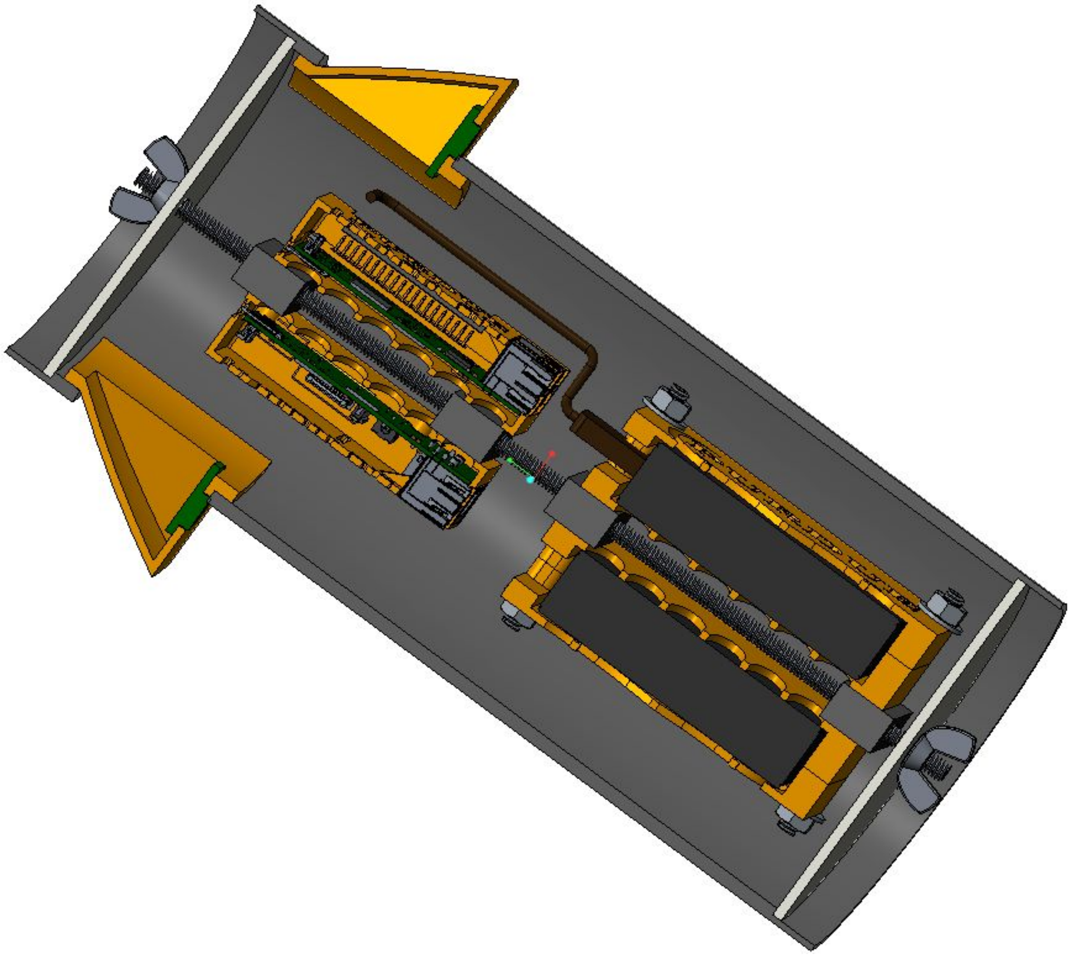
The onboard computer and battery supply will be mounted to a custom fabricated sled. The sled will ride along two parallel threaded rods. A custom shroud fabricated shroud will be made to mount the video camera lense perpendicular to the exterior of the payload bay. The rationality behind this design configuration is that the threaded rods serve the dual purpose of holding the bulkheads located at opposite ends of the payload tube together in addition to providing a mounting anchor within the payload tube. The shroud will be shaped in such a fashion as to minimize aerodynamic drag by maximizing pressure recovery. Preliminary CAD drawings of this construction are illustrated in section 5.1.6.

5.1.3. Vehicle And Payload Interface

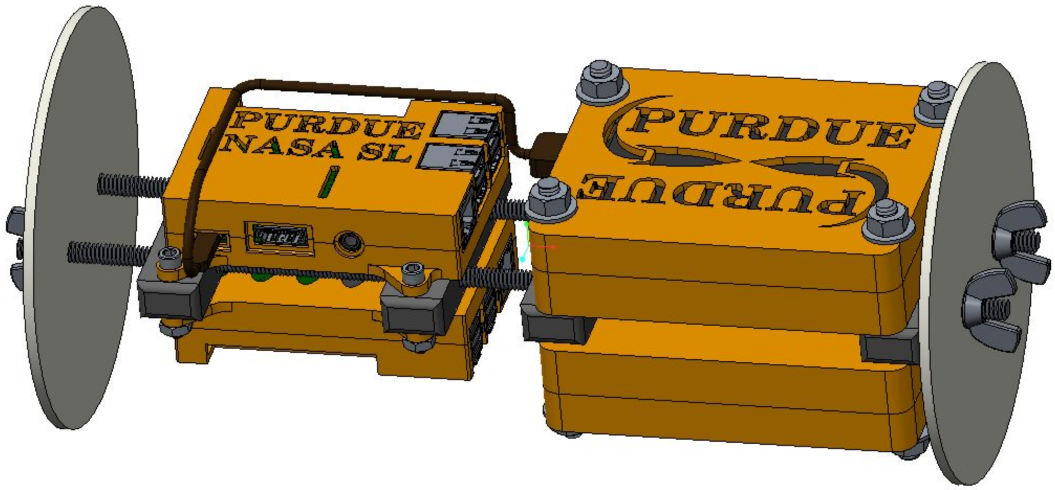
The payload section will be a 12 inch long section of the rocket that is fully enclosed and has two shrouds, as ports for the dual cameras. The section can be seen in the figure below.



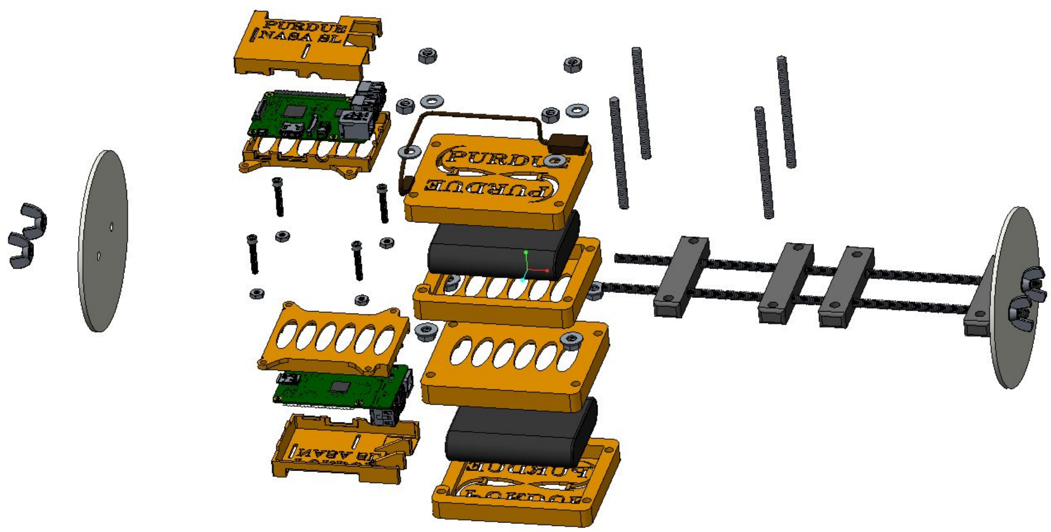
The section will contain a sled that acts as the mount for all the payload hardware. This includes the two batteries, two raspberry pi’s, and 2 cameras, ensuring full redundancy and an even weight distribution within the rocket. A cutaway of the payload section can be seen below.



Looking in more detail, the payload section sled consists of two 1 foot long lengths of threaded rod, and 4 spacers which are mounted to them. These spacers act as the mounts for the batteries and pi's, respectively. Note that each pi and battery has a custom housing that enables it to mount to the sled. A more detailed view of the sled can be seen below.



An exploded view, seen below, shows the components as they would need to be assembled to the sled. It will consist of a mix of COTS (commercial off-the-shelf) and custom (3D printed) hardware.



