STUDENT LAUNCH COMPETITION
2020-2021

CAL POLY POMONA
Preliminary Design Review

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CalPolyPomona

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List of Acronyms

AoA = Angle of Attack

AGL = Above Ground Level

AIAA = American Institute of Aeronautics and Astronautics

APCP = Ammonium Perchlorate Composite Propellant

AR = As Required

CAR = Canadian Association of Rocketry

CDC = Center for Disease Control and Prevention

CDR = Conceptual Design Review

CNC = Computer Numerical Control

CPP = Cal Poly Pomona

FAA = Federal Aviation Administration

FAR = Friends of Amateur Rocketry

FN = Foreign National

FRR = Flight Readiness Review

GPA = Grade Point Average

GPS = Global Positioning System

JPL = Jet Propulsion Laboratory

LRR = Launch Readiness Review

LTE = Long-Term Evolution

LV = Launch Vehicle

MATLAB = Matrix Laboratory

MESA = Mathematics Engineering Science Achievement

MOSFET = Metal–Oxide–Semiconductor Field-Effect Transistor

MSDS = Material Safety Data Sheet

NAR = National Association of Rocketry

NASA = National Aeronautics and Space Administration

NFPA = National Fire Protection Association

NSL = NASA Student Launch

PDC = Program Database

PDR = Preliminary Design

PLA = Polylactic Acid

PPE = Personal Protective Equipment

PPM = Pulse Position Modulation

PVA = Polyvinyl Alcohol

PVC = Polyvinyl Chloride

PWM = Pulse Width Modulation

RAC = Risk Assessment Codes

RAL = Rocket Assembly Laboratory

RCF = Refractory Ceramic Fiber

RFP = Request for Proposal

RSO = Range Safety Officer

RTM = Requirements Traceability Matrices

SBUS = Serial Communication Protocol

SCRA = Southern California Rocket Association

SHPE = Society of Hispanic Professional Engineers

SIM = Subscriber Identification Module

SOW = Statement of Work

SWE = Society of Women Engineers

STEM = Science, Technology, Engineering, and Mathematics

TRA = Tripoli Rocketry Association

UAV = Unmanned Aerial Vehicle

UFP = Ultra-Fine Particle

UGV = Unmanned Ground Vehicle

UMBRA = Undergraduate Missiles and Ballistics Rocketry

USB = Universal Serial Bus

USLI = University, NASA Student Launch Initiative

VOC = Volatile Organic Compound

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1.0 Summary

1.1 Team Summary

Team Name: California State Polytechnic University, Pomona
Organization: Undergrad Missiles Ballistics and Rocketry Association (UMBRA)
Mailing Address: 3801 W Temple Ave, Pomona, CA 91768
Team Mentor: Rick Maschek TRA Level 2 Certification #11388
TeamMentor Contact Info: rickmaschek@rocketmail.com | (760) 953-0011
Documentation of the team's hours for the PDR can be found in **Appendix A**.

1.2 Launch Vehicle Summary

The Launch Vehicle Team has decided to use G-12 fiberglass for the fuselage. The overall architecture of the Launch Vehicle has been systematically determined by evaluating the pro's and con's of each alternative. Estimated masses have been given to each subsystem of the Launch Vehicle and the overall weight of the Launch Vehicle will be approximately fifty-pounds. Motor trade studies are currently still underway and have been reduced to the three best choices thus far with the leading choice highlighted in **Table 3.5-1.** Preliminary fin research is being conducted with the full scale Rocksim simulation model with the sub-scale currently being developed for testing. The target apogee for the team given these models is projected to be 4,000 feet above ground level. The recovery system will be composed of a single deploy system and will use black powder as the preferred method for separation.

1.3 Payload Summary

Payload Title: Odysseus

The planetary lander will eject from the cross section of the rocket at an altitude of 550 ft. This will occur after the nose cone has been deployed during descent, creating the open section of the rocket. To assist with payload deployment, CO_2 canisters will shoot compressed air to push the payload out of the rocket. The lander's parachute, once separated from the rocket, will inflate, safely bringing Odysseus to the ground. Once the lander has touched down, onboard sensors will verify the landing and initiate the auto-leveling sequence. Four linear actuators will unfold arms on the side of the payload which can upright it from any landing position. The three onboard cameras will then take a photo and the microcomputer will upload the photos to a cloud server via the onboard 4G LTE hotspot. The ground team will then stitch the photos together.

2.0 Changes Made Since Proposal

2.1 Launch Vehicle

Change made	Summary	Why?
Primary LV material	Changed the fuselage material from carbon fiber to fiberglass.	The team leads came to agree that the fuselage should be changed to fiberglass to allow for the avionics bay to transmit data easier. Carbon fiber blocks radio frequencies, which would cause the avionics to be stored inside the nose cone. The price difference from carbon fiber to fiberglass was also preferred.
Launch Vehicle Manufacturing	Went from custom design and machining to commercial parts	The COVID-19 pandemic placed the team with manufacturing challenges due to in-person manufacturing. The decision was made to use commercially available components to assemble the Launch Vehicle.

2.2 Payload

Change made	Summary	Why?
Payload Design	Changed the payload design from support arms being independent of payload structure to arms being part of the body and structure as one uniform unit. Before, the support arms were an extension from the payload body. Now, the support arms are included as payload body and walls, making the entire payload structure a single	This change was made in order to increase the diameter of the payload as more housing space is needed for internal components. By making the support arms as part of the body, internal space of the payload is maximized, leading to more room for actuators, batteries, microcontrollers, wires, cameras, etc.

	uniform body.	
Hinges for support arms	The team has incorporated methods for opening and closing the support arms of the payload by using hinges	In the previous design, methods for opening and closing the support arms of the payload were not considered in detail. However, the team has changed and improved this aspect of the payload structure by incorporating hinges that will allow the actuators to push open and pull close the support arms.
Method for actuator control	Data from the gyroscope will be sent to the central microcontroller to process. Once processed signals are sent to a 12-channel PWM driver board which controls the linear actuators.	This change was made to streamline control over actuators. This was also found to be a better overall method for control of multiple PWM devices.
Cameras	Wired pin connection to USB	Simplifies the overall circuit
Method of attaching parachute	Developed a method for attaching the parachute. The team has created holes and housing space at the roof of the payload structure for parachute attachments.	We made this change because previously we did not consider the housing space for the parachute along with any methods of attachment. However, we have made changes by developing a parachute attachment method for landing the payload safely to the group after deployment from the rocket.

2.3 Project Plan

Change made	Summary	Why?
Fundraising	One additional crowdfunding campaign was started	The team found one source of income insufficient for our needs, so a GoFundMe was launched for our team.

3.0 Vehicle Criteria

3.1 Mission Statement

The Launch Vehicle will be launched without the aid of the team and will accelerate to a minimum of 52 ft/sec with a minimum stability margin of 2.0 at rail exit and will reach a target altitude of 4,000 feet where a drogue chute will deploy, slowing the launch vehicle down until the main chute is deployed at 600 feet, followed by the ejection of the payload at 550 feet with the decent time of less than 90 seconds. Once the payload and launch vehicle have landed, the payload will autonomously level itself, take a 360 degree photo, and transmit this photo to the team.

3.2 System Design of Launch Vehicle

The Launch Vehicle went through multiple alternate system designs to ensure that the most efficient, starting with the following:

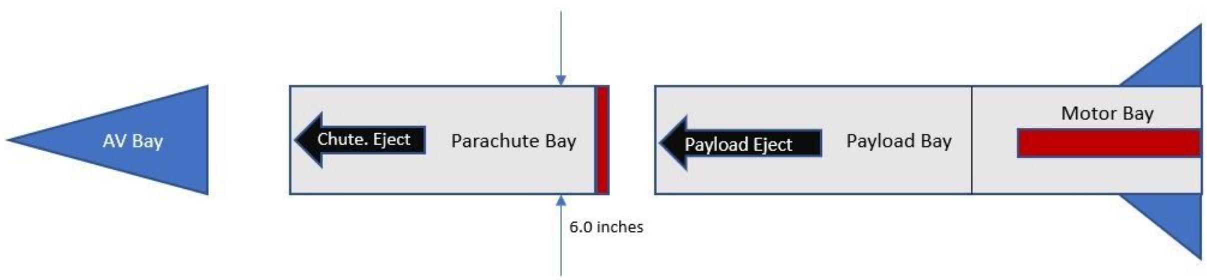

Figure 3.2-1 System Prototype 1

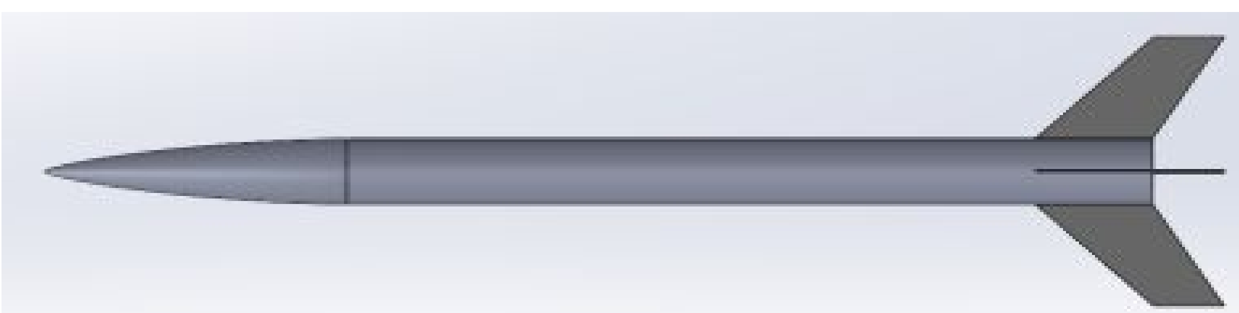

Figure 3.2-2 System Prototype 1 Model

Table 3.2-1 Prototype 1

Positives of Prototype-1	-Lighter than larger prototypes -Cheaper than larger prototypes
Negatives of Prototype-1	-Black powder ejection close to payload -6 inch diameter too small for payload integration -AV Bay restricted in size

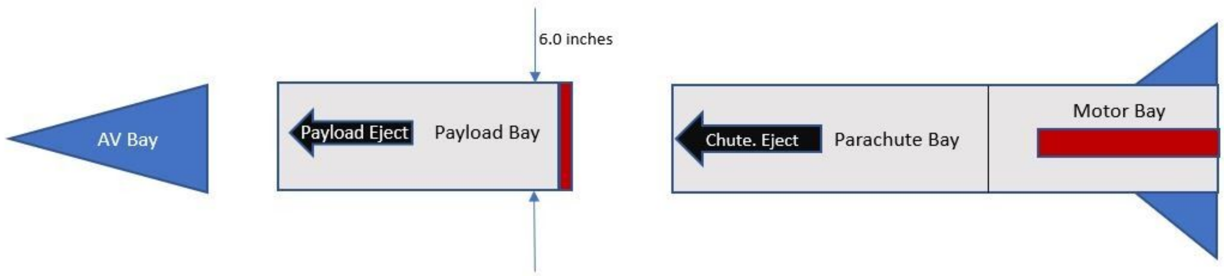

Figure 3.2-3 System Prototype 2

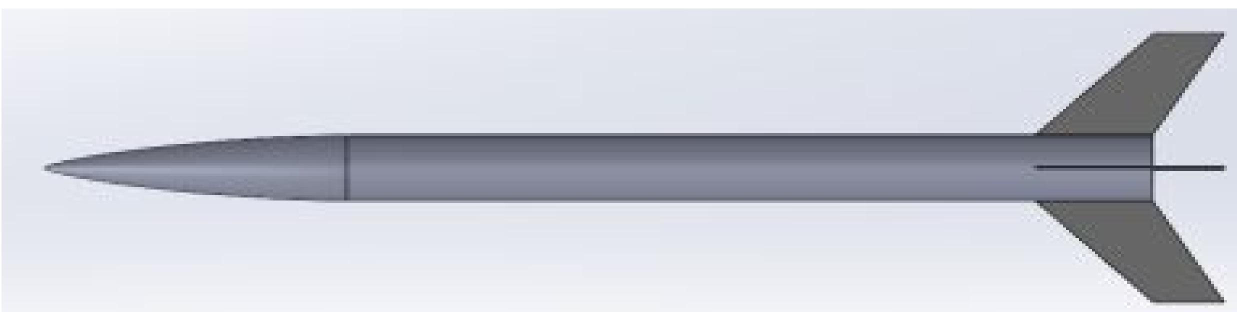

Figure 3.2-4 System Prototype 2 Model

Table 3.2-2 Prototype 2

Positives of Prototype-2	-Lighter than larger prototypes -Cheaper than larger prototypes
Negatives of Prototype-2	-6 inch diameter too small for payload integration -AV Bay restricted in size

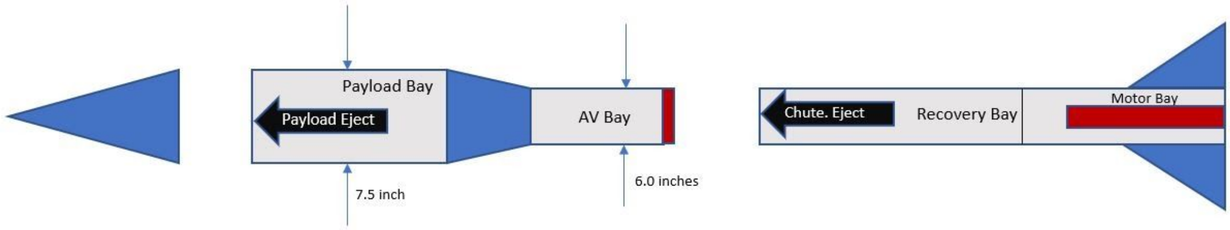

Figure 3.2-5 System Prototype 3

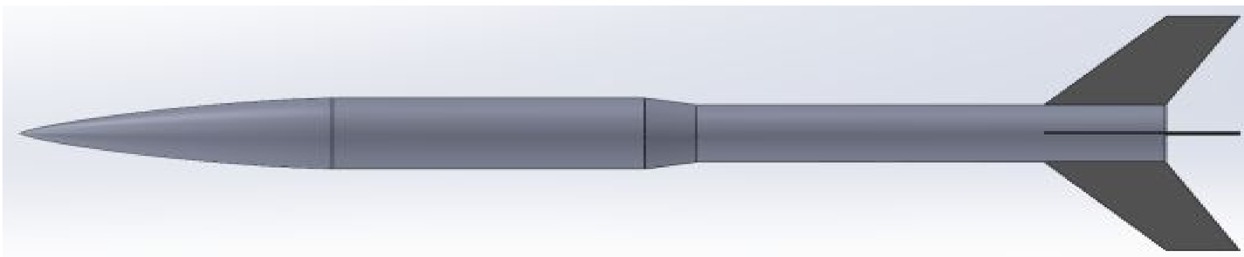

Figure 3.2-6 System Prototype 3 Model

Table 3.2-3 Prototype 3

Positives of Prototype-3	-Meets needs of payload/payload integration
Negatives of Prototype-3	-Expensive to manufacture the conical transition -Stress concentrations may result in failure -Poor Aerodynamics

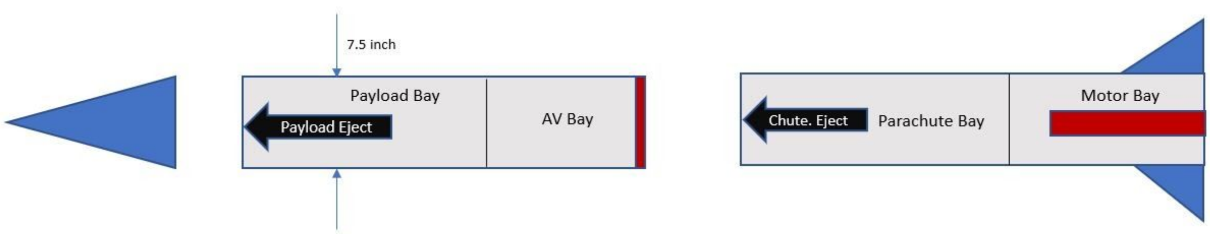

Figure 3.2-7 System Prototype 4

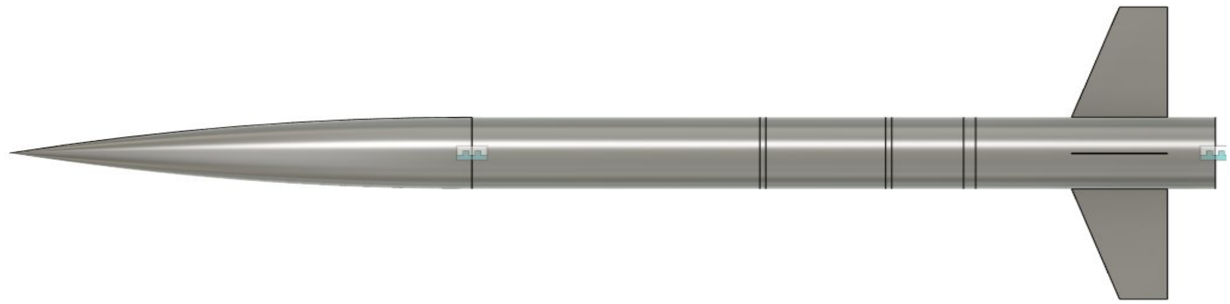

Figure 3.2-8 System Prototype 4 Model

Table 3.2-4 Prototype 4

Positives of Prototype-4	-Consistent dimensions -Weight distribution is much more even with the payload on top
Negatives of Prototype-4	-Second most expensive design -Theoretically weighs the most

3.2.1 System Design Research

To begin the design of the Launch Vehicle, Prototype-3 had to be excluded from the design process due to the cost to manufacture the conical section.

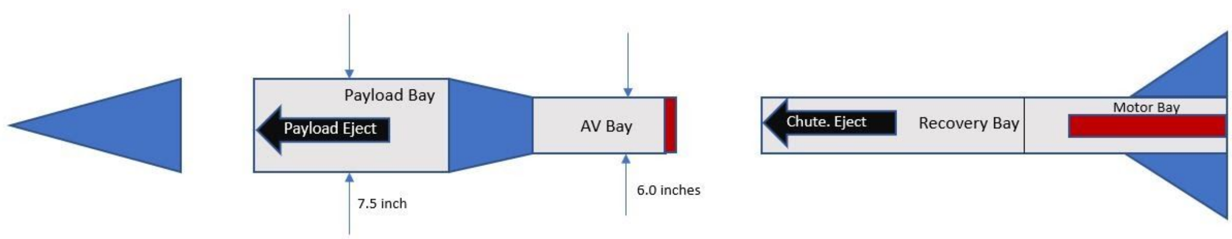

Figure 3.2.1-1 System Prototype 3

The conical section shown in blue which is located in the upper-third of the model would have to be made of 6061-T6 sheet, however given the restrictions to equipment, the team was forced to source this component from local manufacture companies. The cheapest cost to do this was $800 which was far out of the team's financial budget to be spent on one component of the airframe. Thus no further research was put forward in the design.

Prototype-1 was excluded from the design phase because the payload integration design preferred the method of a cone ejection system since it would be easier to eject the cone without using explosive or energetic substances, protecting the payload during the mission.

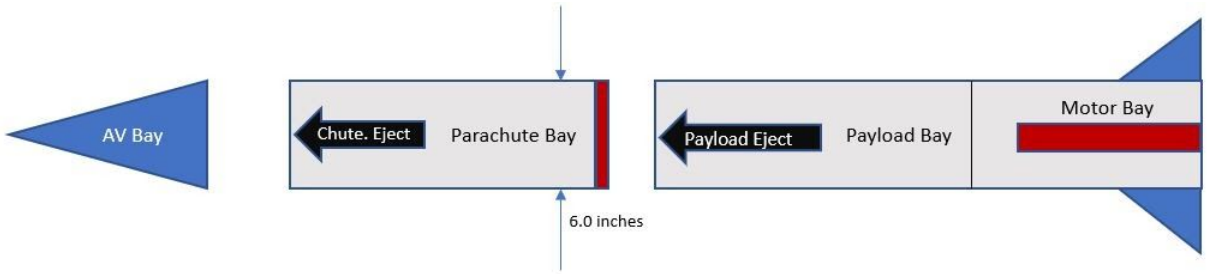

Figure 3.2.1-2 System Prototype 1

Prototype-2 was eliminated as well due to its size restriction since the locking rings used to separate the nose from the airframe would protrude through the fuselage.

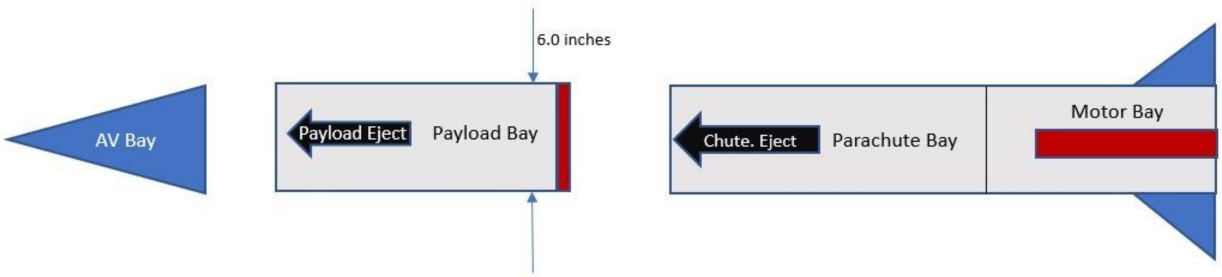

Figure 3.2.1-3 System Prototype 2

Prototype-4 meets the needs for the payload in that it is large enough to contain the payload integration system without any protrusions. Avionic bay will be close to the recovery bay allowing for optimal detonation of black powder charges shown in red. Sourcing a single diameter fuselage will make sourcing the fuselage easier. The negative is that it is theoretically the heaviest design given its size.

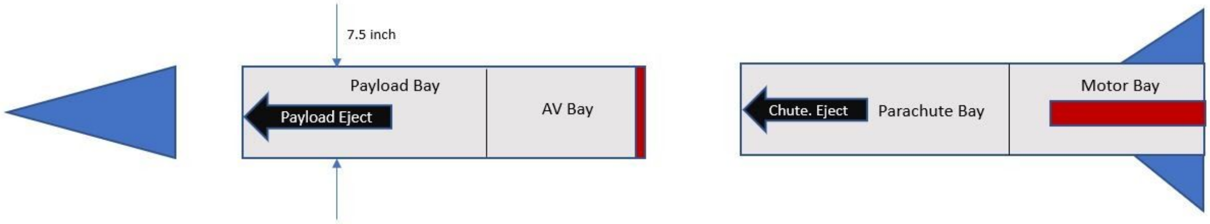

Figure 3.2.1-4 System Prototype 4

3.3 Location of Separation Points and Energy Locations

For Prototypes 1 through 4, the separation points are shown with the direction of the ejection of the payload. Locations of energetic materials are shown in RED. In this case there are the black powder charges for the staging separation, and the motor itself

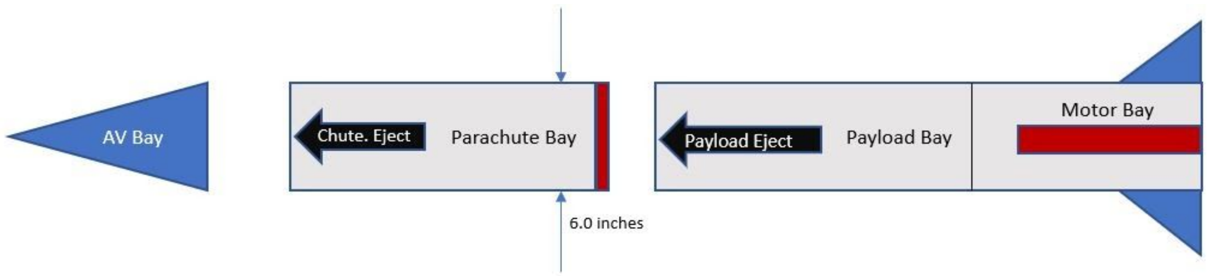

Figure 3.3-1 Prototype-1 Energy and Separation Points

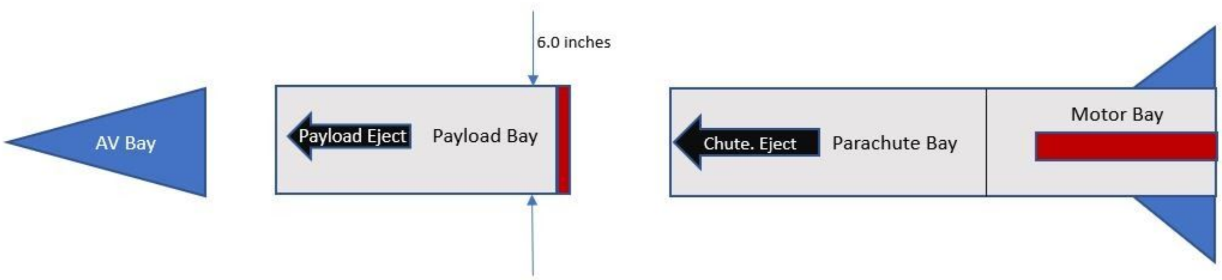

Figure 3.3-2 Prototype-2 Energy and Separation Points

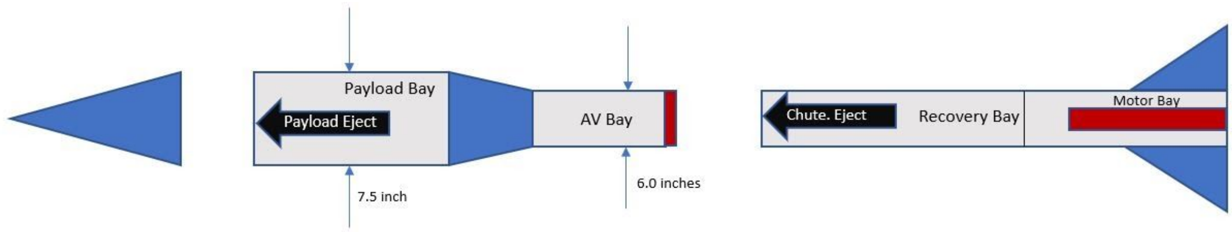

Figure 3.3-3 Prototype-3 Energy and Separation Points

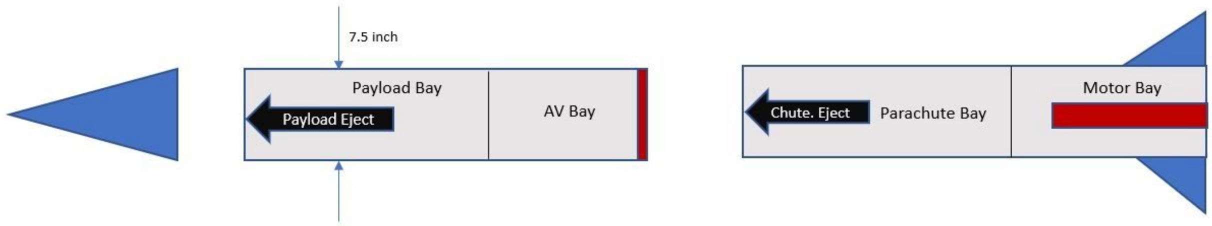

Figure 3.3-4 Prototype-4 Energy and Separation Points

3.4 Leading Launch Vehicle Design

The current launch vehicle design shown below consists of four main sections. These main sections are, starting from the bottom of the rocket and going up, the motor bay, parachute bay, avionics bay, and payload bay.

The motor bay contains all the necessary components to properly retain the motor during flight and the motor itself. These components that will be retaining the motor will be a motor casing and three centering rings that will be purchased as a set from a vendor rather than being manufactured in house in order to cut down on manufacturing time and ensure a proper fit.

The next section above the motor bay is the parachute bay. Within this bay are two parachutes, the drogue chute and the main parachute and the black powder charges that will deploy each parachute at their respective altitudes.

Above the parachute bay is the avionics bay where all the necessary electronic controllers for the rocket will be located.

Above the parachute bay is the payload bay, where the payload and all the necessary components to eject it are housed. The payload itself will be sitting in a barrel that will direct the payload out of the rocket once a pushing force is provided by pressurized carbon dioxide released from the tanks in the payload bay. Prior to this payload deployment, the nose cone will be ejected by activating two solenoids that will push the nose cone off of the rocket and out of the way for the payload to deploy.

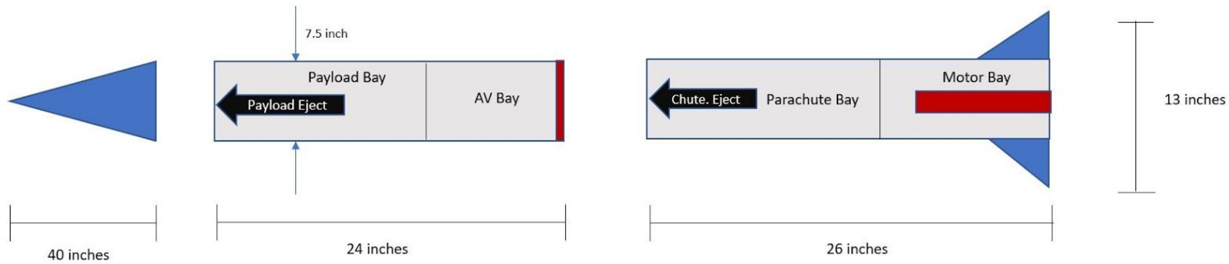

Figure 3.4-1 Dimensional Drawing of Prototype-4

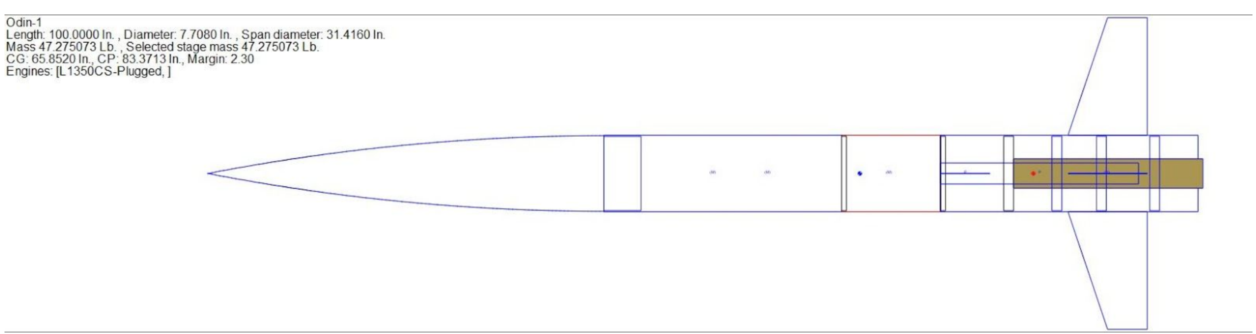

Figure 3.4-2 Current Rocksim Testing Model

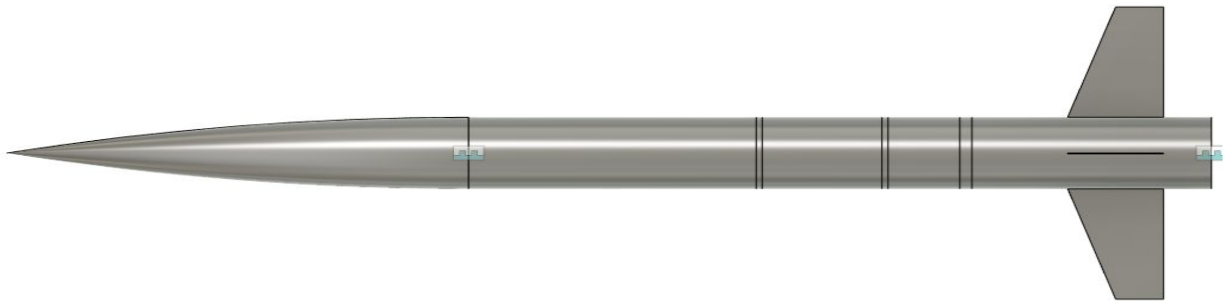

Figure 3.4-3 Current Launch Vehicle CAD Model

Table 3.4-1 Estimated Masses

Nose Cone (kg)	**3.86**
Payload + Avionics (kg)	**4.08**
Recovery + Motor Bay (kg)	**8.79**

3.5 System Research on Motor Selection

To determine our motor choice we first conducted tests through Rocksim to simulate launches to see what projected apogees our rocket was reaching and see how our stability margin was affected with each engine loaded in. Then the rail exit velocity for each motor was obtained from the simulation summary on Rocksim. Our costs for each motor were found online. The data collected is shown on **Table 3.5-1** below.

Table 3.5-1 Motor Data

Motor Data					
Motor	Apogee	Rail Exit V	Avg Thrust	Stability	Cost
L1350CS	4184	59.04	1303	2.27	$250
L610CL	4279	42.3	595	2.07	$332
L1420R	4519	60.29	1424	2.11	$292

For our motor trade study in **Table 3.5-2** we had the rail exit velocity with the highest weight factor because of its fixed design criteria. The apogee was ranked 2nd highest because our success is dependent on reaching our projected altitude. The stability is ranked 3rd since our rocket needs to meet a minimum of 2 in order to meet design requirements. Cost is the lowest weight factor due to the prices of each motor being slightly different from one another.

Table 3.5-2 Motor Trade Study

		Cessaroni L1350CS			Cessaroni L610CL			Aerotech L1420R		
		A			B			C		
Criteria	Weight Factor	Description	Utility Value	Weighted Value	Description	Utility Value	Weighted Value	Description	Utility Value	Weighted Value
Rail Exit Velocity	4	Excellent	2	8	Bad	1	4	Excellent	3	12
Apogee	3	Excellent	3	9	Good	2	6	Bad	1	3
Stability	2	Excellent	3	6	Bad	1	2	Good	2	4
Cost	1	Excellent	3	3	Bad	1	1	Good	1	1
Weighted Total		26			13			20		

The rail exit velocity that our trade matrix was based on whichever motor was closest to the following criteria: 55 ft/s, an apogee of 4,000 ft, a stability margin of 2.25, and a motor cost that minimal. From these parameters, the trade study we conducted led us to choosing Cessaroni L1350CS as our main motor.

4.0 Recovery Subsystem

4.1 Avionics

4.1.1 Altimeters

4.1.1.1 Telemetrum V3

This is a dual-deployment altimeter with a built in GPS that also utilizes telemetry, meaning that we can get data from the rocket in real time. The e-matches can be fired by a LiPo battery, however it can still support a separate pyro battery. The downlink telemetry utilizes a 70cm ham-band transceiver and is paired with the Altus Metrum TeleDongle, which plugs into a computer using a USB port. In order to access the data, AltosUI must be downloaded, which is this company's ground station program. The barometric sensor is good up to 100,000 ft and it can store multiple flights' data. This flight computer has been on rockets that have achieved Mach 1 and reached elevations of greater than 25,000 ft. This is the third iteration of this product and is the most accurate model.. Also has three axis 2000°/sec gyros. The chip is 1" x 2.75"

Figure 4.1.1.1-1 Top Image of Telemetrum v3

Figure 4.1.1.1-2 Bottom Image of Telemetrum v3

4.1.1.1.1 Cost

The Telemetrum itself costs $300 from Chris' Rocket Supplies, LLC and it costs $5 for the shipping. The Teledongle Starter kit (which comes with the Teledongle, a micro-USB cable, a 850 mAh lithium polymer battery, and a 433 Mhz Yagi antenna costs) costs $175.90 from Apogee Components and the shipping costs $11.68. Neither of these have sales tax applied to the purchase. This brings the total cost for the Telemetrum V3 to $492.58.

4.1.1.1.2 Manufacturing

The manufacturing for the Telemetrum will be minimal which is one of the reasons it is worth the hefty price tag. All it requires is screwing the chip into the Avionics Bay and wiring a switch to turn it on and off. We would then need to wire the e-match into the correct screw terminal (this is simple since each terminal is labelled with its dedicated job). When these steps are complete, the Telemetrum is ready for launch and data collection. After this, the ground station would need to be set up to receive the data. To do this, AltOS needs to be downloaded on a Windows laptop and the Teledongle with the Yagi antenna connected to it would get plugged into one of the USB ports on the laptop. The AltOS would then run through the steps to connect the chip to the computer program and once connected, the ground station would be ready for data collection.

4.1.1.1.3 Why it should be chosen

The Telemetrum should be selected because of the wide variety of features it has. The fact that it is a GPS/altimeter combination saves us space in the Avionics Bay and decreases the overall weight of the rocket as well. It's built-in accelerometer can provide data to help with other sub-teams of the rocket. The Telemetrum also boasts downlink telemetry, which means that we don't even need to open the Avionics Bay to collect the data and the data it produces is highly detailed because of the accompanying program. The one reason that this altimeter would not be selected is because of its price, but the team lead made it clear that ease of access and use should be prioritized over cost because of the extenuating circumstances regarding COVID-19. Considering these facts, we have decided to select the Telemetrum as the main altimeter and then select a cheaper option to serve as the redundant altimeter.

4.1.1.2 Rocket Recovery Controller 3 (RRC3)

This is a dual-deployment, barometric altimeter that records the altitude of the rocket and utilizes telemetry, which means that we can get data in real time. The RRC3 is programmable, meaning that we can command the altimeter to release the drogue and main parachutes at our desired elevations, and it can also record and store the data for up to fifteen flights, each flight being at most twenty-eight minutes long. This altimeter does not have gyros or an accelerometer. The RRC3 has a total of eight screw terminals: two for the main parachute, two for the drogue parachute, two for the arming switch, and two for the battery. The RRC3 can use batteries in the range of 4-12V, but is optimized for a 9V battery. In order to utilize the telemetry, it needs to be paired with the Missile Works USB Interface Module and the Missile Works Data Acquisition and Configuration Software. The chip is 3.92" x .925".

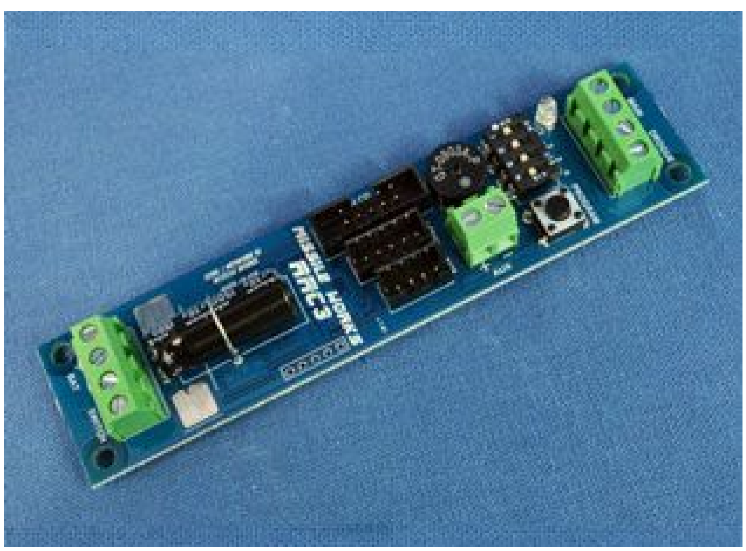

Figure 4.1.1.2-1 Top Image of RRC3

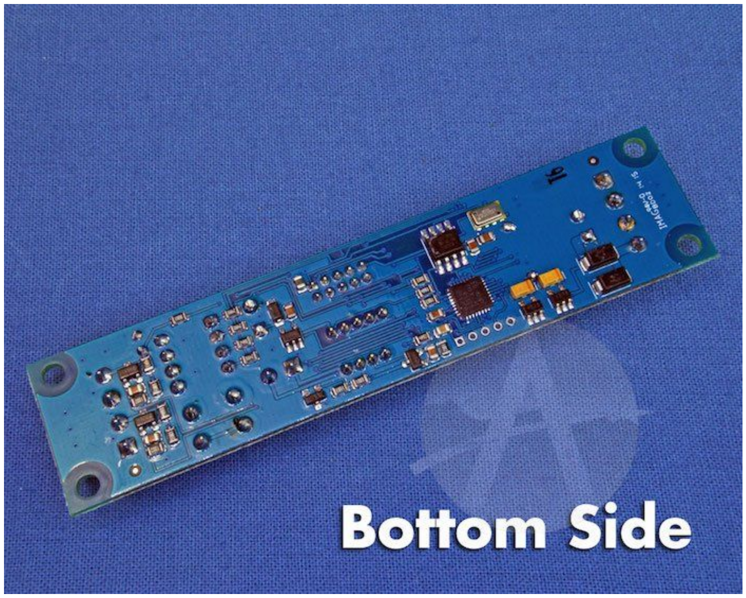

Figure 4.1.1.2-2 Bottom Image of RRC3

4.1.1.2.1 Cost

The RRC3 itself costs $73.95 and the USB interface costs $24.95 and both come from the Missile Works website and the shipping costs $8. The total price comes out to $106.90.

4.1.1.2.2 Manufacturing

This altimeter follows the exact same procedure as the Telemetrum. The chip will get installed in the Avionics Bay, the wires for the battery, switch, and e-match will get screwed into the correct terminals and the chip will be ready at the point. Then we would need to download the RRC3 Altimeter program to a Windows laptop and plug the USB interface in so we can connect the chip to the program to collect the flight data.

4.1.1.2.3 Why it should be chosen

This altimeter has a feature that more costly altimeters have for a cheaper price, and that feature is downlink telemetry. This altimeter is also within our budget at a little over $100 for everything it needs to work. Not only that but the RRC3 has great reviews and good customer support in case we have any questions about the chip or if there is anything wrong with it. However, we are reluctant to go with this altimeter because of the fact it has downlink telemetry. Since our main altimeter already has downlink telemetry, we want our redundant altimeter to be as reliable as possible and telemetry has an inherent risk of not being able to collect the data if there are potential connectivity problems. Plus, we don't want the telemetry of the RRC3 to interfere with the telemetry and GPS of the Telemetrum. We believe that the RRC3 has too many features to be used as a redundant altimeter and we would rather use a cheaper and simpler altimeter to be the backup to the Telemetrum.