5.1.4. On board computer

5.1.4.1. Design Alternatives With Pros And Cons

There are a variety of small computers available on the market that are capable of accomplishing the task of processing the video that will be recorded by the exterior mounted camera. A list of requirements that the computer must satisfy was made In order to narrow the selection of the search. The fulfilment of these criteria was binary with computers either satisfactory or unsatisfactory to expedite the selection process. These initial requirements are listed below:

1. Computer must be less than $100
2. Computer must be less than 4 inches in width

a. This ensures that the computer along with its mounting hardware will be able to fit inside the 4.815 inch diameter payload bay

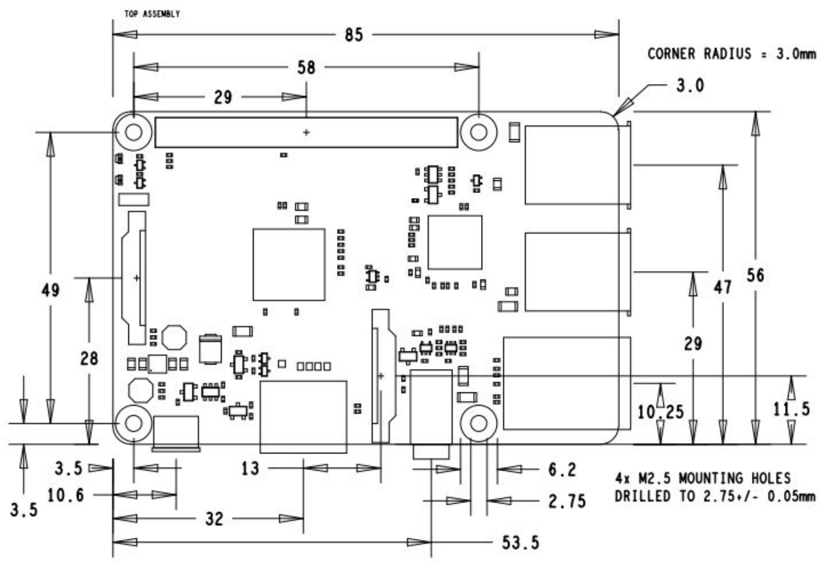
These criteria eliminated hundred of potential computers from consideration. The decision was then made between the top six most popularly available products. These products along with their defining characteristics are listed in the table below:

	Features				
Options	CPU	RAM	Cost ($)	Wireless wifi	Dimensions (cm^3)
Raspberry Pi 3	Quad Cortex A52 @ 1.2 Ghz	1GB SDRAM	35	yes	8.56 x 5.65 x 1.7
Odroid-XU4	Samsung A15 @ 2 Ghz	2GB LPDDR3	60	No	8.3 x 5.8 x 1.0
BeagleBone Black Rev C	AM335x @ 1 GHz	512 MB DDR3	56	No	8.64 x 5.34 x 1.9
Udoo x86	Atom X5-E8000 @ 2,00 GHz	2GB DDR3	90	No	12.0 x 8.5 x 2.5
Dragon Board 410 C	Quad Core A53 @ 1.2 Ghz	1GB LPDDR3	85	yes	12.0 x 6.5 x 2.0
Arduino Industrial 101	Atheros R9331 @2.4 Ghz	64 MB DDR2	40	yes	5.1 x 4.2 x 1.0

5.1.4.2. Leading Choice

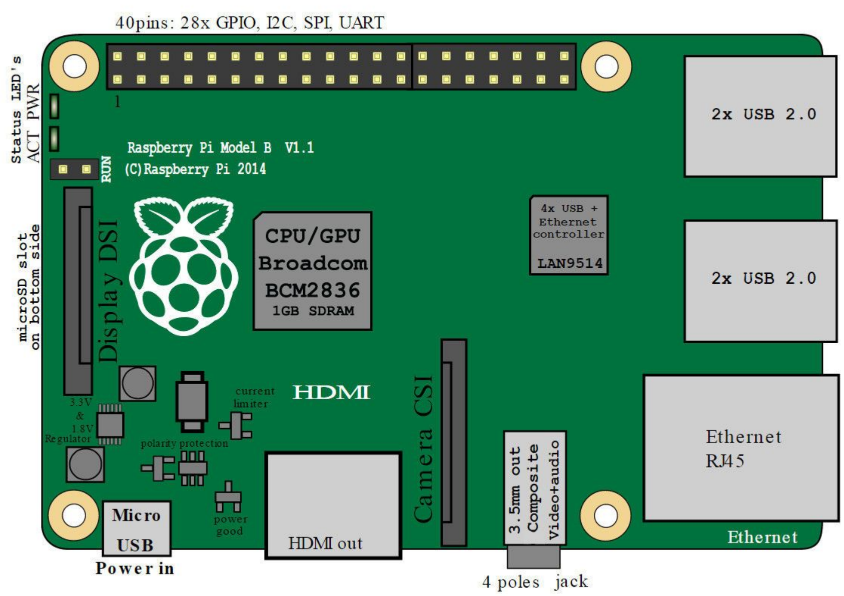
With a list of six potential onboard computers to choose from, the final decision was made based on finding a balance between costs, processing speed, RAM, and availability. Due to budget concerns, it was decided to look at the three lowest cost options. Eventually the Raspberry Pi3B was selected due to user familiarity amongst the team and its combination of decently high processing speed and RAM.

5.1.4.3. Dimensional Drawing

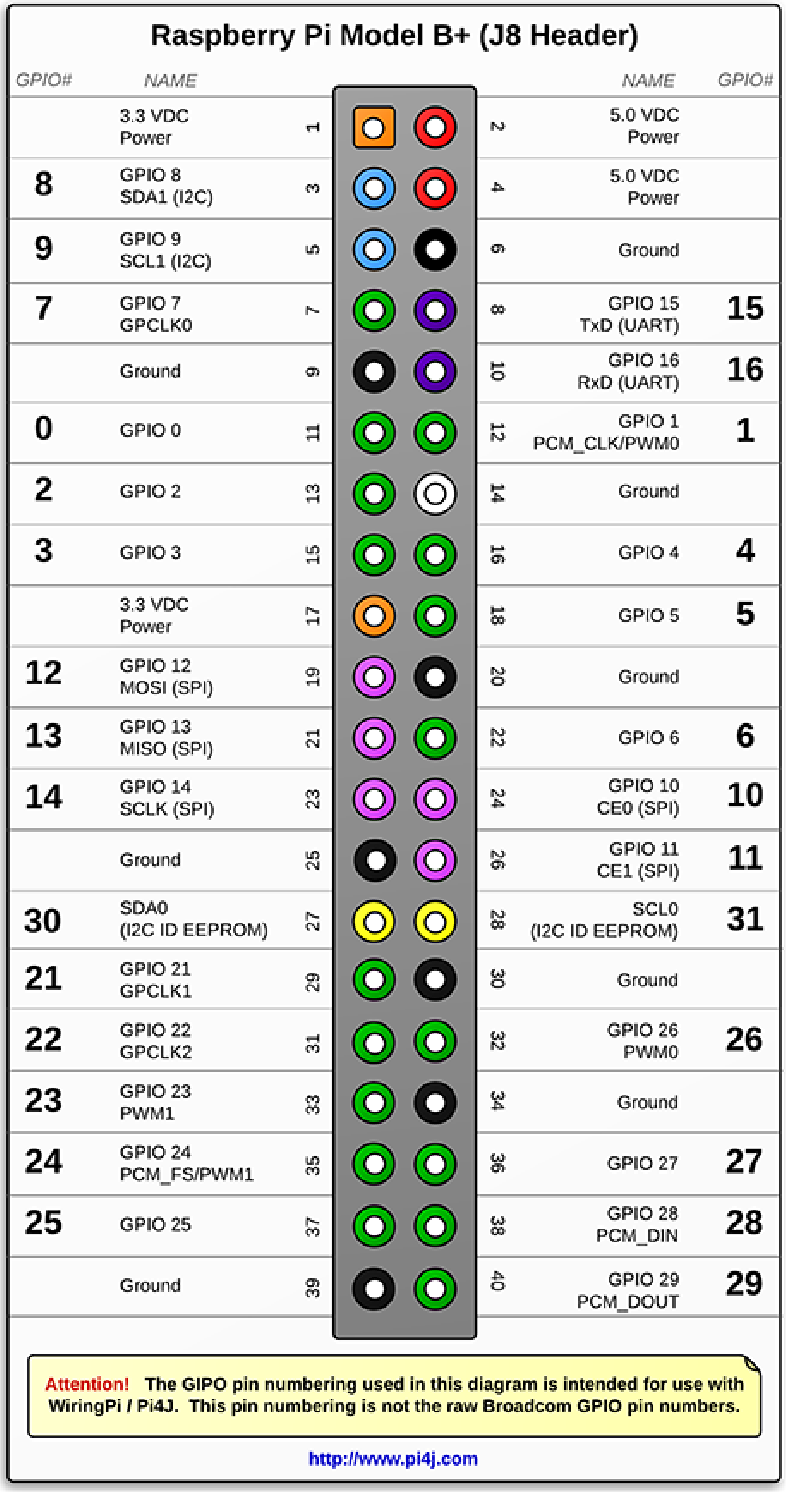


https://www.raspberrypi-spy.co.uk/2014/07/new-raspberry-pi-model-b-revealed/raspberry_pi_model_b_plus_dimentions/#prettyPhoto/0/

5.1.4.4. Wiring Diagram



http://bitsnapper.com/raspberry-pi-2-model-b-1gb-wiki-walkthrough-guide/raspberry-pi-2-model-b-1gb-system-on-chip-diagram-circuit/



http://pi4j.com/pins/model-b-plus.html

5.1.4.5. Estimated Mass

The estimated weight of the Raspberry Pi is 42.0 grams

5.1.5. Camera

5.1.5.1. Design Alternatives With Pros And Cons

There are a large number of potentially viable cameras that can be used to detect the 3 40’x40’ colored targets that our payload will be tracking. In order to aid in the down selection of cameras, a list of baseline requirements were created to filter out any cameras that would not be appropriate for the specifics of the mission and/or would necessitate an unnecessarily complex systems integration process. These criteria, shown below, detail the characteristics deemed minimally acceptable for the mission.

Baseline Camera Selection Criteria

Criteria	Specification	Rationale
Hardware Compatibility	Connects to CSI or USB ports	Connects directly to Raspberry Pi, extra weight, uncertainty with hardware adapters
Software Compatibility	Built in Raspberry Pi system	No time for development of custom drivers
Weight	4 oz.	Limit of payload bay is 2 lbs., assume .5 lbs. for cameras (rest for sled, pi, battery, etc.) 4 oz. allows 2 cameras
Picture Resolution	5 Megapixels	Capture clear images of the ground from flight apex
Frame Rate	720p (60fps)	Capture video feed of ground with minimum blur (assuming rocket spin)
Footprint (W x L x H)	4” x 4” x 1”	Fit in payload bay (~half bay L x W due to sled along centerline
Power Draw	Voltage = 5V, Current = 2A	Powered by Raspberry Pi (inbuilt battery weight untenable)
Cost	$50	Small budget, allows redundancy if necessary
Field of View	45° x 45°	Capture images of targets a minimum altitude
Accurate Color	IR filter	Many compatible cameras are “night vision cameras” that distort colors in daylight

With the above baseline criteria in hand, a thorough search of the possible camera options was undertaken. This search resulted in 11 cameras which were evaluated against the same criteria. The table below details the technical aspects of each camera in the chosen categories.

Camera Technical Details

Item No.	Camera	Resolution (Pixels)	Frame Rate	Port	W x L x H (in)	Weight (oz)	Cost	Field of View
1	Raspberry Pi Camera Module V2	8 MP (3280 x 2464)	1080p (30fps), 720p (60fps)	CSI	.98 x .94 x .35	0.11	$25.99	79°
2	SainSmart Fish-Eye Camera	5 MP (2952 x 1944)	1080p (30fps), 720p (60fps)	CSI	.99 x .95 x .36	0.6	$23.99	72.4°
3	SainSmart Wide angle Camera	5 MP (2952 x 1944)	1080p (30fps), 720p (60fps)	CSI	1 x 1 x .36	0.6	$21.99	160°
4	SainSmart Wide AngleCamera	5 MP (2952 x 1944)	1080p (30fps), 720p (60fps)	CSI	1 x 1 x .36	0.6	$22.99	175°
5	Adafruit Spy Camera	5 MP (2952 x 1944)	1080p (30fps), 720p (60fps)	CSI	.34 x .45 x .70	0.07	$39.95	67.8°
6	Arducam Spy Cam	5 MP (2952 x 1944)	1080p (30fps)	CSI	.63 x .63 x .35	0.32	$29.99	67.8°
7	Huhushop Camera Board REV 1.3	5 MP (2952 x 1944)	1080p (30fps)	CSI	.99 x .95 x .36	0.8	$17.99	67.8°
8	Arducam OV5647 Camera	5 MP (2952 x 1944)	1080p (30fps), 720p (60fps)	CSI	1 x 1 x .2	0.3	$14.99	67.8°
9	Arducam 5 OV5647 Camera w/ CS Mount Lens	5 MP (2952 x 1944)	1080p (30fps)	CSI	1.42 x 1.13 x 2	0.32	$29.99	120°
10	ELP 2.1mm Wide Angle HD Camera	5 MP (2952 x 1944)	1080p (30fps)	USB	1.5 x 1.5 x .75	0.3	$43.00	120°
11	Waveshare RPi Camera G	5 MP (2952 x 1944)	1080p (30fps)	CSI	.98 x .94 x .50	0.3	$28.99	160°

The cameras were then evaluated using a weighted decision matrix to determine the best camera for our purposes. While all of the criteria are quite important, many become less crucial once they pass a certain threshold value, leading to some characteristics being weighted less than would initially be assumed. The ranked cameras are listed below.

Camera Weighted Decision Matrix

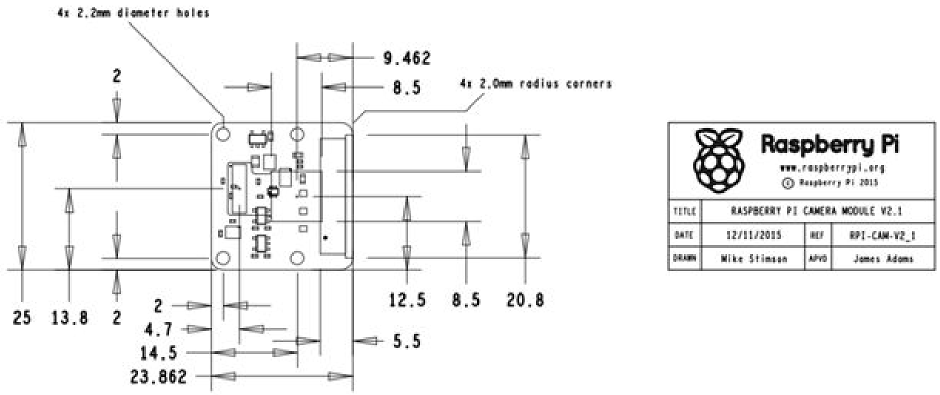
Weights:	5	4	1	2	3	2	3	20	
Weights:	25%	20%	5%	10%	15%	10%	15%	100%	
Camera	**Resolution**	**Frame Rate**	**Port**	**W x L x H**	**Weight**	**Cost**	**Field of View**	**Score**	**Rank**
1	2	2	2	2	4	4	2	2.50	1
2	1	2	2	2	2	5	1	1.90	7
3	1	2	2	2	2	4	4	2.25	3
4	1	2	2	2	2	4	5	2.40	2
5	1	2	2	4	4	2	1	2.10	5
6	1	1	2	3	2	3	1	1.60	9
7	1	1	2	2	1	5	1	1.55	11
8	1	2	2	3	3	5	1	2.15	4
9	1	1	2	1	3	3	3	1.85	8
10	1	1	1	1	3	1	3	1.60	10
11	1	1	2	2	2	3	4	1.95	6

5.1.5.2. Leading Choice

The leading choice is the native Raspberry Pi Camera Module V2. There are some other cameras that rank closely behind the V2 in the decision matrix, but the case for it is bolstered by several less quantifiable factors. For one, being a native camera system, this is significantly more documentation to aid in troubleshooting and interface problems that are encountered. Furthermore, some of the categories where the V2 fell behind, could be improved by relatively simple hardware modifications. For example, it is the most powerful camera, but has a somewhat limited field of view—which could be improved by replacing the lens. In the end, many of these cameras are quite similar and the V2 provides the best baseline, from which a more customized and specific version can be developed for this project.

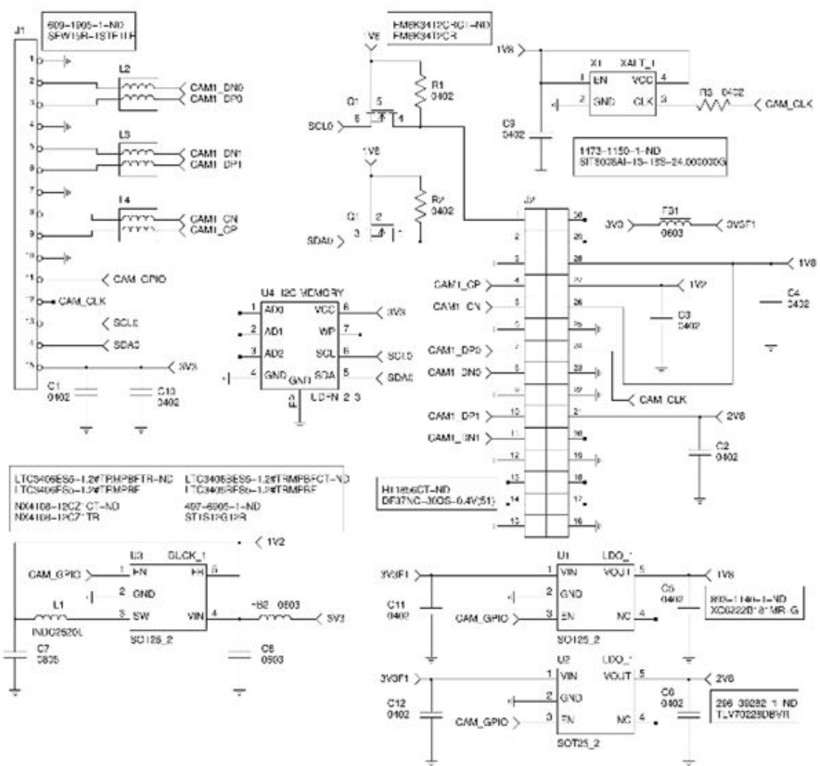
Raspberry Pi Camera Module V2
(https://www.raspberrypi.org/products/camera-module-v2/)