4.1.1.3 EggTimer Proton

This flight computer has a total of six channels meaning that it can support up to six deployments or in-flight events. It has a barometric pressure sensor that is rated up to 60,000 feet and it includes a 120G axial accelerometer which can be used to detect when the rocket is off-axis. . Each channel is totally programmable meaning that any channel can control the main or drogue parachute and the triggering qualifications can be customized. All operations are accessible via WiFi with a range of 100 feet, including arming and accessing the data. The recommended battery to use with this is a 7.4V LiPo battery and the chip is 3.25" x 1.125". This flight computer also has a test mode that will safely test the charges up to 200 feet away and has a built in fail safe that will eject the main parachute if there is a drogue failure to prevent a high speed chute deployment or crash.

Figure 4.1.1.3-1 Pre-Assembled Image of Eggtimer Proton

Figure 4.1.1.3-2 Assembled Image of Eggtimer Proton

4.1.1.3.1 Cost

The Eggtimer Proton costs $75 for the kit and the sales tax is $5.44 and the shipping cost is $4. This brings the total to $84.44.

4.1.1.3.2 Manufacturing

The manufacturing of this altimeter is the hardest out of all the options that we have. The kit requires complete assembly and we would need to solder all the components and the battery onto the board, and the website describes this as a difficult build as well. After the assembly of the sensor, we would need to install it in our Avionics Bay which would follow the same procedures as the rest of the altimeter options that we have. We wouldn't need to do anything to allow for the data transfer because this occurs over WiFi and the only thing that is needed is a browser to connect to the flight computer. A separate computer program or app is unnecessary so the ground station will be ready as long as we have a phone or laptop with WiFi access

4.1.1.3.3 Why it should be chosen

The only reason that we would consider the Eggtimer Proton is the fact that the data collection is extremely simple and requires no additional accessories. However, the reasons we should not buy this flight computer greatly outweigh this. The members of the Avionics Subteam have limited soldering experience and, considering the importance of this equipment, do not want to potentially destroy a $75 dollar flight computer. Also considering the limitations imposed on us in regards to COVID-19, meeting up to build this is going to be challenging because the team members do not currently have a workshop to build this until we are given permission to use the facilities at our university. Because we have simpler and better options at our disposal for this price, we will not be choosing the Eggtimer Proton.

4.1.1.4 StratoLogger CF (SLC4)

This altimeter is a dual-deployment altimeter and is the simplest altimeter out of the ones we have researched thus far because it does not offer built-in telemetry and all the data has to be recorded by plugging a USB into the chip to download to a computer. The SLCF also relays information via a sequence of beeps, but telemetry is possible by buying two XBEES, one for the altimeter and one for the computer. It is capable of recording flight data up to altitudes of 100,000 feet at a rate of 20 samples per second. The main chute deployment is adjustable from 100 feet to 9,999 feet in one foot increments. The SLCF has eight screw terminals: two for the drogue parachute, two for the main parachute, two for the arming switch, and two for a battery. The SLCF can be powered from 4V - 16V but it is ideal if it is powered by a 9V battery. This is the smallest of the altimeters we have researched at 2” x .84”.

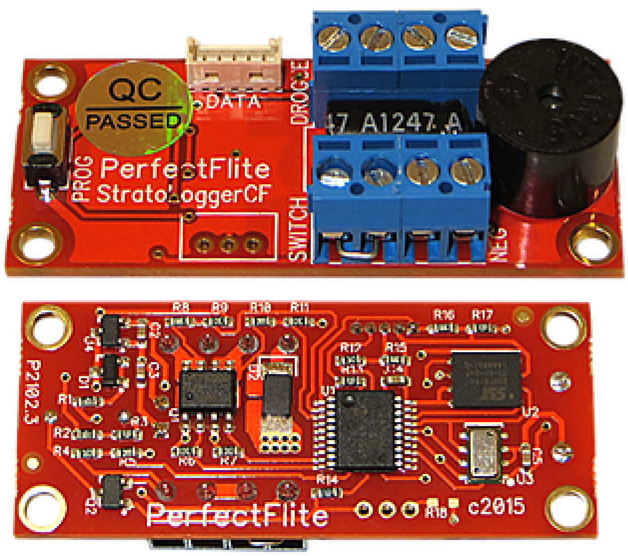

Figure 4.1.1.4-1 Stratologger CF Top and Bottom Image

4.1.1.4.1 Cost

The SLCF is currently being offered at a lowered price of $54.95 and the kit for the wired data transfer (w/o telemetry) is $24.95. Shipping will be $7 for the flight computer. We are not planning to utilize downlink telemetry with this altimeter, so the costs for the XBEE adapters are irrelevant.

4.1.1.4.2 Manufacturing

The manufacturing for this altimeter is straightforward. We just need to install it in the avionics bay and then put the wires for the e-matches, the batteries, and switch in their respective screw terminals. In order to download the data from the flight computer, we need to download the software that comes with the SLCF and simply plug the data transfer cable into the StratoLoggerCF.

4.1.1.4.3 Why it should be chosen

This flight computer has great reviews and is often sold out due to its popularity. Because the data transfer is wired, we do not need to worry about any interference with the telemetry functionality of the Telemetrum. It will have a small footprint in the avionics bay and consumes very little battery, meaning we know that it will be able to sit in launch position for two hours which is a requirement, and four hours when the factor of safety of two is considered. The price is also well within our budget and manages to meet the requirements that we have for our redundant altimeter. This altimeter has no reasons why we shouldn't buy it.

Table 4.1.1.4.3-1 Pros and Cons Chart

	Pros	Cons
Telemetrum V3	-GPS+altimeter -real time telemetry data -simple setup and usage	-cost ($300 + $175.90 for antenna and dongle)
Rocket Recovery Controller 3	-programmable dual-deployment -simple setup and usage	-cost ($73.95 - high for redundant altimeter) -downlink telemetry (already have in main altimeter - possible connectivity issues)
Eggtimer Proton	-programmable deployment (six channels) -test mode	-cost ($84.44 - high for redundant altimeter) -most difficult manufacturing process (requires soldering)
Stratologger CF	-cost ($54.95) -dual-deployment	-limited stock

	-capable of telemetry data transmission (optional) -simple setup and usage	

4.1.2 GPS

4.1.2.1 Telemetrum V3

This is a dual-deployment altimeter with a built in GPS that also utilizes telemetry, meaning that we can get data from the rocket in real time. The e-matches can be fired by a LiPo battery, however it can still support a separate pyro battery. The downlink telemetry utilizes a 70cm ham-band transceiver and is paired with the Altus Metrum TeleDongle, which plugs into a computer using a USB port. In order to access the data, AltosUI must be downloaded, which is this company's ground station program. The barometric sensor is good up to 100,000 ft and it can store multiple flight's data. This flight computer has been on rockets that have achieved Mach 1 and reached elevations of greater than 25,000 ft. This is the third iteration of this product and is the most accurate model as well. Also has three axis 2000°/sec gyros. The chip is 1" x 2.75"

Figure 4.1.2.1-1 Telemetrum v3 Top Image

Figure 4.1.2.1-2 Telemetrum v3 Bottom Image

4.1.2.1.1 Cost

The Telemetrum itself costs $300 from Chris' Rocket Supplies, LLC and it costs $5 for the shipping. The Teledongle Starter kit (which comes with the Teledongle, a micro-USB cable, a 850 mAh lithium polymer battery, and a 433 Mhz Yagi antenna costs) costs $175.90 from Apogee Components and the shipping costs $11.68. Neither of these have sales tax applied to the purchase. This brings the total cost for the Telemetrum V3 to $492.58.

4.1.2.1.2 Manufacturing

The manufacturing for the Telemetrum will be minimal which is one of the reasons it is worth the hefty price tag. All it requires is screwing the chip into the Avionics Bay and wiring a switch to turn it on and off. We would then need to wire the e-match into the correct screw terminal (this is simple since each terminal is labelled with its dedicated job). When these steps are complete, the Telemetrum is ready for launch and data collection. After this, the ground station would need to be set up to receive the data. To do this, AltOS needs to be downloaded on a Windows laptop and the Teledongle with the Yagi antenna connected to it would get plugged into one of the USB ports on the laptop. The AltOS would then run through the steps to connect the chip to the computer program and once connected, the ground station would be ready for data collection.

4.1.2.1.3 Why it should be chosen

The Telemetrum should be selected because of the wide variety of features it has. The fact that it is a GPS/altimeter combination saves us space in the Avionics Bay and decreases the overall weight of the rocket as well. It's built-in accelerometer can provide data to help with other sub-teams of the rocket. The Telemetrum also boasts downlink telemetry, which means that we don't even need to open the Avionics Bay to collect the data and the data it produces is highly detailed because of the accompanying program. The one reason that this altimeter would not be selected is because of its price, but the team lead made it clear that ease of access and use should be prioritized over cost because of the extenuating circumstances regarding COVID-19. Considering these facts, we have decided to select the Telemetrum as the main altimeter and then select a cheaper option to serve as the redundant altimeter.

4.1.2.2 Eggfinder TX

The Eggfinder TX is a basic transmitter designed to fit in the nose cone of the rocket, making it ideal to use as the gps system for our payload due to its small size. The transmitter also takes an OpenLog data logger module which allows us to save our flight data to an on-board micro-SD card. This in turn will allow us to upload the data to a software such as Google Earth to see the actual flight path of the payload. It can also be programmed to one of 72 frequency/ID combinations using the included pairing cable.

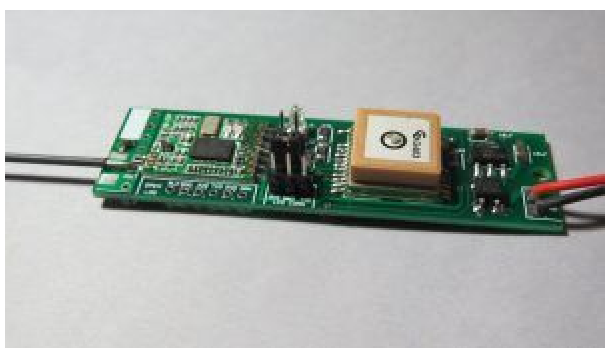

Figure 4.1.2.2-1 Eggfinder TX Transmitter Top Image

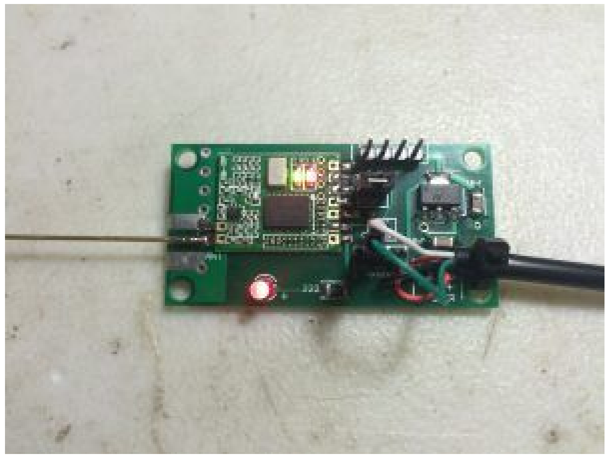

Figure 4.1.2.2-2 Eggfinder TX Transmitter Bottom Image

4.1.2.2.1 Cost

The cost of the Eggfinder TX transmitter is $75 and the cost for the Eggfinder RX “Dongle” Receiver is 25$ but they are also sold in a kit for $90. The benefits about this gps system would be that it doesn't cost nearly as much as other gps units and also its size makes it a perfect candidate to use in the payload. The cons of this system is that it does not have live telemetry meaning we will have to pull the SD card out of the payload to see the data it has recorded.

4.1.2.2.2 Manufacturing

The Eggfinder could be purchased in a few places but the best place would be directly from Eggtimer Rocketry in a kit with both the transmitter and the receiver. The system is fairly simple, only needing an SD card to record data and a free software to show us the results. Preparing for launch is straightforward given that the battery is charged.

4.1.2.2.3 Why it should be chosen

The only reason that we considered the Eggfinder is the fact that its size is small and would fit neatly on the payload. However, the reasons we should not buy this flight computer greatly outweigh this. The members of the Avionics Subteam have limited soldering experience and, considering the importance of this equipment, do not want to potentially destroy a $100 dollar flight computer. The payload GPS additionally requires a gyroscope which the Eggfinder does not have the capability for. Also considering the limitations imposed on us in regards to COVID-19, meeting up to build this is going to be challenging because the team members do not currently have a workshop to build this until we are given permission to use the facilities at our university. Because we have simpler and better options at our disposal for this price, we will not be choosing the Eggfinder TX.

4.1.2.3 Featherweight Tracker

The Featherweight tracker by Argent Data Systems is a high end GPS tracking system with a range up to 300,000 ft with the capability to track into space, and does not require a directional antenna. It is capable of doing this by utilizing 2 satellites giving great reception wherever the rocket may go. The system connects to a ground unit which inturn connects to an android or an iPhone to give live data to the user. The system also provides 3D velocity readings at 10 samples per second. Tracker can run 5 hours on a small, 400 mAhr single LiPo cell. The app uses GPS location, compass and accelerometers to point to your rocket.

Figure 4.1.2.3-1 Featherweight GPS Tracker Kit Image

4.1.2.3.1 Cost

The total cost of this system including the transmitter and receiver runs at about $350. The pros of having this system is that we would be 100% confident in our ability to communicate with the receiver no matter how far the rocket may drift off. The cons of this system is that for $350 it does not have a gyroscope and the capability of dual deployment as the Telemturm does, while both offer live telemetry.

4.1.2.3.2 Manufacturing

We would have to purchase this system directly from Argent Data Systems for $352. This system is probably the most simple of them all due to it being connected to an app on either iPhone or Android. Assuming the batteries are charged this system would require very little work to prep on launch day.

4.1.2.3.3 Why it should be chosen

The Featherweight Tracker will not be selected due to its hefty price tag and lack of on-board sensors such as a gyroscope and also the major downfall of this system is that it does not have the capability to deploy a black powder charge. This system is purley a GPS designed for long range uses which in our case is not needed. The Featherweight Tracker is simply excessive and is not the best candidate given the parameters of our mission. Because we have better options at our disposal for this price, we will not be choosing the Featherweight tracker.

Table 4.1.2.3.3-1 Pros and Cons Chart

	Pros	Cons
Telemetrum V3	-GPS+altimeter -real time telemetry data -ease of use once in AV bay -simple setup and usage	-cost ($300 + $175.90 for antenna and dongle)
Eggfinder TX + RX	-small	-cost ($90) -most difficult manufacturing process (requires soldering) -no live data logging

		(stored in micro SD)
Featherweight Tracker	-long range -does not require directional antenna -real time data to phone app -simple setup and usage	-cost ($350) -cannot deploy black powder charges -lack of on-board sensors

4.1.3 Leading Components

4.1.3.1 Altimeter

For our altimeters, we chose the Telemetrum V3 as our main altimeter with the Stratologger CF as our redundant altimeter. These two ended up being the devices best suited to our needs for a variety of reasons. Though the Telemetrum has a hefty price tag, the functionality it provides as both a GPS and altimeter as well as allowing real time transmission of telemetry data outweighs the increased cost. Setup and usage of the device is relatively simple as described by the manufacturer and the device is backed by reviews proving its worth. Having spent a sizable amount on our main altimeter, we chose to find a redundant altimeter capable of supporting a dual-deployment system while keeping the price to a minimum but still providing the functionality and quality we desired. With this in mind, we selected the Stratologger CF as our redundant altimeter with the only issue in our selection being its limited stock.

4.1.3.2 GPS

As for our main GPS in the AV bay, we chose the Telemetrum V3. As mentioned in the leading component excerpt for our alimeters, the Telemetrum provides the functionality of both an altimeter and a GPS. Though the cost was high, we were able to rationalize our decision because of the large range of the GPS as well as the device's high quality.

4.1.3.3 Redundancy Plan

As mentioned in the excerpt regarding our leading altimeter choices, we chose the Stratologger CF as our redundant altimeter. We do not plan on selecting a redundant GPS for our system as it is not a requirement by NASA. Due to the high quality of the Telemetrum, we are confident in its ability to carry out what we require of it without experiencing any problems before or during launch

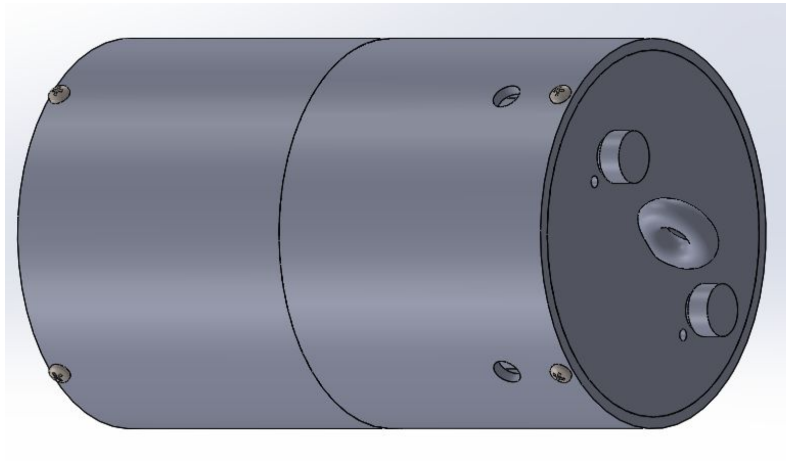

Figure 4.1.3-1 AV Bay With Cover On, Static Pressure Holes Shown

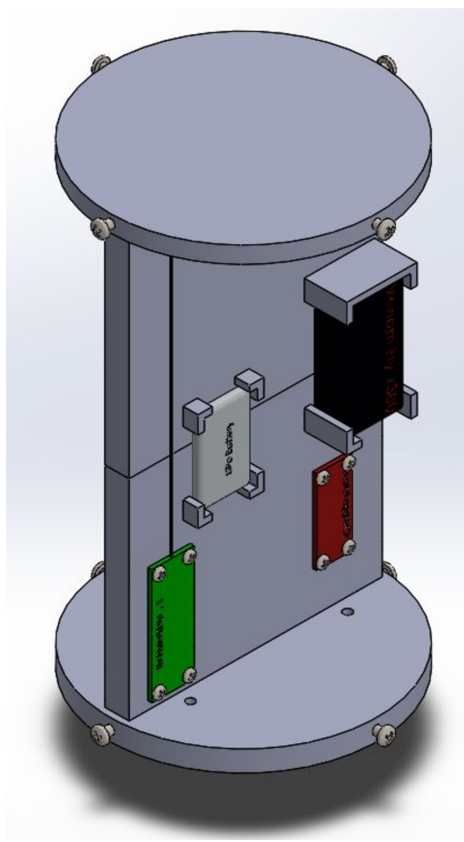

Figure 4.1.3-2 Isometric of Avionics Bay without Cover

4.2 Parachutes

4.2.1 Ejection System Options

4.2.1.1 Spring Ejection System

This method relies on having a compressed high powered spring underneath the parachute canister. The parachute is then capped off by a lid tightly to ensure the spring isn't able to expand. Once it is time to release the parachute, the lid would release by a small pyrotechnic or a mechanism to allow for the spring to expand. This uses the potential energy stored in the spring to push out the parachutes clearly for recovery.

4.2.1.1.1 Cost

The spring system will cost around $70-$90, a custom system will raise the price significantly. The machining or welding may also increase the price significantly.

4.2.1.1.2 Manufacturing

For this system, the components would all be commercially bought and then assembled by our team. The spring canister would most likely be made to order or it can be 3D printed for it to fit the body tube. The need to keep the spring compressed can be done with a locking mechanism which may be also custom made by ourselves or outsourced.

4.2.1.1.3 Why is this an option?

The main reasons to pick this design are that it is a simple idea in theory. There are not a lot of moving pieces. Also, it will be very difficult to make this design redundant. The main reasons that it shouldn't be chosen are that this design is a big and bulky design. This would require a lot of space, which is most likely not a possibility. This is also the heaviest design option, which is not ideal.

Table 4.2.1.1.3-1: Spring Ejection Pros and Cons

Pros	Cons
-Fairly simple -Small amount of black powder -Powerful -Less pyrotechnics	-Very heavy -Very large -Difficult to be redundant -Very pricey

	-Difficult to manufacture

4.2.1.2 Black Powder Ejection System

Black powder ejection is a simple way to achieve deployment. In this system, the black powder wells are filled with black powder. The wells will be held in place on the bulkhead for security with epoxy. The black powder is then packed inside the wells and insulation material on top, then is covered with tape to seal it. Inside the bottom of the canisters are the e-matchs used to ignite the powder for the ejection of the parachutes.

4.2.1.2.1 Cost

These charges are roughly $12 and the canisters are about $15 each. There is a large amount of black powder in our inventory, so the black powder will be cost-free.

4.2.1.2.2 Manufacturing

For this system, we are using the black powder in our inventory. The canisters needed for the black powder can be bought through online suppliers or hardware stores. The small various supplies needed like tape, insulation material, epoxy, and hardware will be purchased through online suppliers or hardware stores.

4.2.1.2.3 Why is this an option?

The black powder ejection system was considered a feasible option, the small amount of space it takes up is ideal with the limited space of the rocket. The team also has some experience with the black powder ejection system. The small amount of space and weight it takes up allows an easier design for redundancy. The disadvantages to this design are the possibilities of more hazard/safety factors with the handling of black powder and a possibility of damaging the parachutes from the explosion.

Table 4.2.1.2.3-1: Black Powder Ejection Pros and Cons

Pros	Cons
-Very simple -Very affordable -Easily able to be redundant -Prior experience of handling -Very light weight -Space saver	-Can be a safety liability -Possibly damage parachutes

4.2.1.3 CO2 Pressure Ejection System

This design is made to hold compressed gas (in this case CO_2) in a lightweight container or cartridges. Then when needed, the gas is released by a mechanism connected to the AV bay to release a small spring. This spring is a high-energy compressed spring with a puncture device to pierce a hole in the tank/cartridge to release the CO_2 at a high velocity to release the parachutes. This allows the parachutes to clear the body tube for deployment.

4.2.1.3.1 Cost

These kits can run roughly about $175 for a kit containing all the necessary hardware/parts along with multiple cartridges, up to 8 cartridges of 12oz or 8oz. If more are needed, each cartridge is about $3 each. Along with the pressure regulator and gauge would be around $30-$50. Finally, the release valves would be about $15 each.

4.2.1.3.2 Manufacturing

This is a system that can be bought commercially. We aren't able to refill the cartridges after a single use, so extra cartridges are needed. Although the kit comes with multiple cartridges, there is a possibility of needing more than the kit provides. If chosen, we would buy the system from Fruity Chutes' online store. The other parts would be bought from other various online stores. The system preparation would require a pressure valve and release valves to make sure that the

C02 cartridges maintain the safety factor which requires more parts to assemble. These parts can also be bought through online stores.

4.2.1.3.3 Why is this an option?

The benefits with this system are that everything comes with all the parts necessary for this method. It also requires less explosive parts for a much more clean release that doesn't put the body structure at risk. It is a very lightweight method of ejection. Some disadvantages are that this system is quite expensive. The cartridges aren't refillable, so if we need more than 8 for testing and launch, then we would need to buy more cartridges which could drive up costs to an already pricey option. Also in order to meet the needed requirements to use this option it would make it a bit more complicated with more parts necessary. To maintain the required safety factor would require additional complexities to this design.

Table 4.2.1.3.3-1: CO2 Gas Ejection Pros and Cons

Pros	Cons
-Lower in weight -Very powerful -Less pyrotechnics	-A bite more pricey -Very complex -A lot of parts necessary -Cartridges aren't refillable -Difficult to be redundant

4.2.2 Parachute Sizing Calculations

To calculate the area of the parachute, which essentially gives us the diameter of the radius of the parachute, we must start off with the drag equation:

$$F_d = ½\, r\, C_d\, A\, v^2$$

We know that the launch vehicle will reach a terminal velocity at some point, so instead of computing an acceleration that converges to 0, we will do our calculations at terminal velocity. At terminal velocity acceleration is 0 and our only forces are drag and weight which are both in the y direction. Which makes the equation

$$mg = \frac{1}{2} r C_d A v^2$$

Rearranging this gives us, ...

$$A = \frac{2mg}{r C_d A v^2}$$

Since the area of the circle is, ...

$$A = \pi r^2$$

the equation for parachute sizing is

$$r = [\frac{1}{\pi}(\frac{2mg}{rCdAv^2})]^{1/2}$$

We know that a parachute diameter for a rocket size of 8ft uses a parachute range from 6ft-14ft. For our calculated main parachute turns out to be 10 ft. Our team wrote Matlab code to calculate and verify this conclusion.

Since we would like to find a drogue parachute that will slow our rocket down to a safe speed for the main parachute to deploy, our calculations will involve the largest lateral area of our rocket.

$$D = (\frac{4LD}{\pi})^{1/2}$$

This equation gives the sizing for our drogue parachute. Our drogue parachute was calculated to be 24 inches. To verify these calculations, we used Matlab code and RockSim to verify that the drogue parachute will give us a descent velocity equal to or less than 80 ft/s to ensure a safe descending velocity for the main parachute to open.

4.2.3 Drift Calculations

The drift away from the launch site is estimated as:

$$Drift = V_w t$$

Where:
V_w = wind velocity (ft/sec);
t = total descent time (sec);

Drift depends on the wind speed at the time of launch. The calculation for drift uses a formula that depends on the wind speed. The descent time is already known using its own calculations; therefore, the drift completely depends on the wind speed at the time of launch.

The payload will separate from the rest of the rocket at 550 ft; however, it will have the same drift as the rest of the rocket since the wind acts on both objects. These numbers were calculated using the drift equation above.

Table 4.2.3-1: Values for Drift (0-20 mph)

Section	0 mph	5 mph	10 mph	15 mph	20 mph
Nose Cone	0 ft	600.56 ft	1201.13 ft	1801.70 ft	2402.27 ft
Payload	0 ft	600.56 ft	1201.13 ft	1801.70 ft	2402.27 ft
Motor	0 ft	600.56 ft	1201.13 ft	1801.70 ft	2402.27 ft

4.2.4 Descent Time Calculations

We modeled our rocket in MATLAB to provide descent times based on these calculations:

$$v = \sqrt{\frac{2KE}{m}}$$

Where:
KE = Kinetic Energy
m = mass of section with greatest mass
v = velocity

Once we have obtained the velocity we use the following equations to calculate total time :

$$T_{main} = \frac{H_{main}}{v}$$
$$T_{drogue} = \frac{A - H_{main}}{80}$$
$$T_{total} = T_{main} + T_{drogue}$$

Where:
T_{main} = time from main parachute release till landing
H_{main} = height when main parachute is released
Tdrogue = time from apogee to main parachute release

A = apogee height
80 = planned velocity from apogee to main parachute release (ft/s)
Ttotal = total descent time

Using the descent time equations, we calculate the total descent time of 81.89 seconds. This time puts us within requirement 3.11, allowing us to land in under 90 seconds starting from apogee.

4.2.5 Kinetic Energy Calculations

Using Matlab our team was able to calculate the landing kinetic energy upon impact of each independent section. First we took the known equation for kinetic energy:

$$KE = \frac{1}{2}mv^2$$

Where:
KE = Kinetic Energy
m = mass of independent section
v = velocity of falling section

Since the maximum kinetic energy upon impact is 75 ft - lbf for any independent, required by NASA, we rearrange the formula above to solve for the maximum velocity each section can descend at.

$$v = \sqrt{\frac{2KE}{m}}$$

Once we obtain the maximum velocity that each section can descend at to fall within the 75 lbf kinetic energy requirements, we choose the lowest out of the three velocities as our descent rate for all three sections to ensure that all sections will meet the requirement.

Once completing these calculations and verifying them with RockSim, the values we obtained are as follows.

Table 4.2.5-1: Kinetic energy values of each section

	Kinetic Energy ($lb_f - ft$)

Section 1 - Nose Cone	22.82
Section 2 - Payload	56.45
Section 3 - Motor & Motor Casing	74.92

4.2.6 Leading Components

4.2.6.1 Ejection Method

The leading ejection system is determined to be the black powder ejection design. The black powder is the simplest of the previously listed methods, and has proven to be the most desirable method. The simplicity, size, and affordability are the main reasons why this is the current leading method. This is chosen because there are more benefits than disadvantages compared amongst the ejection methods. The disadvantages of this method can also be easily minimized unlike the other options. Placing a fire blanket over the parachutes can reduce the risk of damage to the parachute from the black powder. As well as taking the proper precautions to minimize the safety risk can be easily implemented.

4.2.6.2 Drogue Parachute

The parachute chosen is the 24" Compact Elliptical Parachute by Fruity Chutes. The shape that was decided was elliptical because of its stability at high speeds, and it is very cost effective. This parachute costs $72.03. This drogue will allow the launch vehicle to descend fast enough under 90 seconds, but also have some resistance so that the descent of the launch vehicle after drogue deployment does not exceed 80 ft/s.

4.2.6.3 Main Parachute

The main parachute we decided on is the Iris Ultra 120" Compact Parachute by Fruity Chutes. This parachute will cost $541.97. This parachute is a leader because it is the parachute that is most effective in meeting the requirements. The shape we decided was toroidal due to its higher drag coefficient needed for a main parachute.The higher drag coefficient allows the launch vehicle to slowly descend to a velocity that is slow enough to meet the kinetic energy requirement, but fast enough to reach a descent time of less than 90 seconds.

4.2.6.4 Redundancy Plan

Redundancy for our leading design, the black powder ejection, can be achieved by having multiple black powder caps on the bulkhead. The caps will have their own e-match and the redundant charge will be purposely delayed, it will go off a couple seconds after the initial charge is set to detonate. Redundancy for our single deployment parachute ejection is to use two Jolly Logic Chute Releases in series on the main parachute. The main Chute Release will be wrapped around the main parachute until it is to be deployed. The redundant Chute Release will be used in series to ensure its deployment and the safe recovery of the launch vehicle

5.0 Mission Performance Predictions

5.1 Projected Altitude

The team's official projected altitude is 4,000 ft. To arrive at our projected altitude, we ran multiple simulations to represent the scenarios that could be encountered on launch day. To ensure accurate simulations, typical April weather conditions for the launch site were factored in. The major flight characteristics to determine our launch day projected altitude are the wind speed, and launch rail angle of attack. The simulations used angles of attack varying from 5 to 10 degrees as per requirement 1.12, and wind speeds varying from 0mph to 20mph in 5mph increments. The results of these simulations are summarized in **Table 5.1-1**.

Table 5.1-1 Effects of Wind and launch AOA on Apogee

Wind (mph) / AOA (degrees)	5	6	7	8	9	10
0 mph	4124	4103	4079	4050	4019	3983
5 mph	4163	4154	4141	4125	4104	4080
10 mph	4158	4160	4159	4155	4146	4133
15 mph	4116	4129	4139	4144	4147	4145
20 mph	4047	4069	4087	4102	4114	4122

5.2 Flight Profile Simulations

Below is the plot of thrust over time for the Cessaroni L1350CS, with a max thrust occurring at approximately 1.25 seconds.

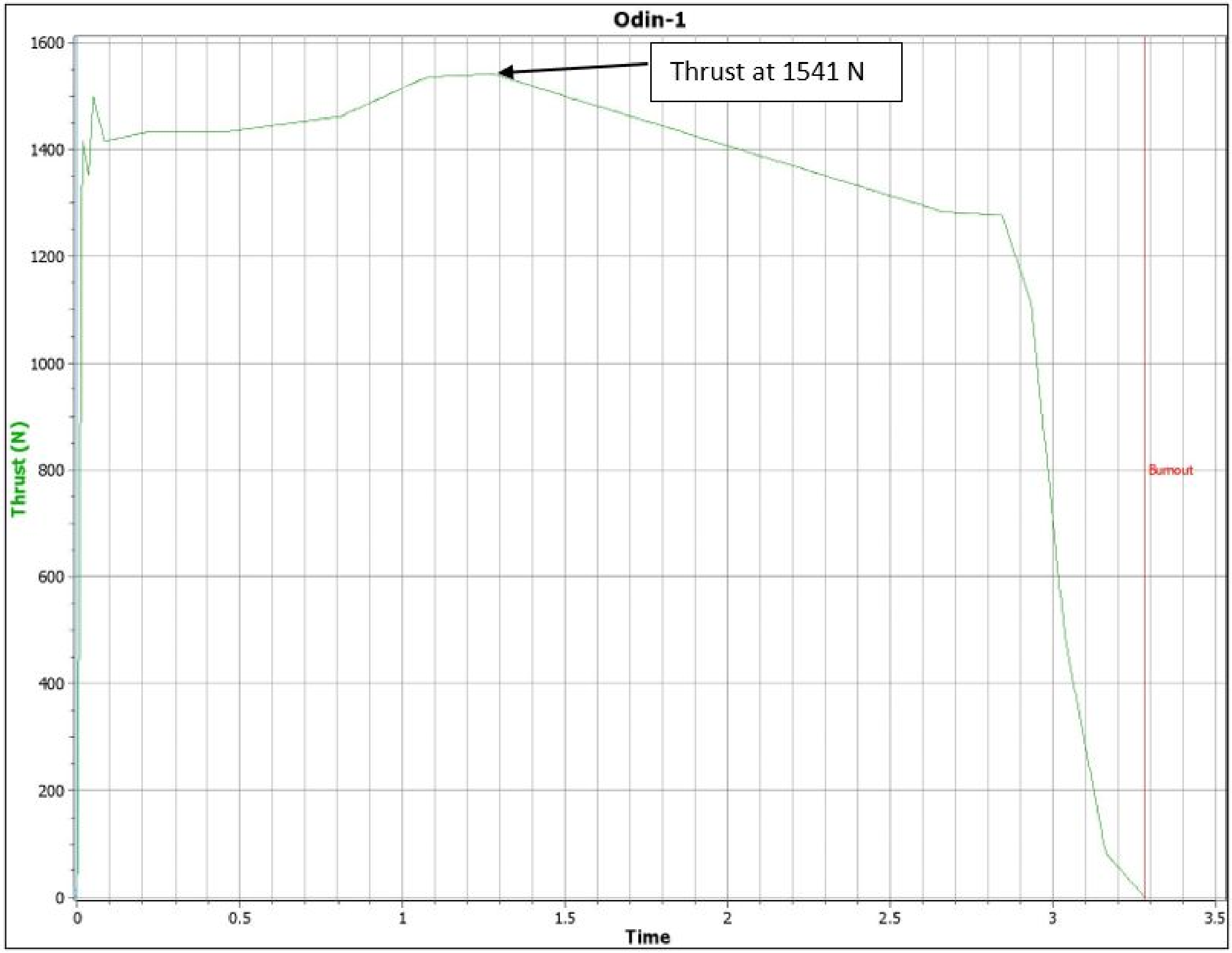

Figure 5.2-1 Cessaroni L1350CS Motor Thrust Curve

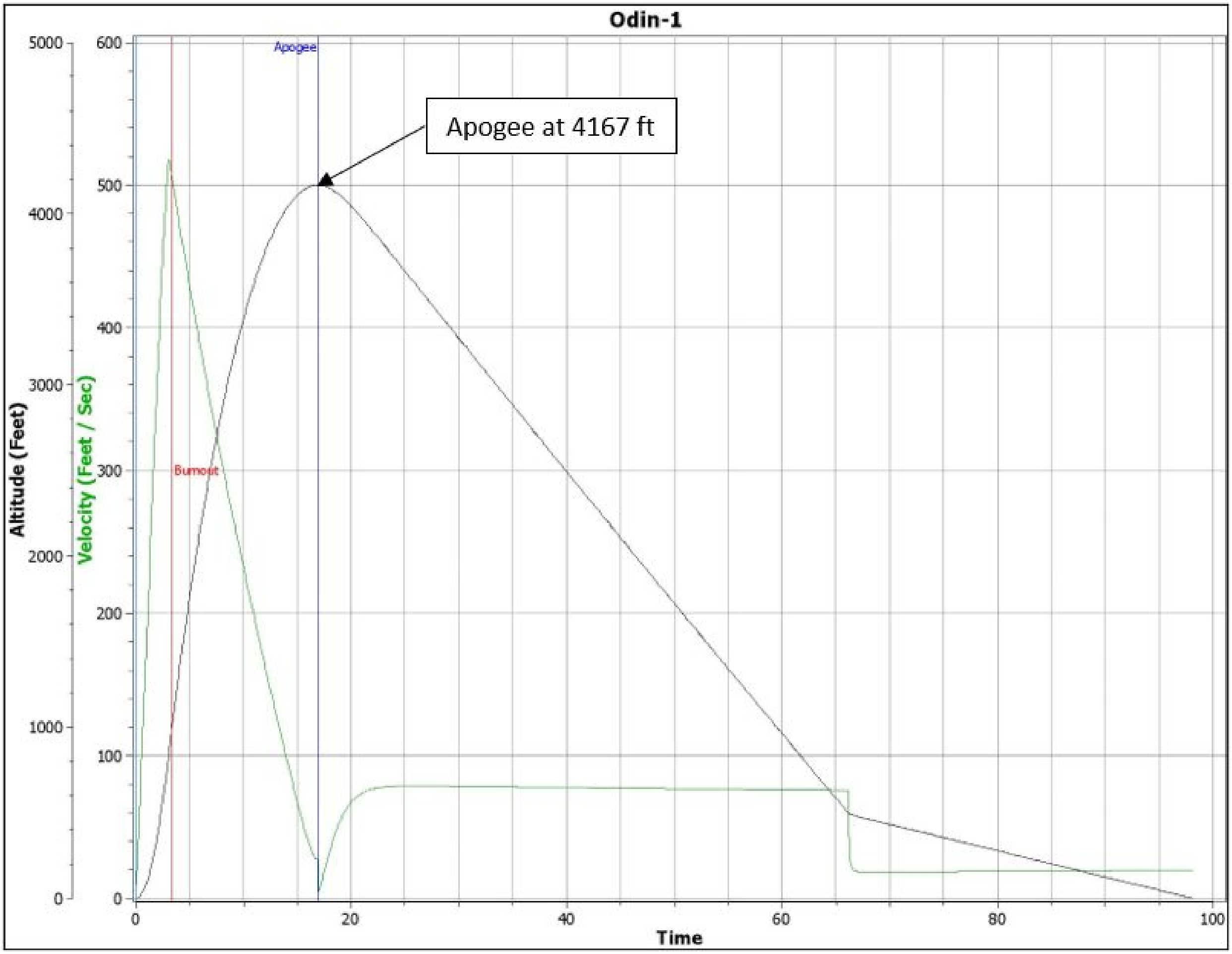

Figure 5.2-2 Light Wind Speeds (3-7 MPH)

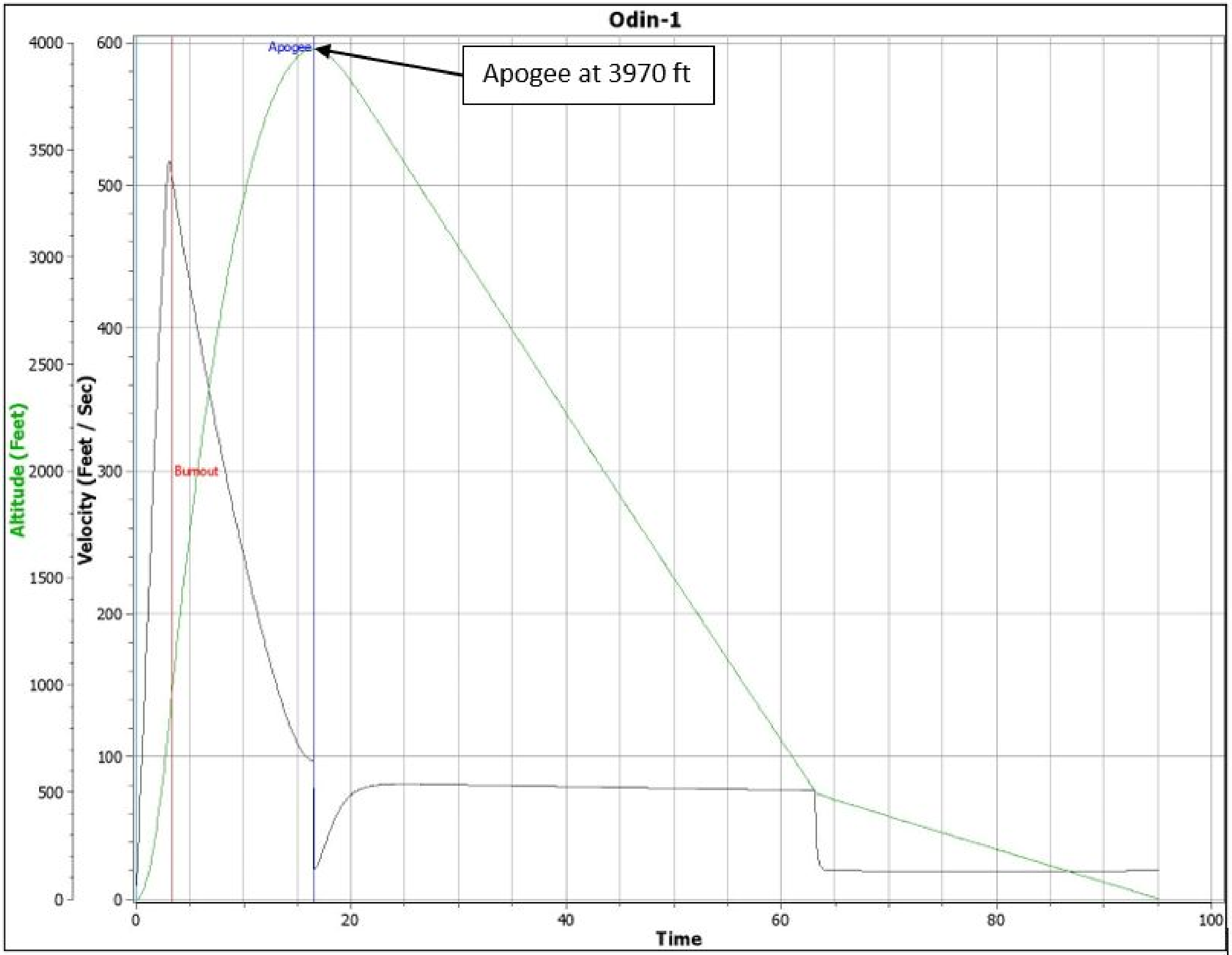

Figure 5.2-3 Slightly Breezy Speeds (8-14 MPH)