5.1.5.3. Dimensional Drawing



(https://www.raspberrypi.org/documentation/hardware/camera/rpi-cam-v2_1-dimensions.pdf)

5.1.5.4. Wiring Diagram



(https://hackaday.io/project/19480-raspberry-pi-camera-v21-reversed)

5.1.5.5. Estimated Mass

The estimated weight of the camera board and attachment cable is a total of 0.12g

5.1.6. Power supply

5.1.6.1. Design Alternatives With Pros And Cons

There are many power supply categories available, and there are hundreds of options within each category. In order to narrow down the possibilities between the variety of options available to the team, a list of basic requirements was created. Although the list was not lengthy, it narrowed down the field of possibilities quite a bit. The requirements on this list are as follows:

1. The battery must be less than $30 per battery
2. The battery must be less than one pound
3. The battery must be less than four inches wide in order to fit into the payload bay (4.815 inch diameter)

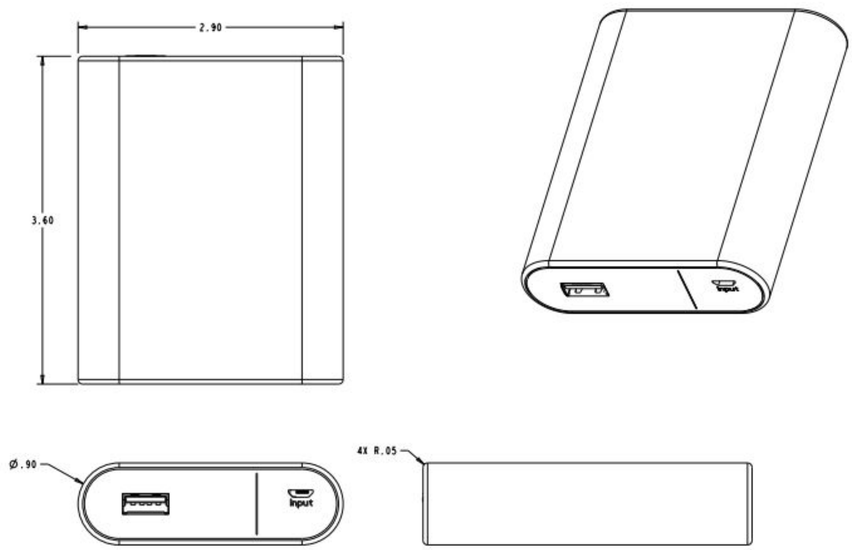
Based on these requirements, the top five options were chosen and listed along with defining options in a spreadsheet which can be seen below.

1	Battery (Supplier/Link)	mAh	L (in)	W (in)	T(in)	m(lb)	Price ($)	Amps (A)	Volts (V)
2	RAVPower Portable Charger with 2 ports (Amazon)	20100	6.81	3.19	0.87	0.84	49.99	2.4 per	5
3	RAVPower Portable Charger with 1 port (Amazon)	6700	3.54	1.57	0.98	0.26	13.99	2.4	N/A
4	Anker PowerCore Charger with 1 port (Amazon)	10000	3.6	2.3	0.9	0.4	25.99	2.4	5
5	Anker PowerCore 2-in-1 Portable/Wall Charger (Amazon)	5000	3.6	2.8	1.2	0.42	25.99	2.1	5
6	ROMOSS USB for Raspberry Pi (Adafruit)	10000	5.4	2.4	0.8	0.64	39.95	2	5 each

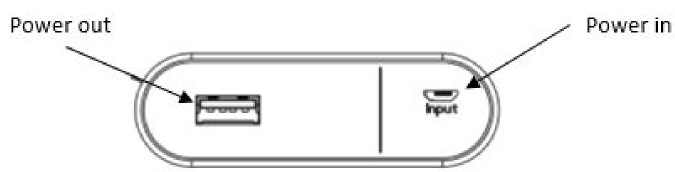
5.1.6.2. Leading Choice

The leading choice for the power supply is two Anker PowerCore Chargers with 10,000 mAh per unit. This options allows for a perfect weight distribution on either side of the mounting sled in the payload bay along with complete redundancy for the payload. This battery fits the cost requirement along with the dimension requirement set by the team.

5.1.6.3. Dimensional Drawing



5.1.6.4. Wiring Diagram



5.1.6.5. Estimated Mass

The estimated mass of the power supply is approximately 0.4 lbs.

5.1.7. Program Language Decision Alternatives

The programming language that we are using for the target detection system on the Raspberry Pi is Python. We are using Python 3 or greater for our program and for program testing. We chose this language for several reasons.

The first reason is that Python code is very easy to both read and write. Also, the Python interpreter allows for quick and easy execution of code. The Python Package Index also allows for quick installation of all relevant packages that are needed, which can be easily used through the terminal in the Raspbian Operating System. Another reason is that a Python program can import OpenCV libraries. OpenCV is an open source library that is very useful in image analysis. Our target detection system program will be built around the OpenCV library and the functions that it contains.

5.1.7.1. Alternative Approaches

We came up with several different algorithm approaches that could be used for our target detection system. The differences in the approaches consist of how we want to obtain the image to be processed, when we want to process the image, and what algorithm we want to use for the detection of the targets.

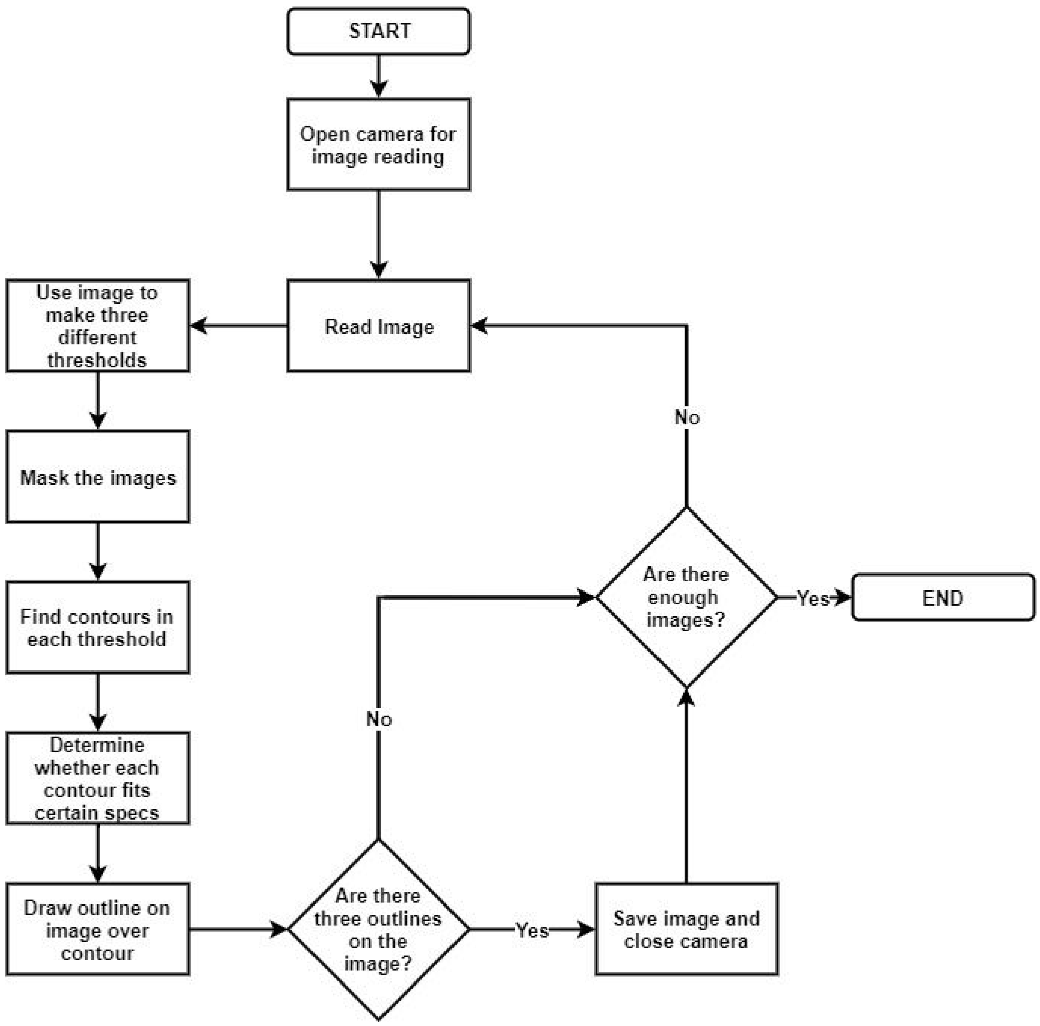
The first consideration comes from how we want to obtain the image. The first way we considered is to take several images at intervals throughout the flight of the rocket. The advantage of this would be low processing power required, and the disadvantage would be a small sample size to process. The second alternative we considered is to record a video during flight, and then analyze the video frame-by-frame. The advantage to this approach is a very large sample size to process and low processing requirements, and the disadvantage would be the amount of space required to store the video file. The last approach we considered is to input a live stream of the camera during flight, and process that stream frame-by-frame in real time. The advantage to this approach is that we have instant feedback on how well the detection is working, and the disadvantage is the high processing power requirements.