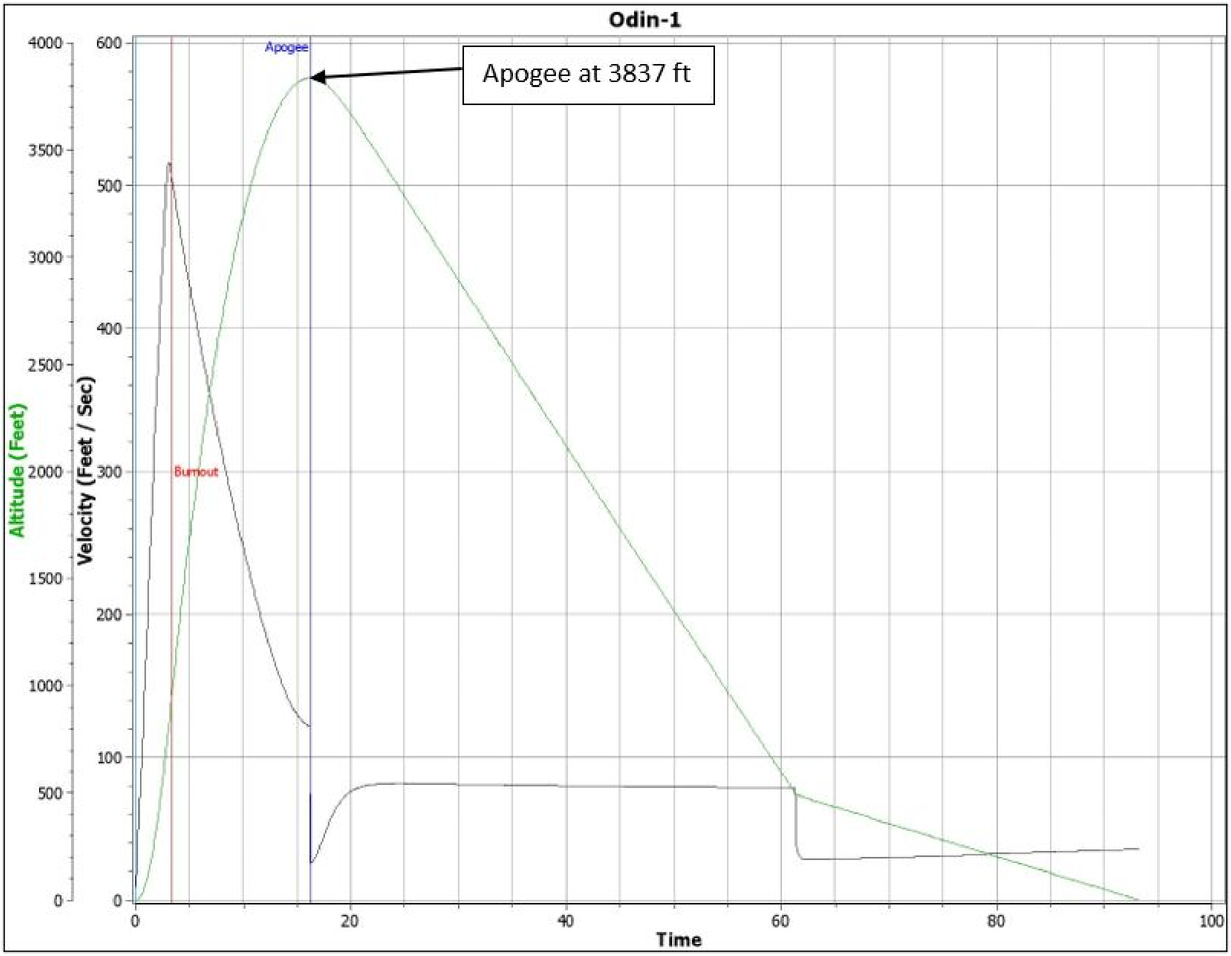

Figure 5.2-4 Breezy Speeds (15-20 MPH)

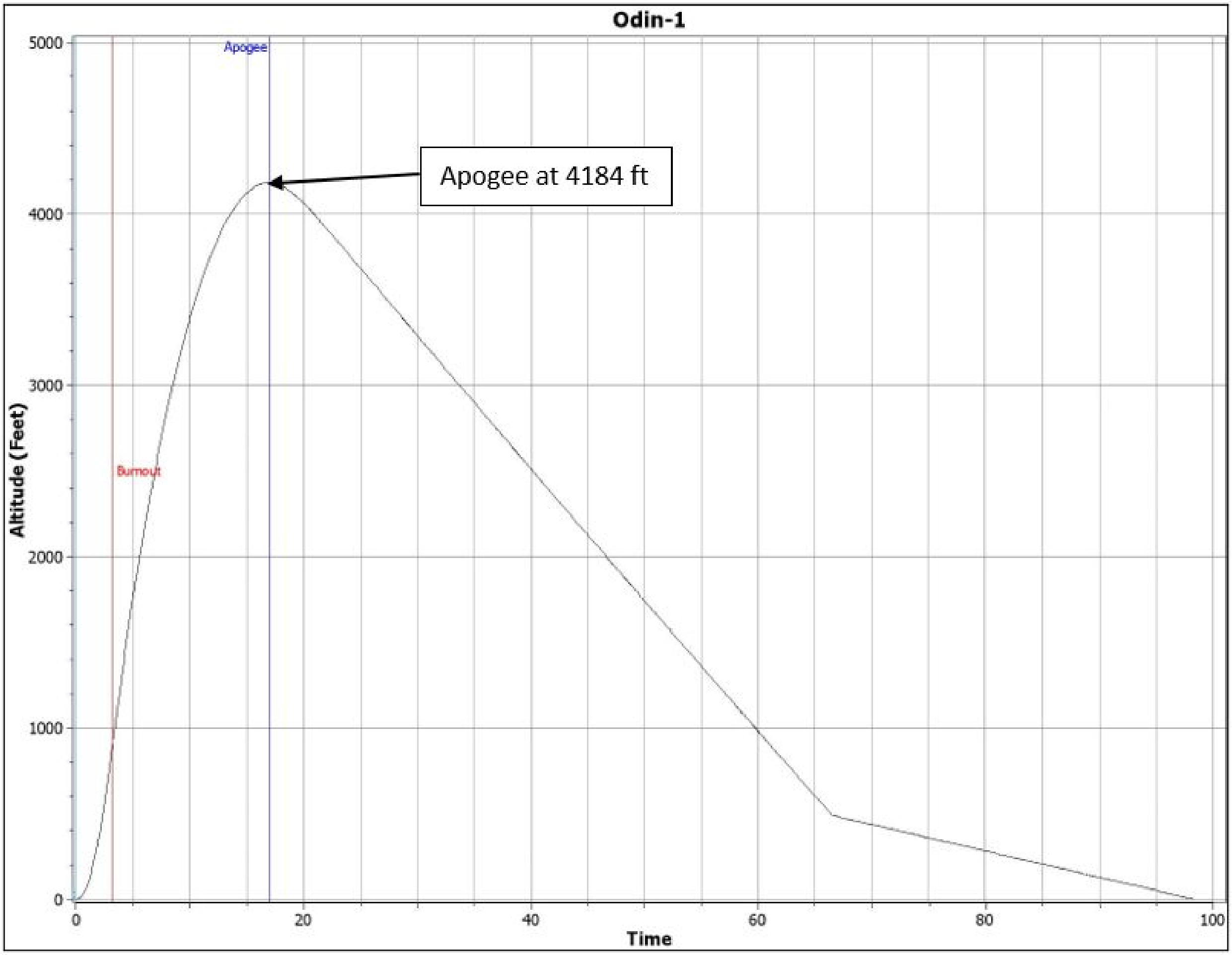

Figure 5.2-5 Max Altitude No Winds

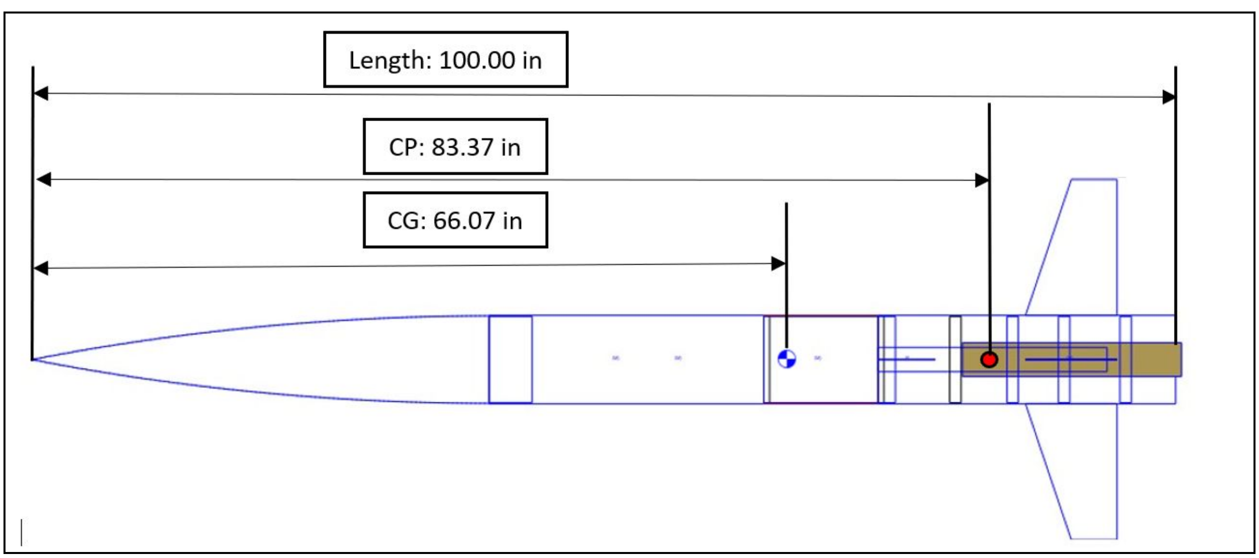

Figure 5.2-6 Rocket Model with CP and CG Locations

Figure 5.2-7 Range of Rocket After Launch at Light Wind Speeds

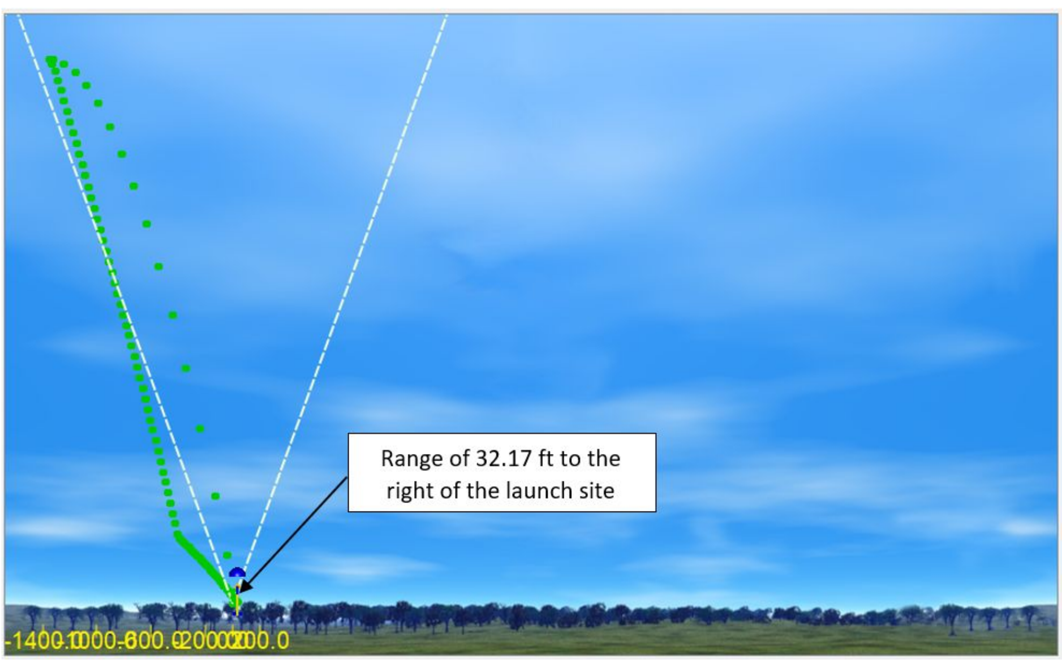

Figure 5.2-8 Range of Rocket After Launch at Slightly Breezy Wind Speeds

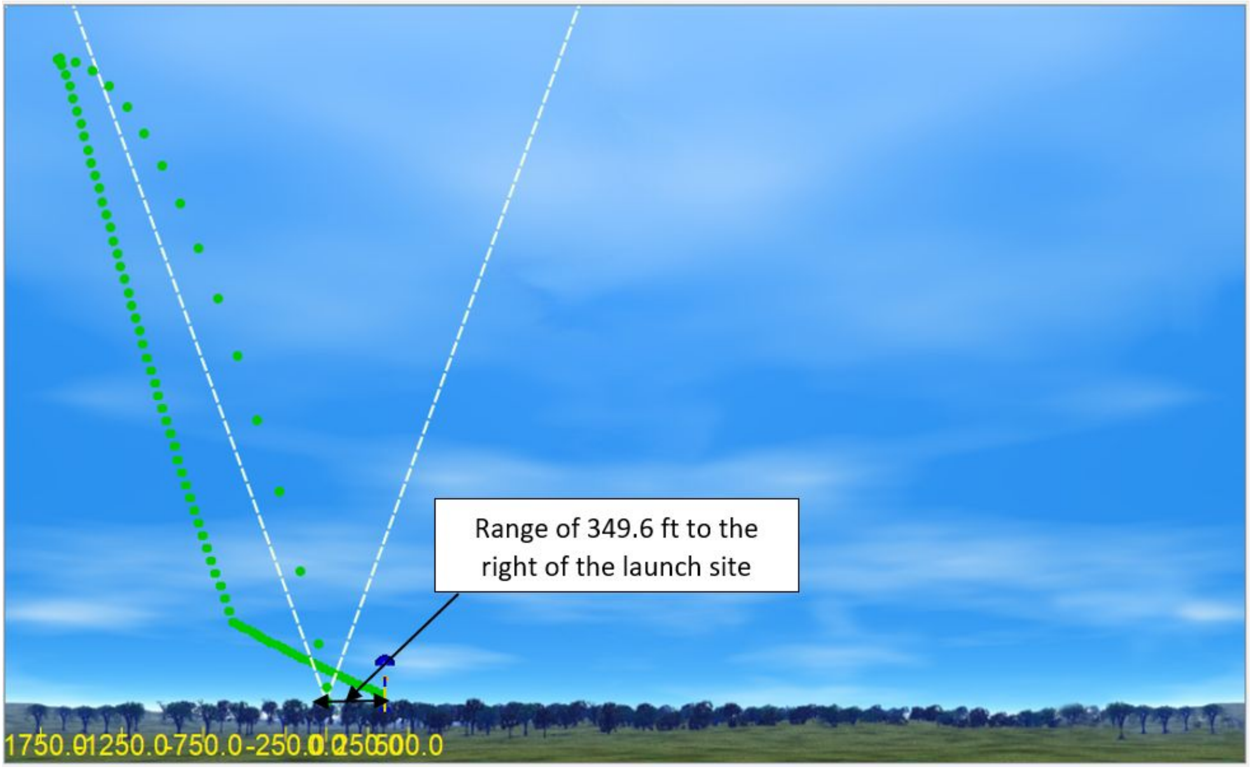

Figure 5.2-9 Range of Rocket After Launch at Breezy Wind Speeds

To ensure that our rocket is robust enough to withstand expected loads, we first solve for the max possible loads that can occur on the rocket as aerospace tradition demands. We define the max stress due to thrust as

$$f_{max} = \frac{P}{A} + \frac{M*C}{I}$$

$$f_{max} = \frac{P}{2*\pi*R*t} + \frac{M*R}{\pi*R^3*t} = \frac{P}{2*\pi*R*t} + \frac{M}{\pi*R^2*t}$$

Where:

P = thrust = 376 lbs

R = radius = 3.8539 in

M = moment

t = wall thickness = 0.1898 in

Our leading motor choice the Cessaroni L1350s has a maximum thrust of 376 lbs and the approximate maximum wind shear V can be shown to be 10% of max thrust.

V = 0.1 * 376 lbs = 37.6 lbs

M = 37.6 lbs * 1 in = 37.6 lb-in

$$f_{max} = \frac{376\ lb}{2*\pi*3.8539in*0.1898in} + \frac{37.6\ lb-in}{\pi*(3.8539in)^2*0.1898\ in} = 81.8109\ psi + 4.2456\ psi$$

$$f_{max} = 86.0565\ psi$$

The running load N_{max} as a result would be given as

$$N_{max} = t * f_{max} = 55.818\ lb/in$$

Next we check the buckling allowable against the max stress

$$F_{cr} = \frac{K_c * \pi^2 * E_c}{12\,(1 - v^2)} * \left(\frac{t}{L}\right)^2$$

$$z = \frac{L^2}{R*t}\sqrt{1 - v^2}$$

Where:

F_{cr} = buckling allowable

z = geometric parameter

L = body tube length = 60 in

V = poisson's ratio = 0.118

$$z = \frac{60^2}{3.8539 * 0.1898} * \sqrt{1 - 0.118^2} = 4,887.21$$

R/t = 3.8539/0.1898 = 20.3

$$K_c = 30$$

$$E = 2700\ ksi$$

$$F_{cr} = \frac{30 * \pi^2 * 2700}{12 * (1 - 0.118^2)} * \left(\frac{0.1898}{3.8539}\right)^2 = 163.86\ ksi$$

Our estimated crippling allowable exceeds our max loads with a large safety margin. Therefore, our rocket would withstand the max stresses in flight. It is paramount to state that our crippling allowable found here be verified and adjusted by physicallying testing our chosen material and geometry specifications.

5.3 Landing Kinetic Energy

Table 5.3-1 Wind Variants Table

Cesaroni L1350				Energy)(J)	Lb-ft
			0 mph		
Recovery Bay and Motor	9.39105	kg	Bay and Motor	101.529	74.865
Payload+Avionics	7.078	kg	Payload+Avionics	76.522	56.425
Nose Cone	2.86	kg	Nose Cone	30.920	22.800
			5 mph		
Wind Speed	Landing V		Bay and Motor	129.914	95.795
0 mph	4.65	m/s	Payload+Avionics	97.916	72.200
5 mph	5.26	m/s	Nose Cone	39.565	29.174
10 mph	6.301	m/s	10 mph		
15 mph	7.988	m/s	Bay and Motor	186.425	137.465
20 mph	10.114	m/s	Payload+Avionics	140.508	103.607
			Nose Cone	56.775	41.864
			15 mph		
			Bay and Motor	299.613	220.926
			Payload+Avionics	225.817	166.511
			Nose Cone	91.246	67.282
			20 mph		
			Bay and Motor	480.319	354.175
			Payload+Avionics	362.015	266.940
			Nose Cone	146.279	107.862

For our launch vehicle, the masses for each independent section was divided between the Nose Cone, Payload and Avionics, and Recovery Bay. When calculating the kinetic energy of each part, the velocity at landing for various wind speeds was taken into account. From **Figure 3.6.3-1**, the right columns of the table show the values calculated for the kinetic energy of each launch vehicle component with varying velocities.

The equation used to calculate the kinetic energy is as follows:

$$KE = (\tfrac{1}{2})*(\text{mass of component})*(\text{velocity at landing})$$

5.4 Descent Time

To accurately estimate the decent time for our rocket while also accounting for wind effects, we used the rocksim software to run through tens of simulations given wind speeds from 0 to 20 and varying angles of attack. The final results of our simulations are presented in **Table 5.4-1**, all of our data cells are recorded in seconds.. Giving these results and taking an average of the expected wind speeds at the Huntsville Alabama launch site in April, we concluded our expected decent time for the rocket to be 87.9 seconds.

Table 5.4-1 Simulated rocket decent time matrix

Wind (mph) / AOA (degrees)	5	6	7	8	9	10
0 mph	87.87	87.61	87.3	86.95	86.54	86.1
5 mph	88.36	88.25	88.09	87.88	87.62	87.32
10 mph	88.29	88.33	88.32	88.25	88.14	87.99
15 mph	87.76	87.93	88.05	88.13	88.16	88.14
20 mph	86.9	87.18	87.45	87.6	87.75	87.85

Our planetary lander is the only other item that descends untethered from the rocket. The planetary lander would be ejected at an altitude of 600 ft which is when the main parachute of the rocket also deploys. The decent time for the planetary lander is shown below:

$$\text{Decent time} = (T_{main} - T_{apogee}) + T_{lander}$$

Where:

T_{main} = main parachute deployment time (T^{+} seconds) = 64.05 s

T_{apogee} = time to apogee (T^{+} seconds) = 16.84 s

T_{lander} = lander decent time after ejection.

To solve for T_{lander}, we first solve for the descending velocity knowing that the drag force equals the weight:

$$D = 0.5 * C_d * \rho * V^2 * A$$

$$D = W$$

$$0.5 * C_d * \rho * V^2 * A = W$$

$$V = \sqrt{\frac{2*W}{C_d*\rho*A}} = \sqrt{\frac{2*5*32.2}{2.2*2.377*10^{-3}*32.2*76.106966}} = 5.01\, ft/s\,.$$

A is our parachute area, and the C_d is it's drag coefficient. Since we now know the rate at which the payload descends, we can now calculate the time it take to decent 600 ft given by:

$$T_{lander} = \frac{600\,ft}{5.01\,ft/s} = 119.76\,s$$

Finally the total decent time for the lander from apogee to touchdown is given as

Decent time = (64.05 - 16.84) + 119.76 = 166.97 s.

5.5 Wind Drift

The wind drift distances that were found in Table 3.6.5-1 were calculated through Rocksim's simulation capabilities. Drifts from no winds, winds at 5 MPH, 10 MPH, 15 MPH, and 20 MPH were found. The Trajectory of the Launch Vehicle can be seen in **Figures 3.6.2-7** through **Figure 3.6.2-8**

Table 5.5-1 Wind Drifts at Various Wind Speeds

Wind Drifts at various Wind Speeds					
Wind Speed:	0 MPH	5 MPH	10 MPH	15 MPH	20 MPH
Drift:	0 ft	12.28 ft (left)	74.37 ft (right)	251.1 ft (right)	507.6 ft (right)

5.6 Alternate Performance Calculation

Apogee can be approximated by hand with a few simplifications. Wind is at rest relative to the launch pad, and average mass during burnout and average drag coefficient throughout flight was used. The flight of the rocket is split into two phases, the motor burn phase and the coasting phase (no thrust). Velocity at burnout is calculated and then used to calculate the height at burnout and height in coasting phase. Diameter of the rocket was converted to meters for future calculations. Drag coefficient was taken from Rocksim data, standard density of air was used and for the motor, data for the Cesaroni L1350CS engine was used. Rocket dimensions and values were denoted as "R". Known values to us are as follows :

$$
\begin{aligned}
D_R &= 7.5\,in \;\approx 0.1905\,\mathrm{m} \\
\rho_{air} &= 1.22\,\mathrm{kg/m^3} \\
C_d &= 0.26 \\
I_{total} &= 4280.166\,\mathrm{N\,s} \\
t_b &= 3.28\,\mathrm{s} \\
m_R &= 19.17\,\mathrm{kg} \\
m_{engine} &= 3.570\,\mathrm{kg} \\
m_{propellant} &= 1.905\,\mathrm{kg} \\
g &= 9.81\,\mathrm{m/s^2}
\end{aligned}
$$

These next values are intermediate calculations for the final calculations such as reference cross sectional area of the rocket and average thrust T:

$$
\begin{aligned}
A_R &= \pi \frac{D_R}{2}^2 \approx 0.02850\,\mathrm{m^2} \\
k &= \frac{1}{2}\rho_{air} C_d A_R \approx 0.004520\,\mathrm{kg\,m^{-1}} \\
T &= \frac{I_{total}}{t_b} \approx 1304\,\mathrm{N} \\
m_b &= m_R + m_{engine} - \frac{1}{2} m_{propellant} \approx 21.79\,\mathrm{kg} \\
\alpha &= \sqrt{\frac{T - m_b g}{k}} \approx 491.3\,\mathrm{m\,s^{-1}} \\
\psi &= \frac{2k\alpha}{m_b} \approx 0.2038\,\mathrm{s^{-1}} \\
m_c &= m_R + m_{engine} - m_{propellant} \approx 20.84\,\mathrm{kg} \\
\lambda^2 &= -\frac{m_c g}{k} \approx -45220\,\mathrm{m^2/s^2}
\end{aligned}
$$

Lastly, velocity at motor burnout is evaluated for the final calculations:

$$
\begin{aligned}
V_b &= \alpha \frac{1 - e^{-\psi t_b}}{1 + e^{-\psi t_b}} \approx 158.4\,\mathrm{m\,s^{-1}} \\
H_b &= \frac{m_b}{2k} \ln \frac{\alpha^2}{\alpha^2 - V_b^2} \approx 264.5\,\mathrm{m} \\
H_c &= \frac{m_c}{2k} \ln \frac{\lambda^2 - V_b^2}{\lambda^2} \approx 1017\,\mathrm{m} \\
Apogee &= H_b + H_c = 1281\,\mathrm{m} \approx 4204\,\mathrm{ft}
\end{aligned}
$$

Using this approximation, apogee was approximated to be at 4204 ft assuming no wind, constant drag coefficient, and constant mass during burnout. This helps verify our previous rocket's apogee range and shows our simulations are accurate.

Landing kinetic energy for the simple case (no wind) can be verified by solving for the landing velocity of the entire mass due to the parachute and using the result in the kinetic energy equation for each respective mass as follows:

$$v = \sqrt{\frac{2 m_R g}{C_d \rho_{air} A}}$$

Where:

$$\begin{aligned} g &= 9.81\,\mathrm{m/s^2} \\ m_R &= \text{mass of rocket } = 19.17\,\mathrm{kg} \\ C_d &= 2.2 \\ \rho_{air} &= 1.22\,\mathrm{kg/m^3} \\ A &= A_{\text{Parachute}} - A_{\text{Spill Hole}} \approx 7.07\,\mathrm{m^2} \\ A_i &= \pi r_i^2 \end{aligned}$$

Substituting:

$$v = \sqrt{\frac{2 \times 19.17\,\mathrm{kg} \times 9.81\,\mathrm{m/s^2}}{2.2 \times 1.22\,\mathrm{kg/m^3} \times 7.07\,\mathrm{m^2}}} = 4.45\,\mathrm{m\,s^{-1}}$$

Lastly:

$$\begin{aligned} \mathrm{KE}_{\text{Bay+Motor}} &= \frac{1}{2} \times 9.39\,\mathrm{kg} \times (4.45\,\mathrm{m\,s^{-1}})^2 = 93.1\,\mathrm{J} \approx 68.6\,\mathrm{lb_f\ ft} \\ \mathrm{KE}_{\text{Payload+Avionics}} &= \frac{1}{2} \times 7.08\,\mathrm{kg} \times (4.45\,\mathrm{m\,s^{-1}})^2 = 70.1\,\mathrm{J} \approx 51.7\,\mathrm{lb_f\ ft} \\ \mathrm{KE}_{\text{Nose Cone}} &= \frac{1}{2} \times 2.86\,\mathrm{kg} \times (4.45\,\mathrm{m\,s^{-1}})^2 = 28.3\,\mathrm{J} \approx 20.9\,\mathrm{lb_f\ ft} \end{aligned}$$

Assuming there is no wind speed, and only the main parachute supplies the drag force. Kinetic energy for the recovery bay and motor, payload and avionics, and nose cone, were 93.1 J, 70.1 J and 28.3 J respectively.

5.7 Performance Prediction Differences

As for the apogee approximations, the hand calculation does not account for a varying drag coefficient as well as varying mass during the motor burn phase. It also does not account for any wind variations. As a result of this, the calculated apogee can possibly be higher than the actual apogee on launch day. This calculation can instead be seen as a confirmation of the maximum theoretical altitude and reaffirmation of lower apogees due to varying winds.

Similarly, differences in landing kinetic energy can be attributed to not accounting for varying winds upon descent, and not considering drag from the drogue parachute after the main parachute has been deployed. Secondly, the mass of the parachutes themselves were not considered giving us a slightly lower kinetic energy value. These values calculated by hand help confirm our expected landing kinetic energy values. These values help us determine the minimum landing kinetic energy expected and help create a baseline.

6.0 Payload Criteria

6.1 Payload Objective

The objective of our payload is to complete all the requirements set by the handbook. This includes: ejecting the payload during descent at 550 feet, receiving live GPS coordinates, landing safely, leveling, sending orientation readings, sending a panoramic picture of the area, all done autonomously. A successful test of our payload will include: ejecting payload at 550 feet, landing without any damage to payload or its contents, leveling to within ± 5 degrees from vertical, and sending all required telemetry.

6.2 System Alternatives

Below, the various alternative solutions to our system will be discussed, including the various electronics and materials for our design. These alternatives were based by many factors, but were heavy on: weight, feasibility, and cost.

6.2.1 Payload Design Alternatives

Several payload design concepts have been explored by the team during research and experimentation. Early on, it was prioritized to design a shape that would aid in the self-leveling process. This enforced a structural design involving an elliptical shape with major electronic components located near the base to lower the center of gravity. This bottom heavy aspect of the payload design increases the chances of the payload being able to complete the landing process in an up-right orientation. Using this shape, several design concepts were developed, the pros and cons of each are described below.

The Self-Stabilizing Leg design, shown below in **Figure 6.2.1-1**, is the simplest design of all the considerations. The shape is designed such that if the payload were to land on its side, the curved shape of the legs would guide it back to an upright position. An issue here is that in an event where the payload lands on its base, but is still at an angle, such as on a hill, there is no other mechanism to ensure the payload meets the minimum 5 degree offset from vertical.

Pros:

- Easy to manufacture
- Limited electronics needed

Cons:

- No active stabilization
- Large diameter
- Low reliability

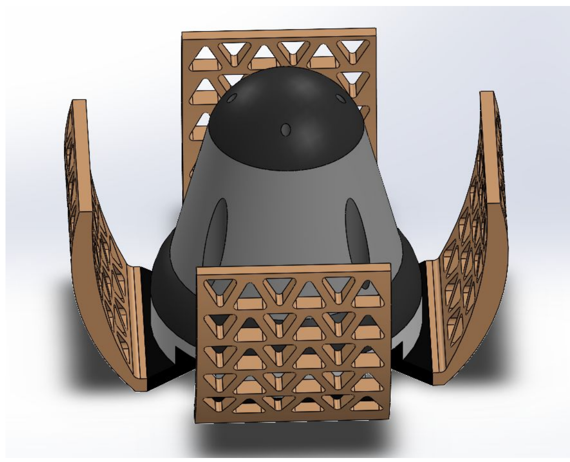

Figure 6.2.1-1 Self-Stabilizing Legs

The quadcopter design, as shown below in **Figure 6.2.1-2**, is an iteration on the previous Self-Stabilizing design. This concept attaches a section with four rotors to be used during descent of the payload. This system allows the payload to scan the terrain and find a suitable location for landing. Again, once landed the side would allow the payload to passively right itself.

Pros:

- Allows for selection of optimal landing zone
- Drastically reduces impact velocity as compared to a parachute

Cons:

- Large diameter
- Difficult to manufacturer and program
- Expensive

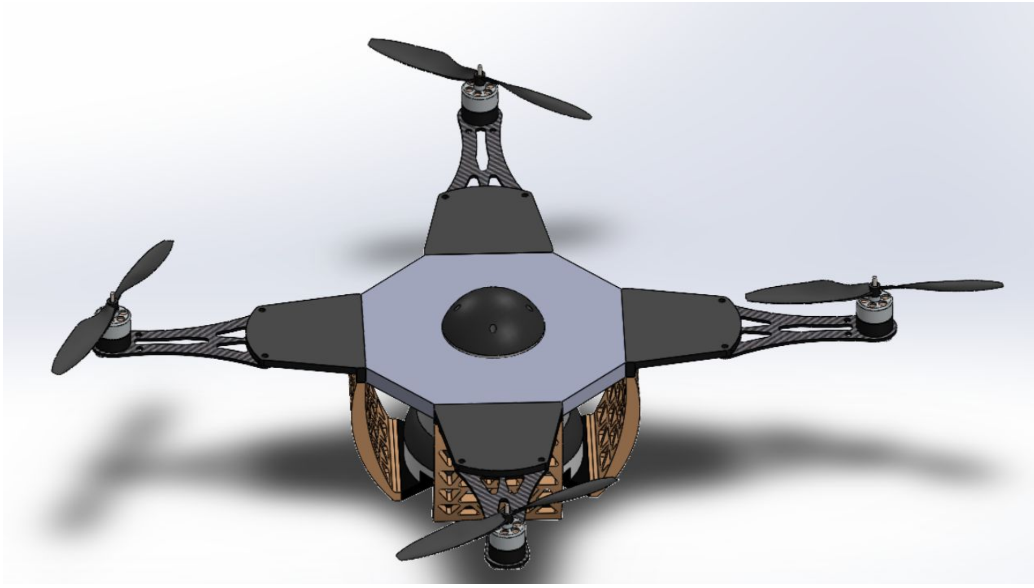

Figure 6.2.1-2 Quadcopter

The Actively-Stabilizing Leg design, as shown below in **Figure 6.2.1-3**, follows a similar shape to the two previous designs. However, it makes use of a system to rotate the legs, hinged at the base, out and downward. Once landed, with the help of an onboard gyroscope, the legs will be able to move independently to change the angle of the payload as needed. To achieve the rotation of the legs, either a servo motor and gear train system or linear actuators will be needed. The pros and cons of which are discussed below in Section 6.2.9.

Pros:

- Active leveling system
- Reduced diameter
- Large interior for electronics

Cons:

- Moderately Expensive
- Complicated electronic system

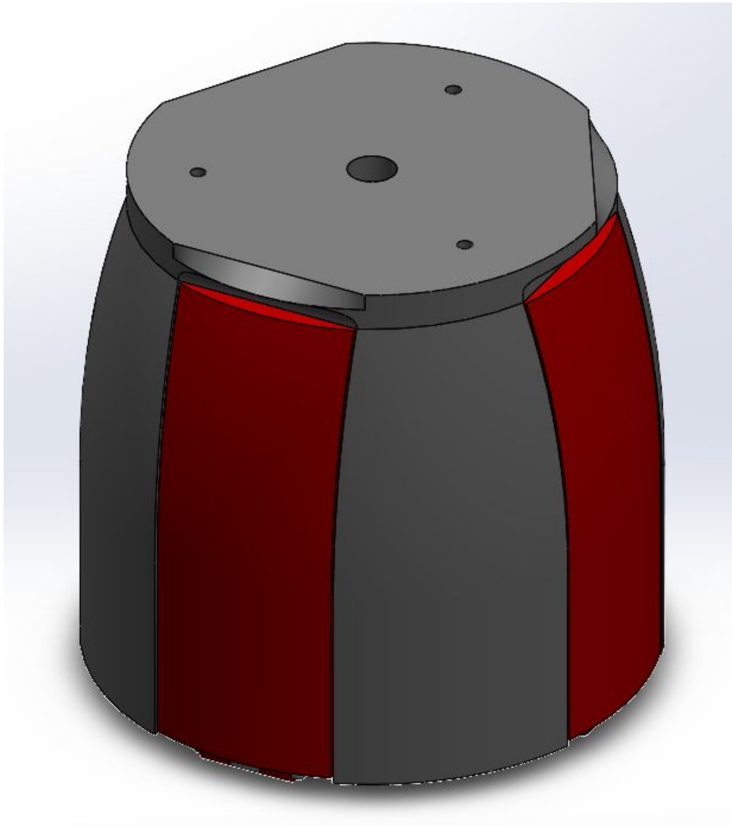

Figure 6.2.1-3 Actively-Stabilizing Legs

6.2.2 Payload Structure Material

The structure of the payload is required to hold all contents inside safely and therefore, be impact resistant to the landing impact and the parachute deployment impact. In order to pick the correct material, a decision matrix was made to pick a material that was light, inexpensive, and feasible to manufacture. Due to the unique geometry associated with the payload, the team decided it would be most feasible to 3D print the main structure.

Since there are a multitude of 3D printing materials available, the team is planning to perform various physical tests to aid in determining the best filament to use. Shown below in **Table 6.2.2-1**, is a decision matrix describing the research done for various common filaments.

The filaments will be compared based on their printing feasibility, weight, cost, and impact resistance. The expected kinetic energy the payload will have to endure was found to be 3.39

joules. This was done using the expected weight of the payload and its terminal velocity, via a calculator from *fruitychutes.com*, as shown below in **Figure 6.2.2-1**.

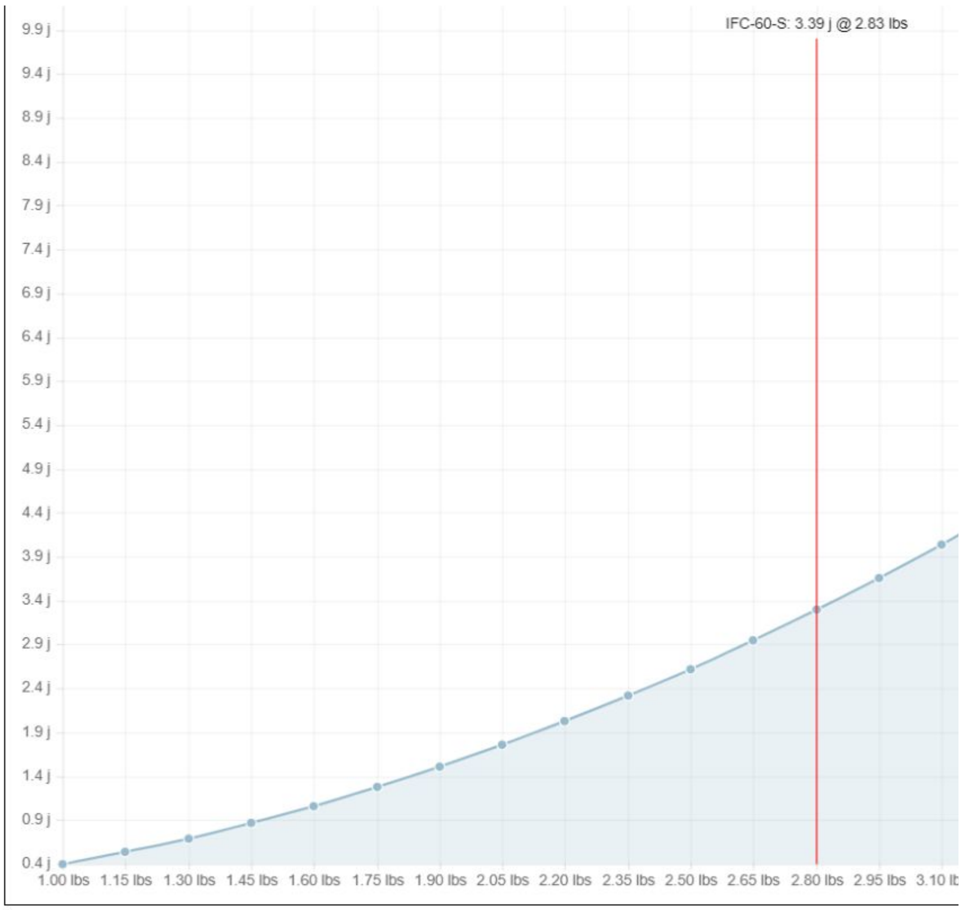

Figure 6.2.2-1 Expected Kinetic Energy vs. Weight

Table 6.2.2-1 Payload Trade Matrix

		Option #1		Option #2		Option #3		Option #4		Option #5	
		Hatchbox PLA		PLA Nano		Overture PETG		Nylon 12		NylonX	
Criteria	Weight Factor	Utility Value	Weighted Value	Utility Value	Weighted Value	Utility Value	Weighte d Value	Utility Value	Weighted Value	Utility Value	Weighted Value
Feasibility to print	4	10	40	8	32	7	28	4	16	4	16

Weight	7	6	42	5	35	7	49	9	63	10	70
Cost	5	7	35	5	25	6	30	3	15	2	10
Impact Resistance	8	5	40	7	56	8	63	9	72	10	80
Weighted Total		157		148		170		166		176	
Summary		One of the easiest filaments to print and inexpensive, but least impact resistant		Heaviest filament, but higher on impact resistant.		Expected choice for payload if able to absorb impact.		Harder filament to print, but impact resistant is promising.		Light and most impact resistant, but expensive and hard to print.	

6.2.3 Micro Controller Alternatives

The microcontroller is the component through which all other electronics will connect and communicate. For this reason, it was important to pick one that is able to properly accommodate every other component. It was also important that the board have access to an extensive coding library to ensure the system can be properly programmed and work reliably.

The first choice for this purpose was the Arduino Uno, as most of the team had past experience with this device. The main concern with picking the Arduino Uno was the processing capability, as well as being able to send data to the cloud to access from the ground control. Its smaller size was a benefit, but since its storage capabilities limited the team's ability to send data to the cloud it was no longer considered.

Pros:

- Small Board
- Easy to Use
- Easily accessible documentation
- Lots of add on compalabilites

Cons:

- Low storage
- Low processing power
- Limited ports

Figure 6.2.3-1 Arduino Uno

Another microcontroller system that was considered was the Raspberry Pi 4. This alternative is another widely used device, allowing the team access to a large public library of codes to use as a reference when programming the system. The additional computing power of the Pi allows it to overcome the pitfalls of the Arduino. However, this board is very large, so the design of the payload would need to be specifically shaped in order to accommodate it and simultaneously stay within a 6 inch diameter requirement as set by the payload integration system.

Pros:

- Powerful processor
- Integrated SIM card slot for wireless data transmission
- Integrated camera ports
- High modularity and customization

Cons:

- Large size

Figure 6.2.3-2 Raspberry Pi 4 Model B

Another Raspberry Pi product under consideration was the Raspberry Pi Zero, a much smaller and simplified version of the 4 model, with all the processing capabilities. One of the biggest issues instantly found though, was how many ports were available as well needing to solder them, which was a concern as they would need to survive the landing impact, which may not be reliable without professional soldering.