The second consideration comes from when we want to process the image. Depending on which approach we take from how we obtain our input, we can either process the images in real time or do the processing after the sample has been collected. Processing in real time has larger power requirements, but provides instant feedback and only successful detections could be stored. Processing at the end would require extra time at the end of the flight to process the images collected during flight.

The third consideration comes from which algorithm we want to use to detect the colored square targets. One approach to detecting the colored square targets would be to detect contours in an image and search for squares. Once a square is found, the mean LAB value for that square would be calculated and then that square would be labeled to a certain color depending on which of the given RGB values it most closely represented. LAB values would be used in this case because the distance between two points on the LAB color space has perceptual meaning, unlike RGB and HSV, and could be used to find the closest representative color. A second approach to detecting the colored targets would be to filter each image into three separate thresholded images depending on the given RGB values of the targets. These three thresholded images should only reveal the three target colors, and then the program would simply check whether or not the contours in that image are representative of a tarp.

5.1.7.2. Flow Chart

The flowchart below is for the preferred approach which analyzes images in real time by filtering based on the preset RGB values. On program start, the camera would be opened up and would be available to grab images at any point on the flight. The program then enters a loop that reads an image, parses that image, and then saves that image depending on the amount of targets detected. Once enough images have been saved, or enough time has passed, the program will terminate, and all images will be saved.



5.1.7.3. Optimization Algorithms

One consideration we have for optimizing performance on our system is to convert our code from Python into C++, and compile it that way on the Raspberry Pi. We believe this would give a moderate increase in performance as C++ is a lower level language that works better with memory. Also, the OpenCV libraries that are currently used with Python are native to C++. Another consideration to optimize performance if a real-time image processing approach is chosen would be to run a concurrent thread that is grabbing images from the camera while an image is being processed so that a new image is always available when it is requested. Since the image grabbing function in current use is a blocking operation that stalls the program until an image is obtained from the camera, a concurrent thread would make sure that there is always a new image ready for parsing by the time the previous image is done analyzing. Running a concurrent thread that handles image requests from the camera would both smooth and increase FPS, and increase overall performance.

6. Project Plan

6.1. Requirements Verification

6.1.1. General Requirements Verification Plan

General requirements will be met by ensuring that each subteam operating within the scope of the project are aware of their respective tasks, plans, and procedures. In addition, all team members will become familiar with tasks, plans, and procedures of other subteams in order to understand how each team is interconnected and affects the project as a whole. Furthermore, members will be able to work in multiple disciplines and participate in subteams that they are not directly assigned to in order to make them a more rounded individual and gain a broader understanding of everything taking place within the group. Lastly, everyone will gain firsthand experience in design, construction, and launching of high powered rockets prior to the completion of the competition in Huntsville, Alabama. By ensuring the transparency and fluidity of group work, team members will cooperate in a manner that mitigates any risks to the general requirements.

6.1.2. Vehicle Requirements Verification Plan

The plan to verify vehicle requirements is to conduct a series of ground tests and electronics tests followed by at least one sub scale test flight and one full scale test flight. Ground testing will be done to ensure that ejection charges are appropriately sized and supply enough pressure to successfully deploy the drogue and main recovery gear. Electronics testing will be done to ensure that our circuits are operating properly without any indication of a short or open in the system. In place of energetics, we will use light bulbs as an indication that the circuit is complete and the bulbs illuminate, signaling an ejection charge. A minimum of one sub scale flight will be performed to ensure that our vehicle is stable, our electronics operate as intended, and our recovery devices deploy as expected. It will also give us an opportunity to test our experiment, which will be discussed later in further detail. Lastly, a full scale flight test will be performed to further validate the vehicle's stability, systems, and recovery. It will give us an additional chance to properly size our ejection charges, become familiar with the launch procedures and checklists, and give the team practice using GPS and telemetry receivers for vehicle tracking.

6.1.3. Recovery System Requirements Verification Plan

The recovery system will be tested on the ground as well as in at least one full scale flight. The avionics will remain the same for all flights, and we will ground test with them to ensure that they work as designed, ignite the ejection charges, properly pressurize the airframe sections enough to break the shear pins, and fully deploy the recovery gear. The gear will also be tested in flight, as we will be using the same recovery gear on the full scale test flight as in the competition flight. Furthermore, each parachute will be subjected to a drop test in order to determine inflation time and altitude loss from the time it was deployed to the time it fully inflated.

6.1.4. Experiment Requirements Verification Plan

In order to verify the experimental requirements, extensive testing will be done to ensure that the payload target detection program is feasible and capable of target detection. On all subscale flights there will be a small payload with a camera along with tarps scattered on the ground. The payload camera for the subscale flights would only work to grab video of the scattered tarps on the ground and not be used for real-time target detection so that the video can then be later used to correct and optimize the target detection program. The camera used on all subscale flights will be the same camera that is being used in the final payload design to ensure identical image quality all throughout testing. The full scale test flight will allow for accurate testing on the robustness and feasibility of the payload as a whole. On the full scale test flight, real-time target detection will be used in order to test the functionality of the payload to make sure that the designed target detection program is working. Again, like in the subscale test flights, the full scale test flight will have tarps scattered for use in target detection. The full scale test flight will also allow further testing of the power capacity and power capability of the payload batteries to ensure that the target detection system receives enough power to operate effectively.

6.1.5. Safety Requirements Verification Plan

The safety team prioritizes the wellbeing of all involved with the launch when making its requirements. The requirements of the safety team are verified by how well the people involved with the launch follow and are aware of safe procedures and how safe the launch is overall. In order to ensure all working on this project understand the safe practices which are relevant to it, all team members will sign a team safety statement (Section 4.10). This statement is an affirmation by team members that they will comply with all relevant laws and regulations and the NAR High Power Rocketry Safety Code and will obey all instructions given by the Safety Officer and Range Safety Officer, whether verbally or through team safety documents. It also affirms that members are aware that safety breaches are dangers which can completely halt the launch of the rocket. As well as this, documents created by the safety team for this project and relevant safety resources (such as materials safety data sheets) will be discussed by the safety officer in front of the entire project team to keep them aware of proper project procedures and any dangers associated with high-power rocketry they may not have been aware of.

6.2. Team Derived Requirements

6.2.1. Vehicle Team Derived Requirements

The vehicle will be tested to operate within the requirements provided in the 2018 USLI College and University Handbook:

1. The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL).
2. The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner. Teams will receive the maximum number of altitude points (5,280) if the official scoring altimeter reads a value of exactly 5280 feet AGL. The team will lose one point for every foot above or below the required altitude.
3. Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.
4. Each altimeter will have a dedicated power supply.
5. Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).
6. 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.
7. 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 vehicle or is recovered separately from the main vehicle using its own parachute.
8. The launch vehicle will be limited to a single stage.
9. The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.
10. The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components.
11. 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 Range Services Provider.
12. The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by Range Services).
13. 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).
    a. Final motor choices must be made by the Critical Design Review (CDR).
    b. Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.

14. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:
    a. 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.
    b. Each pressure vessel will include a pressure relief valve that sees the full pressure of the valve that is capable of withstanding the maximum pressure and flow rate of the tank.
    c. Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.
15. The total impulse provided by a College and/or University launch vehicle will not exceed 5,120 Newton-seconds (L-class).
16. 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.
17. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.
18. All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets.
    a. 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.
    b. The subscale model will carry an altimeter capable of reporting the model's apogee altitude.
19. All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate 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 a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight:
    a. The vehicle and recovery system will have functioned as designed.
    b. The payload does not have to be flown during the full-scale test flight. The following requirements still apply:
        i. If the payload is not flown, mass simulators will be used to simulate the
        payload mass.

    ii. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.
  c. If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale demonstration flight.
  d. The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulates, as closely as possible, the predicted maximum velocity and maximum acceleration of the launch day flight.
  e. The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.
  f. 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).
  g. Full scale flights must be completed by the start of FRRs (March 6th, 2018). If the Student Launch office determines that a re-flight is necessary, then an extension to March 28th, 2018 will be granted. This extension is only valid for re-flights; not first-time flights.
20. Any structural protuberance on the rocket will be located aft of the burnout center of gravity.
21. Vehicle Prohibitions
  a. The launch vehicle will not utilize forward canards.
  b. The launch vehicle will not utilize forward firing motors.
  c. The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).
  d. The launch vehicle will not utilize hybrid motors.
  e. The launch vehicle will not utilize a cluster of motors.
  f. The launch vehicle will not utilize friction fitting for motors.
  g. The launch vehicle will not exceed Mach 1 at any point during flight.
  h. Vehicle ballast will not exceed 10% of the total weight of the rocket.