Pros:

- Small
- Powerful processing capabilities

Cons:

- Not enough ports for cameras
- Soldering concern

Figure 6.2.3-3 Raspberry Pi Zero W

6.2.4 Camera Alternatives

Initial design of camera implementation made use of MIPI ports on the microcontroller to transfer image files. In order to produce a 360 degree panoramic photo 3 cameras will be needed to take simultaneous photos. The resulting files would then be stitched together to produce the final photo. Because the micro controllers we investigated had only one MIPI port an adapter is required to connect more than 1 camera. An adapter found uses a set of pins on the microcontroller as well as the main MIPI to over multiple usable MIPI ports.

Pros:

- Inexpensive
- 180-degree field of view

Cons:

- Requires adapter
- Takes up a lot of pins

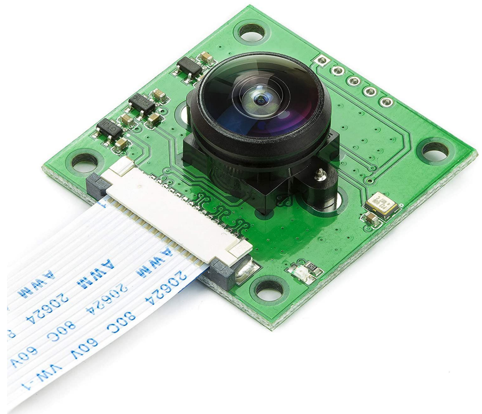

Figure 6.2.4-1 Arducam Fisheye Camera

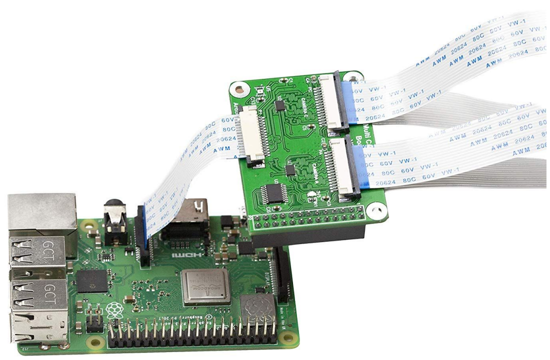

Figure 6.2.4-2 Arducam Multi Camera Adapter

Another camera alternative was one that uses USB connections rather than MIPI ports. This removed the need for an adapter module, as the Raspberry Pi 4 had enough USB ports to accommodate 3 cameras. However, this camera was larger and significantly more expensive than the previous consideration.

Pros:

- USB connector eliminated need for adapter
- 180-degree field of view
- Easy to program

Cons:

- Expensive
- Large mounting plate

Figure 6.2.4-3 Fisheye Lens with USB Connector

The last camera alternative discussed was a 360 degree panoramic camera. A 360 degree camera will be able to complete the payload objective of taking a panoramic photo in one cycle. Whereas other camera alternatives require multiple cameras and photo stitching to produce this photo. A major drawback to this choice though is that it would need to be shielded or housed in the internal payload structure until the payload has required to protect against any damage from the initial jettison and descent. This means that a method for deploying the camera at landing is needed; if the camera fails to deploy no picture will be obtained and the mission objective will be considered failed.

Pros:
- Can produce a panoramic photo without any kind of post-processing

Cons:
- Expensive
- Requires extra protection
- Large

Figure 6.2.4-4 360 degree camera

6.2.5 Altimeter

An altimeter would be used to tell the system when to start the auto leveling sequence. This ensures that the legs of the payload do not try to unfurl while inside the rocket, which would prevent proper deployment. The two distinctions between most of the altimeters were the communication protocol and accuracy of their readings. The options we were looking for were altimiters that used an I2C protocol in order to keep as many pins open as possible, and one that would provide a high degree of accuracy. Since the system is required to have a GPS, the team considered using one in place of an altimeter, however it was discovered during research that GPS systems were quite inaccurate when used in this way, so that option was discarded.

The MPL3115A2 was a good option due to its high accuracy and low price. However, its documentation was not easily found. While it could suit the team's needs, more work would need to be done to understand how to incorporate it into the system than was necessary with other available options.

Pros:

- Accurate to ± 1 foot
- Inexpensive
- I2C Protocol

Cons:

- Hard to find documentation

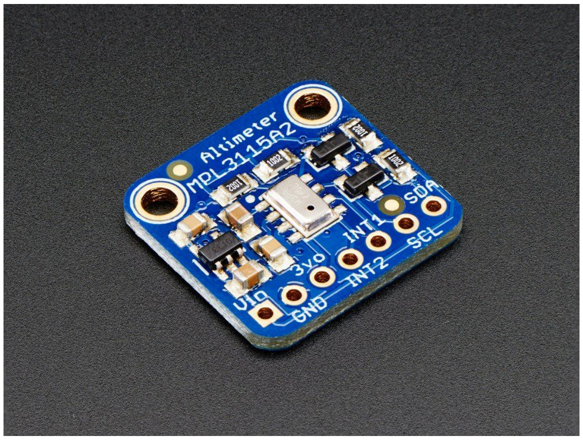

Figure 6.2.5-1 MPL3115A2 Altimeter

The BMP388 was another option. This altimeter was a popular board used by hobbyists, so the documentation and support for this board was enticing. With both I2C and SPI, the communication protocol was not something to worry about.

Pros:

- Small
- I2C communication
- Lots of Documentation
- Inexpensive

Cons:

- No on board altitude calculator

Figure 6.2.5-2 BMP388 Altimeter

6.2.6 Gyroscope and Accelerometer

In order to do an automatic leveling command within the ±5 degree required, a combination of a gyroscope and accelerometer were needed. As with the altimeter, the communication protocol was an important factor to consider and an accurate reading.

The first option is Adafruit's 9 degree of freedom IMU board. Although this product looked very promising on the many features it could offer, it did not have the features we were looking for. The board's calibration for accurate reading was great to get accurate readings, but a board already calibrated with accurate readings would be superior. The documentation for this product was also less popular.

Pros:

- Lots of features
- Calibration feature for sensors
- Multiple communication protocols

Cons:

- Lack of documentation

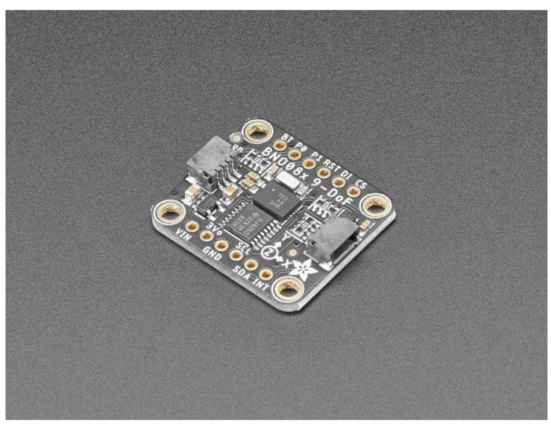

Figure 6.2.6-1 Adafruit 9-DOF IMU Board

Another gyroscope and accelerometer option is the MPU6050. This board is small, runs on I2C protocol, and provides XCL and XDA pins to expand to more I2C sensors. The board is able to transmit accurate positioning data to the Raspberry Pi for data interpretation.

Pros:

- 6-axis accelerometer and gyroscope

- Uses I2C protocol

Cons:

- No longer in production from manufacturer

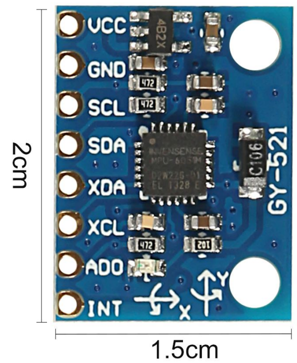

Figure 6.2.6-2 MPU6050 Gyroscope and Accelerometer

6.2.7 GPS Module

Since our payload is planned to separate from the rocket, we are required to have a tracking system on the payload. For the GPS, we are looking for something as simple as a plug-and-play device. Since the GPS would only be used to find the payload if lost, a GPS with an accurate reading was required within +-100 feet is desired. Another feature we were looking for was one that would be able to connect to multiple satellites (3+) in case of a malfunction with one satellite.

This GPS choice is the BN-880, as it is well used by the drone community. This means it should be accurate enough for our payload. This was perfect since the accuracy stated was ±6 feet. The documentation for this device was easily found since it was so popular.

Pros:

- Low power consumption
- Accurate positioning
- Lots of documentation

Cons:

- No included antenna
- No mounting holes

Figure 6.2.7-1 BN-880 GPS

Another GPS option was the Waveshare 4G/LTE module with GPS antennae. This option is beneficial because it allows for GPS tracking as well as data transmission in one device. This is done through an LTE Module that can use a SIM Card to transmit data to the cloud, and includes a GPS Module with antenna to also give us real live tracking of the payload. The reason for choosing this board was that it combined two of the boards that were needed on the payload, reducing the price, size, and weight. There was also documentation that was easy to find and use to incorporate with the raspberry pi.

Pros:

- Easy to find documentation
- Lighter, inexpensive, and smaller that using two boards
- Easy to integrate

Cons:

- GPS hat takes up more space
- LTE data may be unreliable if signal is weak

Figure 6.2.7-2 GPS Module and Transmitter

6.2.8 Motor Controller Alternatives

Several methods for controlling the motors necessary for the leveling system were discussed during our research. The first method utilizes relays to control signals sent to each individual motor. This would require a power distribution board to give power to each relay separately, it would also require each relay to be connected to the central microcontroller separately.

Pros:

- Each motor can receive different signals and trigger time
- Actuators can receive regulated voltage directly from power distribution board through relays

Cons:

- Complex electrical system as each relay is independent.
- If one relay fails to work, payload will be unable to self sabalize as each relay is independent.

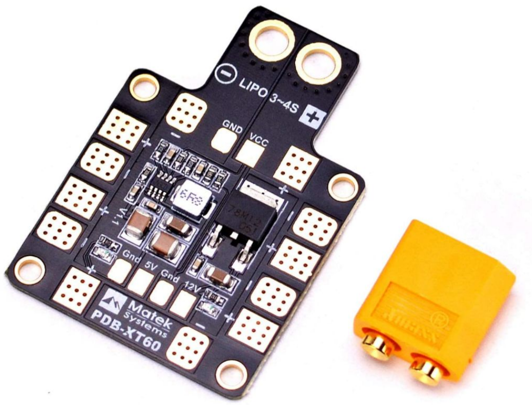

Figure 6.2.8-1 Power Distribution Board

Figure 6.2.8-2 Relay

A similar alternative method was proposed that used MOSFETs rather than relays to control signals sent to the motors. This method would save room and weight on the payload; the allocated room inside the payload is very limited so this is ideal for the overall internal structure of the payload.

Pros:

- Each motor can receive different signals and trigger time
- Motors can receive regulated voltage directly from power distribution board through relays
- Lightweight and small

Cons:

- Complex electrical system as each relay is independent.
- If one relay fails to work, payload will be unable to self sabalize as each relay is independent.

Figure 6.2.8-3 IRF740 MOSFET

A third option for motor control utilizes a 16 channel PWM servo driver with I2C interface. The driver board is able to be connected directly to an I2C hub that allows all devices that operate on I2C protocol to connect directly to the central microcontroller. Each channel on the driver can be controlled individually but only requires one power input to function.

Pros:

- Centralized motor control
- Each relay can be controlled individually
- Up to 4 motors can be powered from 1 source

Cons:

- Any mode of failure for the driver board causes failure of all motors

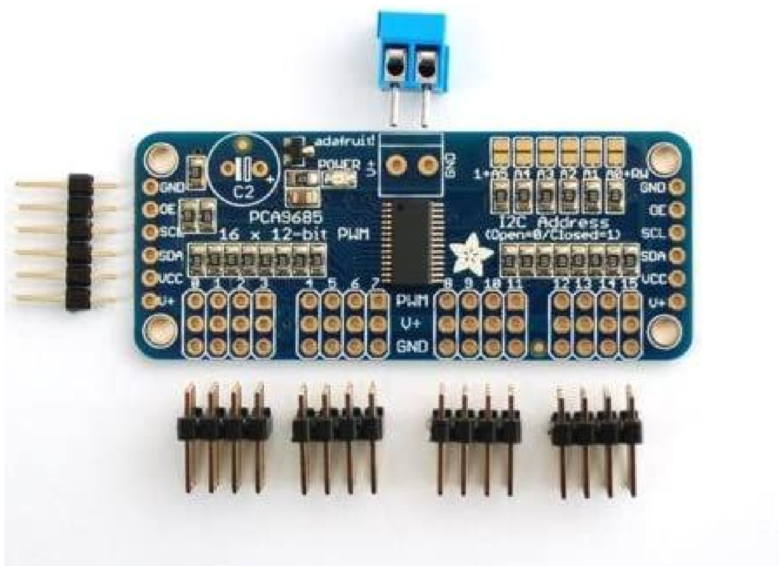

Figure 6.2.8-4 PWM Driver

6.2.9 Leveling System Alternatives

The payload system utilizes support legs that extend outward away from the core structure, in order to achieve balance. Achieving balance required the development of a leveling system focused on accurately opening and closing the support legs and leveling the structure.

One method for achieving this system was based on incorporating linear actuators that can extend and retract, thus, opening and closing the support legs as governed by the payload gyroscope for leveling. This is a simple and compact solution as the actuators do not require any additional hardware, such as gears, in order to function.

Pros:

- Less housing and control system space, and power supply required
- Direct contact and force application at the attachment location on the payload leg supports
- No other components or systems such as a gear train required for controlling the movement of the leveling system
- Allows for simple hinge-joint design incorporated at the base of the support legs, appropriate installation for current payload structure CAD model

Cons:

- Taller payload structure required for housing linear actuators vertically
- Actuators apply force at an angle resulting in limited leg rotation
- Leveling system for operating the payload leg supports relies heavily on the functionality of the hinge-joints

Figure 6.2.9-1 Linear Actuator

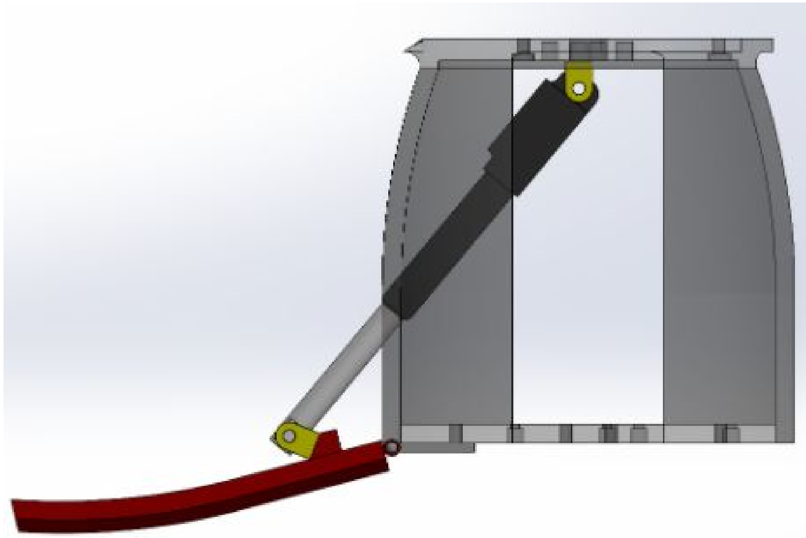

Figure 6.2.9-2 Linear Actuator Leveling System

Another method explored by the team involved the incorporation of servo motors along with gear trains for controlling the movement of the payload leg-support system. This system required a gear train, which drastically increases its size requirement when compared to the linear actuators, however, it allows for higher precision and greater rotation of the legs.

Pros:

- More precise leg-support movement through angular rotation controlled in degrees increments for driving gears
- More rotation ability available for closing and opening of payload leg supports

Cons:

- Large housing space required for servo motors and gear train
- More power supply and control system housing space required as creating a uniform connection between all four servos requires several electronic components
- Higher chance of system failure as gear-driven systems require precise gear ratios for ensuring large lifting capacity output by servo-motor driven gear train
- Difficult to incorporate in current payload structure design model because of payload size restrictions

Figure 6.2.9-3 Servo Motor

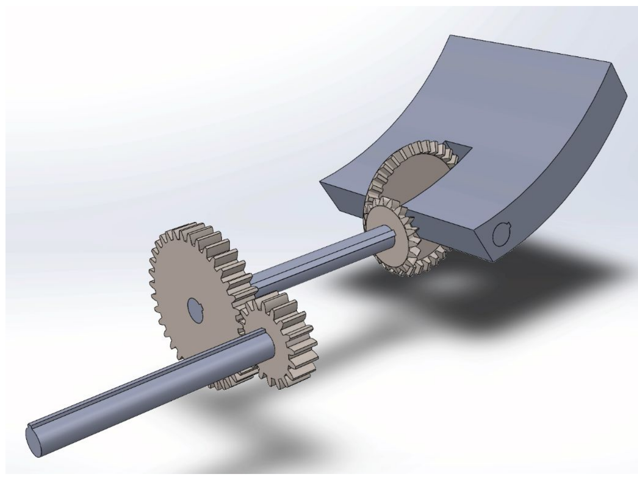

Figure 6.2.9-4 Servo Motor Leveling System

6.2.10 Batteries

The amount of mAh was the worry when picking the battery. Reasons to use other batteries would include the weight and discharge rate they offer. In order to pick the correct battery a chart was made with each of the electronic components to take into account the amperage each component would take.

Table 6.2.10 -1 Leading Electronics' Power Requirement

Name	Amperage (A)	Time being used (h)	Storage (mAh)
Raspberry Pi	0.05	4	200
Linear Actuators	.46 while used 0.0033 on idle	1/30 while used 4 on idle	14 while used 13.2 on idle

MPU6050	.0036	4	14
BMP388	.000003	4	0.01
PWM Driver	0.03	4	120

The battery chosen for the payload will be chosen using the amount of mAh summed up and add extra mAh for security. This leads to experimenting with batteries with at least 1000mAh. The type of battery chosen will be LiPo. The reason for this is because it is well known by the drone community to be as light as possible, while giving more power than other battery types.

6.2.11 Parachutes

The options for parachutes stem from requirements such as weight, size, desired payload descent speed, and parachute size. For the purpose of payload descent, the team focused on two different types of parachute shapes, toroidal, and octagonal. The team decided that a downward velocity of 4 meters per second would be targeted to achieve a 10.27 N-m or 7.6 ft-lb kinetic energy upon touchdown. This is based on a payload weight of 1.28 kg or 2.83 lbs. Seeing as how this value is far below the 75 ft-lb requirement for the rocket, the payload should avoid any damage upon landing. Below is a table for different options of parachutes for the above requirements.

Table 6.2.11 -1 Parachute Options

Toroidal	Octagonal
60” Iris Ultra Parachute from Fruity Chutes	60” Nylon Parachute from Sunward Group ltd.

<table>
<tr><td>
</td><td></td></tr>
<tr><td>Pros:
- Correct diameter for desired descent speed.
- Carrying capacity (19 lbs.)
Cons:
- Heavy (10.82 oz)
- Is not very size appropriate.</td><td>Pros:
- Correct diameter for desired descent speed.
- Lightweight (4.71 oz)
- Carrying capacity (10 lbs.)
- Takes up less space
Cons:
- Thinner material, more susceptible to damage.</td></tr>
</table>

6.3 Leading components

In this section, we discuss the leading electronics chosen to be used for the payload. We will explain why we chose these over the system alternatives.

6.3.1 Leading Payload Design

The leading payload design is the actively-stabilizing leg system as shown above in Figure 4.2.1-3. This design was ideal because it allows the system to change its orientation based on its landing location. Compared to the more passive stabilizing system, this design is more reliably able to meet the 5 degree offset requirement. It is also cheaper, and easier to manufacture and program than the quadcopter based design. A majority of the payload will be manufactured using 3D printing utilizing NylonX if needed. Additional hardware, such as screws and nuts, necessary for assembly of the payload, will be purchased from the hardware supplier McMaster Carr. In some instances, a screw and nut fastening system will not be possible such as hard to reach areas or where the screw will fully penetrate the two sections to be binded. In these cases, a threaded aluminum insert, as shown below in **Figure 4.3.1-1**, will be placed into a pre-made hole in the plastic which will then expand as a screw is threaded into it, locking it into place, securing the connection. Aside from the main housing and the four legs used for leveling, a separate housing for the cameras will need to be 3D printed. This will contain holes for the camera lenses to be placed through, and be placed at the top of the payload to avoid obscuring the cameras. This housing will be attached to the main body using the screw and threaded insert method mentioned above. Additionally, there are holes cut into the top of the camera housing which allows for the parachute cables to be threaded through and tied off in order to secure the parachute to the payload. A full model and dimensions of each 3D printed component is shown below in Section 4.4.

Figure 6.3.1-1 Aluminum Threaded Insert

6.3.2 Leading Micro Controller

The current leading choice for the central microcontroller is the Raspberry Pi 4 model B. This was chosen for its ease of use and extensive developer tool catalogue as well as for its multiple USB ports and pins. With this microcontroller a design has been created that utilizes all 40 pins, I2C protocol, and 3 USB ports. This design streamlines the input/output needed for all components to communicate as needed. Using I2C protocol allows the measurement devices to easily send output data to the PI where it can interpret and send proper input signal to operate the linear actuators needed for self stabilization.

6.3.3 Leading Camera

The leading camera choice is a 180 degree fisheye USB camera, implementation into the rocket will use 3 of these cameras. It was found that by using the multiple USB's available on the Raspberry Pi 4 instead of MIPI ports or pins the overall circuit for the payload could be simplified. Using a USB camera also simplifies programming as it has an easy to use consumer interface. Using multiple USB ports eliminates the need for any additional adapters unlike other mentioned alternatives which use an adapter to give more MIPI ports.

6.3.4. Leading Altimeter

The BMP388 was the best choice to use for an altimeter. It was a small with low power consumption, yet still provided precise measurements. It also had tons of documentation that could be used on its I2C protocol. This altimer was the simplest altimeter that met the requirements needed on the payload.

6.3.5 Leading Gyroscope and Accelerometer

The MPU 6050, like the BMP388, was a simple gyroscope and accelerometer to use with tons of documentation. The plug and play feature was used by a teammate before and suggested to use on its I2C protocol. This board had everything needed with little cons, small, light, low power consumption, precise, and easy to use.

6.3.6 Leading GPS Module and Transmitter

While looking for options on transmitting data back to ground control, this board was found that was optimal for our use. It is a LTE Module that can use a SIM Card to transmit data to the cloud, and includes a GPS Module with antenna to also give us real live tracking of the payload. The reason for choosing this board was that it combined two of the boards that were needed on the payload, reducing the price, size, and weight. There was also documentation that was easy to find and use to incorporate with the raspberry pi.

6.3.7 Leading Motor Control Method

The current leading method for motor control utilizes a 16 channel PWM servo driver with I2C interface. The driver's ability to individually control each channel, and therefore each motor, while only requiring one power input to function. This is of great benefit because unlike the alternative methods this centralizes motor control to one controller. Whereas the alternatives utilized relays and MOSFETs as a singular motor controller.

6.3.8 Leading Leveling System

The leading leveling system involves the use of four linear actuators. This system was preferred over the servo motors for a few reasons. First, the linear actuators are more compact. Servos motors would require the use of a gear train in order to increase the torque offered and change the direction of rotation in order to properly move the legs. Second, the linear actuators are more reliable. Another major issue with the gear train is that it is likely to fail when experiencing the impact of landing, as the gear may no longer mesh well, the actuators do not have this issue. The third reason the linear actuators would perform better than the servo motors is design feasibility. The actuators simply need to be selected for the amount of force they can deliver, while servo motors would require the design of a gear train which drastically overcomplicates the overall payload design process.

Once deciding on the use of linear actuators, the amount of force they are required to produce had to be calculated. This was done by analyzing the free-body diagram of the leveling system in its most critical state, as seen below in Figure 4.3.8-1. The maximum force required of the actuators occurs when the payload has landed completely on its side. In order to level the payload, the actuator must be able overcome the weight force of the payload, acting at its center of gravity.

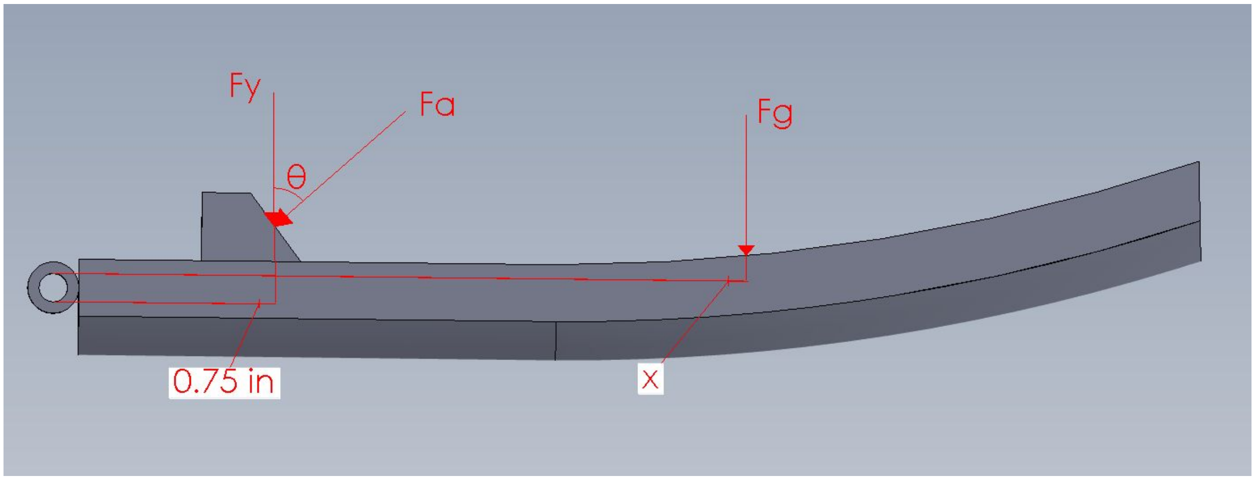

Figure 6.3.8-1 Leveling System Free Body Diagram

In **Figure 6.3.8-1** above, Fa is the force delivered by the linear actuator, θ is the angle the actuator makes with the horizontal, Fy is the resulting vertical force, Fg is the weight force of the payload, and x is the distance to the center of gravity from the axis of rotation. Through an iterative process, the linear actuator force and resulting maximum allowable center of gravity distance were determined via the following equations.

$$Fy = Fa * sin(\theta)$$
$$Fy\,(0.75) \geq Fg * x \Rightarrow x = Fy\,(0.75)/Fg$$

Based on the design geometry, θ was determined to be 30°. Also, the total weight of the payload was determined based on the necessary electronic weights, in addition to the mass of the 3D printed components. The weight of the printed parts was found from multiplying the density of the NylonX filament, 0.036 lb/in^3, by the volume of the parts given by the SolidWorks models. The total weight of the payload was determined to be 2.83 lbs. An actuator that can provide up to 18 lbs of force was chosen, and by using the above equations, the center of gravity distance, x, was found to be 2.39 in. As long as the actual center of gravity is below this value, the actuator should be able to lift the payload.

6.3.9 Leading Parachute Option

The leading parachute option favors a 60 inch octagon-shaped nylon parachute from Apogee Components, manufactured by Sunward Group Ltd. This parachute has a maximum capacity of

10 lbs., more three times the expected weight of the payload. This parachute is also the more lightweight and smaller volume option, two important characteristics when factoring in the spatial constraints of the payload bay. The parachute also provides an expected descent velocity of around 4 meters per second as calculated from the following formulas.

$$V = \sqrt{(2 \times g \times m)/(\rho \times C_d \times S)}$$

Where V is the downward velocity of the payload, g is the acceleration due to gravity (9.81 m/s^2), m is the mass of the payload in kilograms, ρ is the density of air approximated to be 1.225 kg/m^3, C_d is the coefficient of drag estimated to be 0.75, and S is the area of the parachute canopy.

6.4 Payload Models and Dimensions

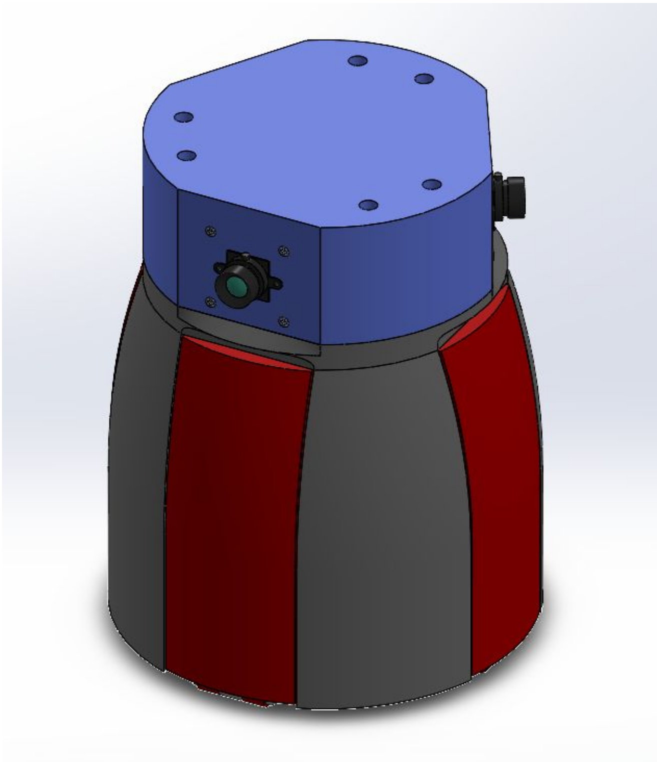

Figure 6.4-1 Isometric View of Payload in Closed Position

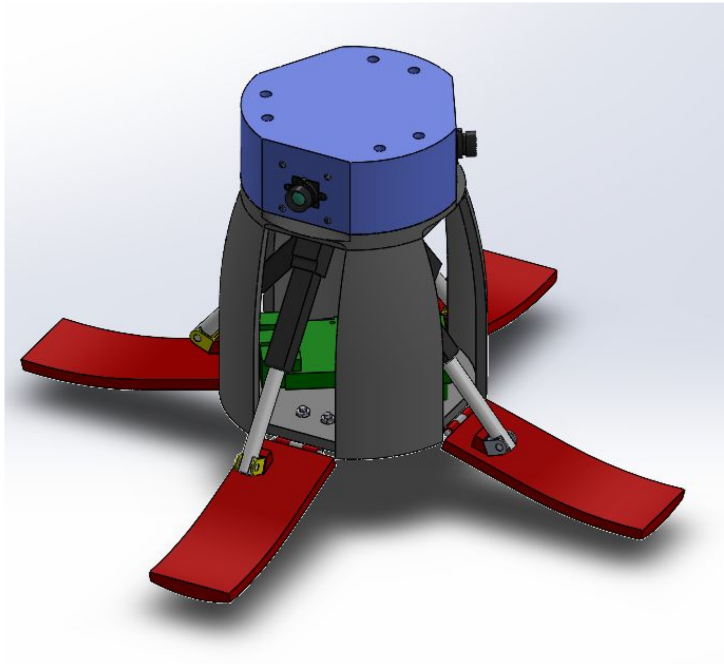

Figure 6.4-2 Isometric View of Payload In Open Position

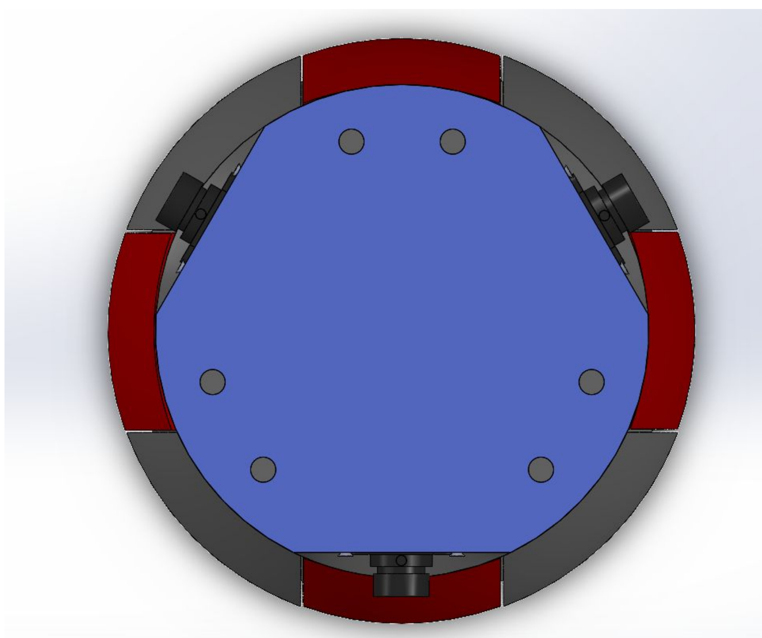

Figure 6.4-3 Top View of Payload

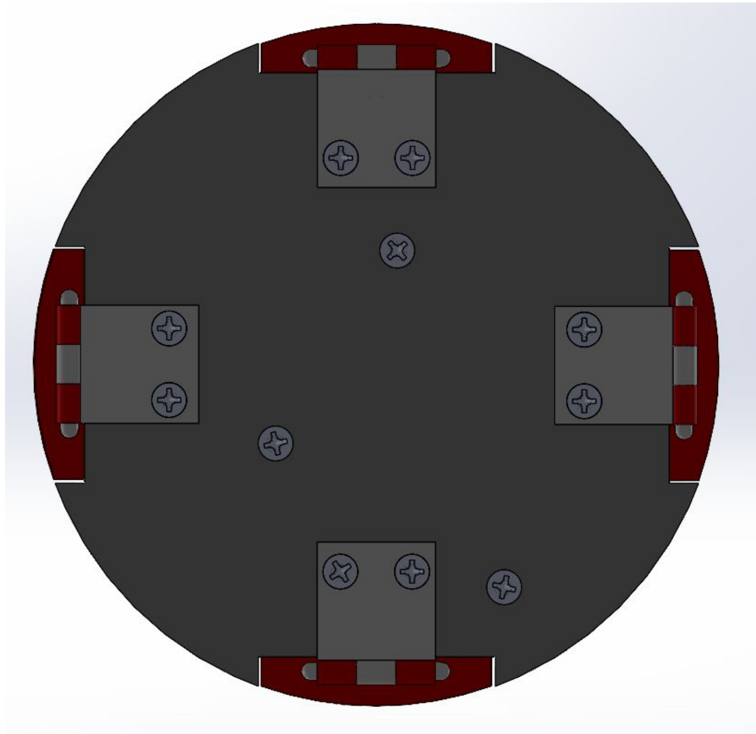

Figure 6.4-4 Bottom View of Payload

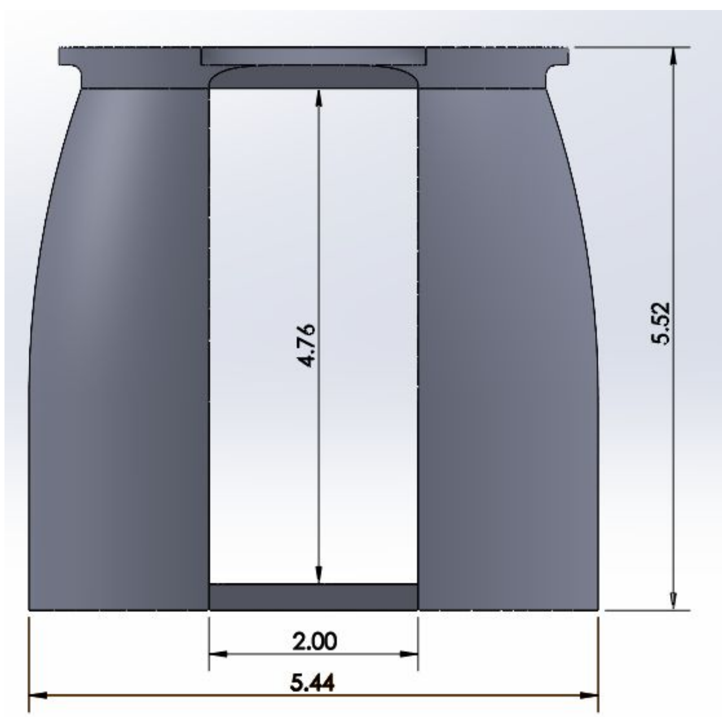

Figure 6.4-5 Payload Housing Side View Dimensions

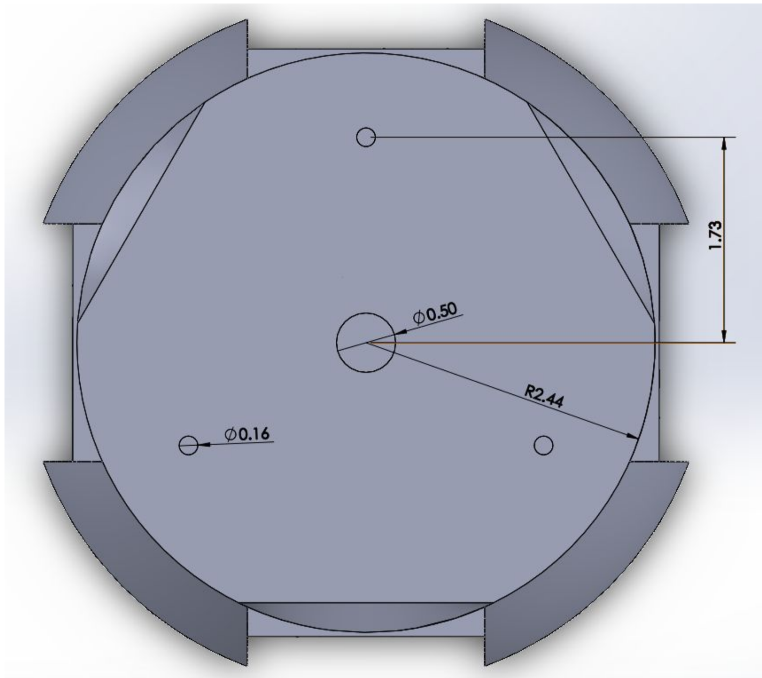

Figure 6.4-6 Payload Housing Top View Dimensions

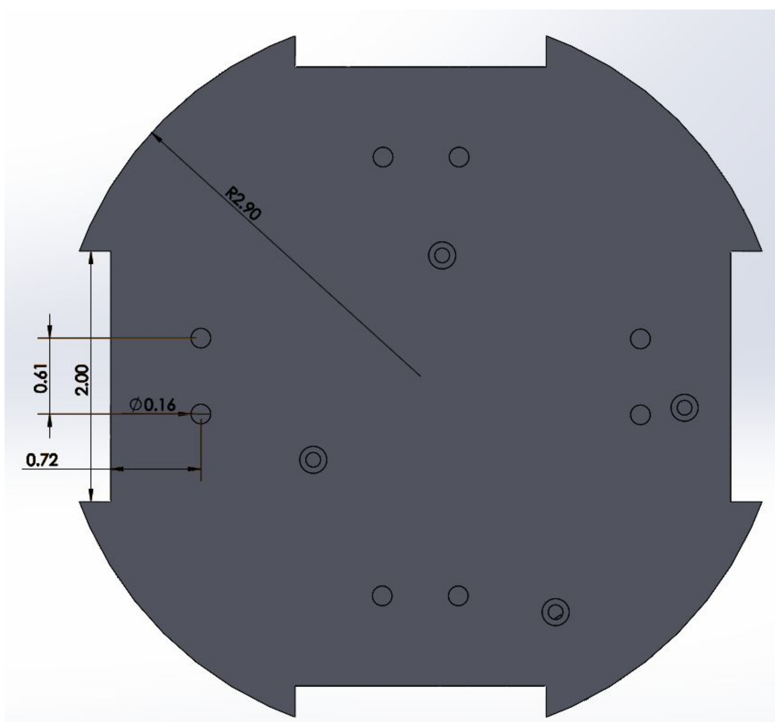

Figure 6.4-7 Payload Housing Bottom View Dimensions

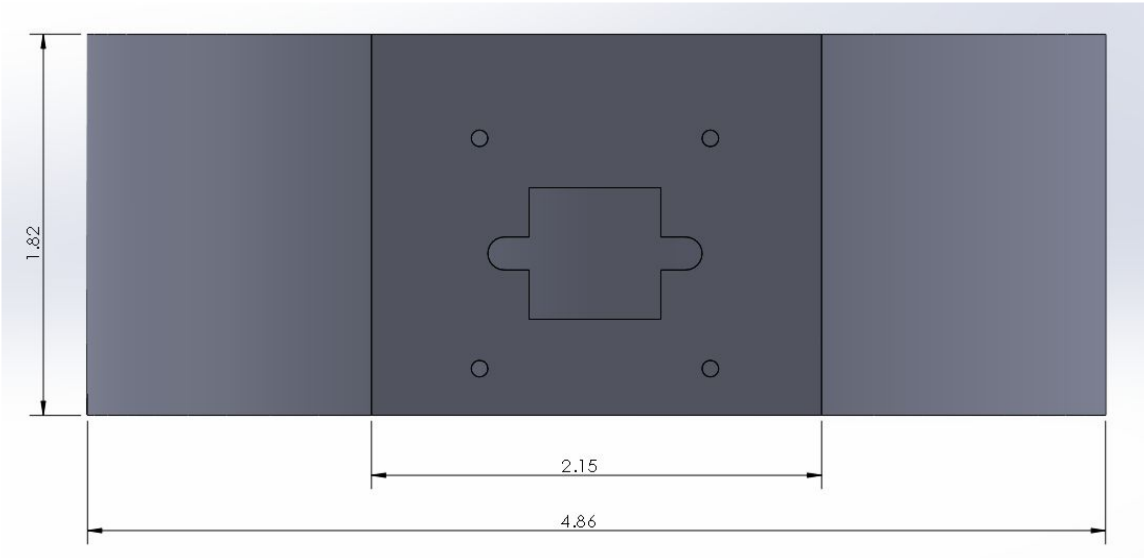

Figure 6.4-8 Camera Housing Side View Dimensions