6.2.2. Payload Team Derived Requirements

The payload team has five specific requirements for the rocket beyond the scope of the NASA guidelines as well as the necessary mission of the payload. They are as follows (in no particular order):

1. Identifies targets based on color.

   As this is the main mission of the payload, it is of utmost importance. The rocket must be able to identify and differentiate between the three targets. The approximate values have been released, so the values are known. No two are particularly close to each other in color, so the program should not have too difficult of a time identifying the differences.
2. Identifies targets based on shape.

   The algorithm developed for use onboard the rocket will be optimized to not only identify the specific RGB values of the targets, but also the shape of the targets. For instance, if the targets are large, rectangular tarps, the code will notice and be able to differentiate that tarp from another that is another shape, such as a square. Being able to differentiate between shapes can help the code determine where one tarp ends and another begins to that it is not confused about the shift in RGB value.
3. Latency threshold less than 100 ms/loop iteration.

   The algorithm used must be efficient and not have too much latency. This is very important in identifying the targets, so the team has placed high priority on the latency threshold. As a result, the team decided that 100 milliseconds per loop iteration is sufficient to allow the code to run smoothly enough to not have any major delays during the flight. Any lower was unreasonable given the code and amount of time allowed to work. Any higher and the code may have issues with identification.
4. Sum of the payload components must not exceed two pounds.

   Placing the payload in the rocket requires that the payload itself be small and light. A heavy payload can have drastic effects on the avionics of the rocket. As such, the Purdue Student Launch team as a whole decided that two pounds was sufficient enough to perform the actions necessary for the competition while also not being a burden on the avionics team. As was later discovered, two pounds was fully sufficient to perform the actions necessary and the payload was allowed a fully redundancy setup.
5. Battery supply powers system must operate for three hours.

   Although the rocket will not be in the air for three hours, there are many factors that may influence the time between the rocket setup and the launch. Since the team members will be unable to interact with the rocket after it has been set for launch, the payload must be able to withstand the potentially long amount of time it may sit, untouched. Three hours was decided to be a sufficient amount of time to cushion the launch and thus, the battery must last at least three hours.

6.2.3. Recovery Team Derived Requirements

The recovery system will be tested to operate within the requirements provided in the 2018 USLI College and University Handbook:

1. The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.
2. Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.
3. At landing, each independent sections of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.
4. The recovery system electrical circuits will be completely independent of any payload electrical circuits.
5. All recovery electronics will be powered by commercially available batteries.
6. The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.
7. Motor ejection is not a permissible form of primary or secondary deployment.
8. Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.
9. Recovery area will be limited to a 2500 ft. radius from the launch pads.
10. An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.
    a. Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device.
    b. The electronic tracking device will be fully functional during the official flight on launch day.
11. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).
    a. 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.
    b. The recovery system electronics will be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.
    c. 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.

d. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.

6.2.4. Safety Team Derived Requirements

The safety team has four derived requirements for the rocket considering the scope of the NASA guidelines and the mission of the payload. They are as follows (in no particular order):

1. Achieve full compliance with local, state, and federal laws and maintain a positive reputation as a team which prioritizes lawful rocketry.
2. Provide each team member with the knowledge required to work safely with high-power rockets and any hazardous materials associated with these rockets.
3. Create and utilize fully-functional hazard analysis and contingency plans to both prevent and react optimally to any emergency situations.
4. Have an organized set of procedures which can be followed at all times to enforce safe construction and launch practices and to be fully prepared for any emergency. This includes adhering to the team safety statement and following established safety checklists for pre-launch, launch, and post-launch.

6.2.5. General Team Derived Requirements

The general requirements for the team as a whole, as agreed on unanimously by the team members are as follows:

1. Create and maintain a functioning website and social media profile with regular project updates, documents, and milestones that highlight our progress as it relates to the scope of the project.
2. Not spend any money out of pocket using personal funds without a means of being fully reimbursed through Purdue SEDS or some other school related organization.
3. Have a successful sub scale flight and recovery on a sub scale motor while carrying a functional payload system.
4. Have a successful full scale test flight and recovery on a full scale motor while carrying a functional redundant payload system.
5. Successfully design, build, and test a working on board payload capable of meeting the requirements derived by the team and presented to us by NASA within the 2018 USLI College and University Handbook.
6. Fulfill and exceed all educational engagement requirements presented to us by NASA within the 2018 USLI College and University Handbook.

7. Have a functioning and attractive rocket booth that highlights the work done by our team, including a functional payload on display for viewers to see and a full scale rocket for spectators to interact with.
8. No disqualification by any means whatsoever.
9. Successful finish of the competition in Huntsville, Alabama.

6.3. Budgeting and Timeline

6.3.1. Line Item Budget

6.3.1.1. Full Scale Rocket

Rocket Parts	Unit Cost	Quantity	Total
5:1 5" Von Karman FWFG Nosecone	108.95	1	108.95
5" G10 FG Avionics bay lid	16	6	96
5" FWFG Airframe, 30" long	85	3	255
Custom Airframe Slotting, 3/16" wide, 15" long	6	3	18
5" FWFG Switch Band, 2" long	7	2	14
5" FWFG Coupler, 12" long	53	2	106
3" FWFG Motor Tube, 30" long	50	1	50
1/8" G10 FG Centering Ring	9	2	18
1/2" Plywood Centering	5	2	10
3/16" G10 FG Fins	20	3	60
Skyangle Cert 3 XL Parachute	189	1	189
Skyangle Cert 3 Drogue Parachute	27.5	1	27.5
18" x 18" Nomex Parachute Protector	10.95	2	21.9
40' Long Double Looped Kevlar Tether	61	2	122
Large Rivet Package	4.5	2	9
1515 Series Rail Button Package of 4	7.95	1	7.95
75mm AeroPac Flanged Motor Retainer	50	1	50
5"/75mm SC Precision Thrust Plate	55.59	1	55.59
Aerotech 75mm 3G Hardware Set	450	1	450
Aerotech 75mm 3G L1520-T Reload	199	2	398
			2066.89

6.3.1.2. Sub Scale Rocket

Item	Unit Cost	Quantity	Total
5:1 3" Ogive Standard Wall FWFG Nosecone	58.95	1	58.95
3" G10 FG Avionics Bay lid	10	6	60
3" FWFG Standard Wall Airframe, 60" long	100	1	100

Custom Airframe Slotting, 3/32" wide, 7.5" long	5	4	20
3" FWFG Switch Band, 1" long	4	3	12
3" FWFG Coupler, 6" long	15	2	30
38mm FWFG Standard Wall Motor Tube, 30" long	32	1	32
1/8" G10 FG Centering Ring	6	2	12
1/4" Plywood Centering	3.55	2	7.1
3/32" G10 FG Fins	10	3	30
Top Flite 50" Main Parachute	26.95	1	26.95
Top Flite 15" Drogue Parachute	6.95	1	6.95
9" x 9" Nomex Parachute Protector	6.95	2	13.9
20' Long Double Looped 5/16" Kevlar Tether	26.99	2	53.98
Medium Rivet Package	3.5	2	7
1010 Series Rail Button Package of 4	6.95	1	6.95
38mm AeroPac Motor Retainer	25	1	25
CTI 38mm 4G Casing	50.6	1	50.6
CTI 38mm 4G I470 WT Reload	55	1	55
			608.38

6.3.1.3. Travel

Item	Unit Cost	Quantity	Total
Hotel Room	200	24	4800
Gas	40	32	1280
			6080

6.3.1.4. Avionics

Item	Unit Cost	Quantity	Total
TeleMetrum - Altus Metrum	$321.00	1	$321.00
TeleDongle - Altus Metrum	$107.00	1	$107.00
RRC3+ Sport - Missile Works	$70.00	1	$70.00
9V Battery - Duracell	$6.00	4	$24.00
Dual Altimeter Wiring Kit - Binder Design	$20.00	1	$20.00
3/4" Panel-Mount Key Switch - McMaster-Carr	$14.10	1	$14.10
2-1/2" Sch 40 PVC Cap - Socket 447-025	$1.60	6	$9.60
National Hardware 1 Count 1/4-in to 20 x 2.5-in Stainless Steel Plain Eye Bolt with Hex Nut	$1.00	4	$4.00

Hillman 0.375-in x 36-in Standard (SAE) Threaded Rod	$2.90	2	$5.80
#10-32 Stainless-Steel Wing Nut (6-Pack)	$7.80	1	$7.80
Srews, bolts, nuts	~$10.00	1	$10.00
Sled - 3D Printed	~$5.00	2	$10.00
Masking Tape	$7.08	1	$7.08
FFFFg Black Powder	$26.00	1	$26.00
Arrow 3-element Yagi	$49.00	1	$49.00
			$685.38

6.3.1.5. Payload

Item	Unit Cost	Quantity	Total
Raspberry Pi Model 3B	35.1	1	35.1
10,000 mAh battery, 5V 2.4A output	25.99	1	25.99
Raspberry Pi V2 camera	23.99	1	23.99
Raspbery Pi power recorder			TBD
3D print material			TBD
Threaded barstock			TBD
nuts / wingnuts			TBD
			85.08

6.3.1.6. Branding

Item	Unit Cost	Quantity	Total
T-Shirts	15	32	480
Polos	15	32	480
			960

6.3.1.7. Social

Item	Unit Cost	Quantity	Total
Website	0	1	0
Instagram Boost	1	5	5
Facebook Boost	1	3	3
			8

6.3.2. Funding Plan

6.3.2.1. Sources Of Funding

Assuming that the team requires around $11000, there will be three primary ways funds will be made to support the NASA USLI project:

1. Skip-a-meals and Campus Fundraisers: Skip-a-meals are social events where individuals can mention the name of our organization at a designated food

establishment and a percentage (usually half) of money they spend at the establishment will be given to the team. These events usually last for a whole afternoon.

2. Non-profit and Educational Grants: Although these can easily fund a large chunk of our expected required budget, experiences have shown that finding private grants that specifically meet the criteria of a student organization can sometimes be hard to find. The team will consult both private companies and school departments here on campus for this. SEDS, as our supervising organization, has provided us with some starting funds that will allow us to purchase materials for the sub scale rocket, and potentially some of the required parts for the full scale, but nothing beyond that. We have identified a few grants that we have applied to, but are still awaiting responses from organizations.

3. Company Sponsorship and Community Donations: Are very much dependent on personal outreach and social image. We are reaching out to companies that we are buying parts from to sponsor our project, making monetary donations and in return, have their logo somewhere on the materials we bring to Huntsville. We are currently starting a crowdfunding campaign, which will go live mid-december, with public access to our crowdfunding page at the beginning on january.

Our current goal is to have almost all of our methods of fund acquisition determined before the end of the fall semester. If the team is attempting to apply for grants, paperwork can take significant time to process. Doing grant applications in advance, especially if our team need the money to be able to manufacture the rocket, is going to be very important. Our group has not created a chart for how much money will be made in each of these three categories, as the amounts can vary significantly. It is also important that everyone on the team reaches out to anyone they know who may have leverage to have a company sponsor us, or better yet, make a personal donation.

Because events could not be organized earlier in the year, the chart below is still only an estimate. This chart differs from our proposal's funding plan in that we now have a category for our crowdfunding campaign. Consultation from the director of digital fundraising on Purdue's campus has verified that $3500 is a reasonable amount to expect from our month-long campaign.

Fund Source	**Funds Generated**
SEDS Treasury	$700
Restaurant Socials (4 throughout year)	$800 ($200 each)
Federal and Private Grants	$3000 (across multiple grants)
Crowdfunding Campaign	$3500

Company Sponsorship	$3000 (in materials)
TOTAL:	$11000

6.3.2.2. Allocation Of Funds

As of right now, and as it shall be until the end of november, individuals on the team will purchase parts using their own money. Once parts are ordered by an individual, they must keep their receipt or other proof of purchase. In addition, those who order an item must sign and submit a payment request reimbursement certificate, stating that the expenses presented for reimbursement are legitimate. The purchases will then be reimbursed by SEDS. It is worth noting that although we will likely receive funds from crowdfunding and restaurant socials earlier than company sponsorships, they have been allocated to expenses not directly involved with the rocket, this is because many companies and grants will require approval of the usage of the funds they provide.

Funding Type	**When funds will be generated**	**Allocated to:**
SEDS Treasury	Currently Available	Sub-scale and Full-scale rocket
Restaurant Socials	Begin late-November, end late-January	Branding materials and merchandise
Crowdfunding Campaign	Begin mid-December, end at end of January	Travel expenses
Company Sponsorship	Earliest mid-December	Full-scale Rocket
Federal and Private Grants	Earliest early-January	Full-scale Rocket

6.3.2.3. Material Acquisition Plan

We do not currently have a complete list of materials, but almost all materials will be obtained from online sources. Currently all materials will be acquired by purchasing items on a personal account and getting reimbursed through our parent organization. Once we have outside funds to purchase materials, they will be kept in an account moderated by our faculty advisor’s department, Computer and Information Technology. This allows us to take funds immediately out of a moderated account if we need it.

6.3.3. Educational Engagement

6.3.3.1. Documentation of Outreach

Educational Engagement Activity Report

Please complete and submit this form each time you host an educational engagement event.
(Return within 2 weeks of the event end date)

School/Organization name: Purdue USLI Team / Purdue SEDS

Date(s) of event: October 22nd, 2017

Location of event: West Lafayette, Purdue Campus

Instructions for participant count

Education/Direct Interactions: A count of participants in instructional, hands-on activities where participants engage in learning a STEM topic by actively participating in an activity. This includes instructor- led facilitation around an activity regardless of media (e.g. DLN, face-to-face, downlink.etc.). Example: Students learn about Newton's Laws through building and flying a rocket. ***This type of interaction will count towards your requirement for the project.***

Education/Indirect Interactions: A count of participants engaged in learning a STEM topic through instructor-led facilitation or presentation. Example: Students learn about Newton's Laws through a PowerPoint presentation.

Outreach/Direct Interaction: A count of participants who do not necessarily learn a STEM topic, but are able to get a hands-on look at STEM hardware. For example, team does a presentation to students about their Student Launch project, brings their rocket and components to the event, and flies a rocket at the end of the presentation.

Outreach/Indirect Interaction: A count of participants that interact with the team. For example: The team sets up a display at the local museum during Science Night. Students come by and talk to the team about their project.

Grade level and number of participants: *(If you are able to break down the participants into grade levels: PreK-4, 5-9, 10-12, and 12+, this will be helpful.)*

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
K-4	53			
5-9				
10-12				
12+				
Educators (5-9)				
Educators (other)				

Are the participants with a special group/organization (i.e. Girl Scouts, 4-H, school)? Y N

If yes, what group/organization?

Linnwood Elementary School

31

Briefly describe your activities with this group:

We gave the children a variety of supplies like card board, discorded plastics, and other recyclables. With these they attatched their own designs to stomp rockets and then tested them, attempting to make them better each time.

Did you conduct an evaluation? If so, what were the results?

N/A, not enough time, Students had to return to their school

Describe the comprehensive feedback received.

We were told by the teachers that more launching stations and materials would make for less clashing of the students and would make the process of launching/testing the rocket much easier.

Educational Engagement Activity Report

Please complete and submit this form each time you host an educational engagement event.
(Return within 2 weeks of the event end date)

School/Organization name: Purdue SEDS/USLI

Date(s) of event: 10/21/17

Location of event: Purdue Campus, West Lafayette

Instructions for participant count

Education/Direct Interactions: A count of participants in instructional, hands-on activities where participants engage in learning a STEM topic by actively participating in an activity. This includes instructor- led facilitation around an activity regardless of media (e.g. DLN, face-to-face, downlink.etc.). Example: Students learn about Newton's Laws through building and flying a rocket. ***This type of interaction will count towards your requirement for the project.***

Education/Indirect Interactions: A count of participants engaged in learning a STEM topic through instructor-led facilitation or presentation. Example: Students learn about Newton's Laws through a PowerPoint presentation.

Outreach/Direct Interaction: A count of participants who do not necessarily learn a STEM topic, but are able to get a hands-on look at STEM hardware. For example, team does a presentation to students about their Student Launch project, brings their rocket and components to the event, and flies a rocket at the end of the presentation.

Outreach/Indirect Interaction: A count of participants that interact with the team. For example: The team sets up a display at the local museum during Science Night. Students come by and talk to the team about their project.

Grade level and number of participants: *(If you are able to break down the participants into grade levels: PreK-4, 5-9, 10-12, and 12+, this will be helpful.)*

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
K-4				
5-9	75			
10-12				
12+				
Educators (5-9)				
Educators (other)				

Are the participants with a special group/organization (i.e. Girl Scouts, 4-H, school)? Y N

If yes, what group/organization?

Briefly describe your activities with this group:

walked 3 groups of 25 Students through the Process of splitting into teams and planning a trip to mars. Had them select a role (scientist, mechanic, leader, etc.) select STEM tools for the problem (Imager, lander, rover, altimeter) and plan a flight path and landing spots.

Did you conduct an evaluation? If so, what were the results?

Yes, children enjoyed the activity and while some were upset in the beginning by clashing teams, by the end all of the groups learned to work together.

Describe the comprehensive feedback received.

N/A, activity was recieved with positivity and enthusiasm.

Educational Engagement Activity Report

Please complete and submit this form each time you host an educational engagement event.
(Return within 2 weeks of the event end date)

School/Organization name: Purdue Space day 2017

Date(s) of event: 10/21/2017

Location of event: Purdue University - West Lafayette, IN

Instructions for participant count

Education/Direct Interactions: A count of participants in instructional, hands-on activities where participants engage in learning a STEM topic by actively participating in an activity. This includes instructor- led facilitation around an activity regardless of media (e.g. DLN, face-to-face, downlink.etc.). Example: Students learn about Newton's Laws through building and flying a rocket. ***This type of interaction will count towards your requirement for the project.***

Education/Indirect Interactions: A count of participants engaged in learning a STEM topic through instructor-led facilitation or presentation. Example: Students learn about Newton's Laws through a PowerPoint presentation.

Outreach/Direct Interaction: A count of participants who do not necessarily learn a STEM topic, but are able to get a hands-on look at STEM hardware. For example, team does a presentation to students about their Student Launch project, brings their rocket and components to the event, and flies a rocket at the end of the presentation.

Outreach/Indirect Interaction: A count of participants that interact with the team. For example: The team sets up a display at the local museum during Science Night. Students come by and talk to the team about their project.

Grade level and number of participants: *(If you are able to break down the participants into grade levels: PreK-4, 5-9, 10-12, and 12+, this will be helpful.)*

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
K-4	35	15		
5-9				
10-12				
12+				
Educators (5-9)				
Educators (other)				

Are the participants with a special group/organization (i.e. Girl Scouts, 4-H, school)? Y N

If yes, what group/organization?

31

Briefly describe your activities with this group:

1. Made small rockets and launched them
2. Made space suits with kids
3. Made a capsule to protect an egg w/kids
4. Lead kids around campus
5. Talked with kids a bout rockets and space

Did you conduct an evaluation? If so, what were the results?

Yes, all the students seemed to enjoy them.
Also all of the parents said we did great and that they were all excited for next year.

Describe the comprehensive feedback received.

Overall good job, most are looking forward to next year.

Educational Engagement Activity Report

Please complete and submit this form each time you host an educational engagement event.
(Return within 2 weeks of the event end date)

School/Organization name: Purdue USLI team / Purdue SEDS

Date(s) of event: October 14th, 2017

Location of event: Market Square, Lafayette, Carnahan hall

Instructions for participant count

Education/Direct Interactions: A count of participants in instructional, hands-on activities where participants engage in learning a STEM topic by actively participating in an activity. This includes instructor- led facilitation around an activity regardless of media (e.g. DLN, face-to-face, downlink.etc.). Example: Students learn about Newton's Laws through building and flying a rocket. ***This type of interaction will count towards your requirement for the project.***

Education/Indirect Interactions: A count of participants engaged in learning a STEM topic through instructor-led facilitation or presentation. Example: Students learn about Newton's Laws through a PowerPoint presentation.

Outreach/Direct Interaction: A count of participants who do not necessarily learn a STEM topic, but are able to get a hands-on look at STEM hardware. For example, team does a presentation to students about their Student Launch project, brings their rocket and components to the event, and flies a rocket at the end of the presentation.

Outreach/Indirect Interaction: A count of participants that interact with the team. For example: The team sets up a display at the local museum during Science Night. Students come by and talk to the team about their project.

Grade level and number of participants: *(If you are able to break down the participants into grade levels: PreK-4, 5-9, 10-12, and 12+, this will be helpful.)*

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
K-4	22			
5-9	27			
10-12				
12+				
Educators (5-9)				
Educators (other)				

Are the participants with a special group/organization (i.e. Girl Scouts, 4-H, school)? Y N

If yes, what group/organization?

31

Briefly describe your activities with this group:

Purdue SEDS and USLI members used Tynker, a simple code-teaching program, to walk nearly 50 K-9 children through the process of coding and animation.

Did you conduct an evaluation? If so, what were the results?

Yes, we conducted an evaluation and asked the 17 children who were willing to participate whether they learned anything and whether it was fun, 15 said they learned something and 12 said it was fun.

Describe the comprehensive feedback received.

From the parents, we were informed that more emphasis on how the code worked, and not just how to put it together, would have made for a better learning experience.

6.3.3.2. Outcome of Outreach

Depicted Above: Purdue SEDS and Purdue USLI Members host 700 children from the Lafayette area for Space Day, an annual event for the education and engagement of elementary and middle school students. At this event Astronaut Mark Polansky interacted with the kids and gave a presentation on the benefits of STEM involvement and the excitement of space exploration. At this event the children were broken up into groups of 35 - 50 and participated in a variety of STEM related activities which varied by age range.

Depicted Above: Children attend Mini-Makers Faire in Lafayette, staffed by volunteer Purdue USLI Members. Children ages 8 through 15 got a chance to use Tynker to explore the uses and basic skills of coding and animation through coding.

6.3.3.3. Plans for Future Outreach

Through establishing relationships with Purdue University, outreach organizations like Mini-Maker Faire in the Lafayette area, and student organizations like AIAA and SEDS, Purdue's USLI team plans on continuing their education and engagement of youth in the Lafayette and West Lafayette area.

6.3.4. Timeline

The Purdue SL team will be following the timeline listed below. This outlines events such as general team meetings, meetings or teleconferences with NASA officials, launch opportunities, deadlines, and miscellaneous events.

Date	Event
09/09/2017	Purdue SL general meeting
09/16/2017	Purdue SL general meeting
09/20/2017	Proposal due to project office by 5PM CDT
09/22/2017	Purdue SL general meeting
09/30/2017	Purdue SL general meeting
10/06/2017	Awarded proposals announced
10/07/2017	Purdue SL general meeting
10/08/2017	Indiana Rocketry Launch
10/12/2017	Kickoff, PDR Q&A
10/14/2017	Purdue SL general meeting
10/21/2017	Purdue SL general meeting
10/28/2017	Purdue SL general meeting
11/03/2017	Web presence established, URL sent to project office
11/03/2017	PDR reports, slides, and flysheet posted online by 8AM CDT
11/03/2017	Midwest Power Launch
11/04/2017	Purdue SL general meeting
11/04/2017	Midwest Power Launch
11/05/2017	Midwest Power Launch
11/06/2017	PDR video teleconferences start
11/11/2017	Purdue SL general meeting
11/18/2017	Purdue SL general meeting
11/25/2017	Purdue SL general meeting
11/29/2017	PDR video teleconferences end
12/2/2017	Purdue SL general meeting

12/06/2017	CDR Q&A
12/09/2017	QCRS Launch
12/09/2017	Purdue SL general meeting
12/16/2017	Purdue SL general meeting
12/23/2017	Purdue SL general meeting
12/30/2017	Purdue SL general meeting
01/06/2018	Purdue SL general meeting
01/11/2018	Final day for subscale launch
01/11/2018	Final motor choice made for launch
01/12/2018	CDR reports, slides, and flysheet posted online by 8AM CDT
01/13/2018	Purdue SL general meeting
01/16/2018	CDR video teleconferences start
01/20/2018	Purdue SL general meeting
01/27/2018	Purdue SL general meeting
01/31/2018	CDR video teleconferences end
02/03/2017	Purdue SL general meeting
02/07/2018	FRR Q&A
02/10/2018	Purdue SL general meeting
02/17/2018	Purdue SL general meeting
02/24/2018	Purdue SL general meeting
03/03/2018	Purdue SL general meeting
03/04/2018	Final day for full scale launch
03/05/2018	FRR reports, slides, and flysheet posted online by 8AM CDT
03/06/2018	FRR video teleconferences start
03/10/2018	Purdue SL general meeting
03/17/2018	Purdue SL general meeting
03/22/2018	FRR video teleconferences end
03/24/2018	Purdue SL general meeting
03/31/2018	Purdue SL general meeting
04/04/2018	Travel to Huntsville, Alabama
04/04/2018	LRR
04/05/2018	Launch week kickoff and activities
04/06/2018	Launch week activities
04/07/2018	Launch day

04/07/2018	Banquet
04/08/2018	Backup launch day
04/27/2018	PLAR posted online by 8AM CDT

7. Appendix A

7.1. NAR High Power Safety Code

7.1.1. 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.

7.1.2. 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.

7.1.3. 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, or heat sources within 25 feet of these motors.

7.1.4. 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 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.

7.1.5. 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.

7.1.6. 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.

7.1.7. 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 material if the rocket motor being launched uses titanium sponge in the propellant.

7.1.8. 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.

7.1.9. 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.

7.1.10. 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).

7.1.11. 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.

7.1.12. 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.

7.1.13. 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.

7.2. NAR Minimum Distance Table

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500

20,480.01 — 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors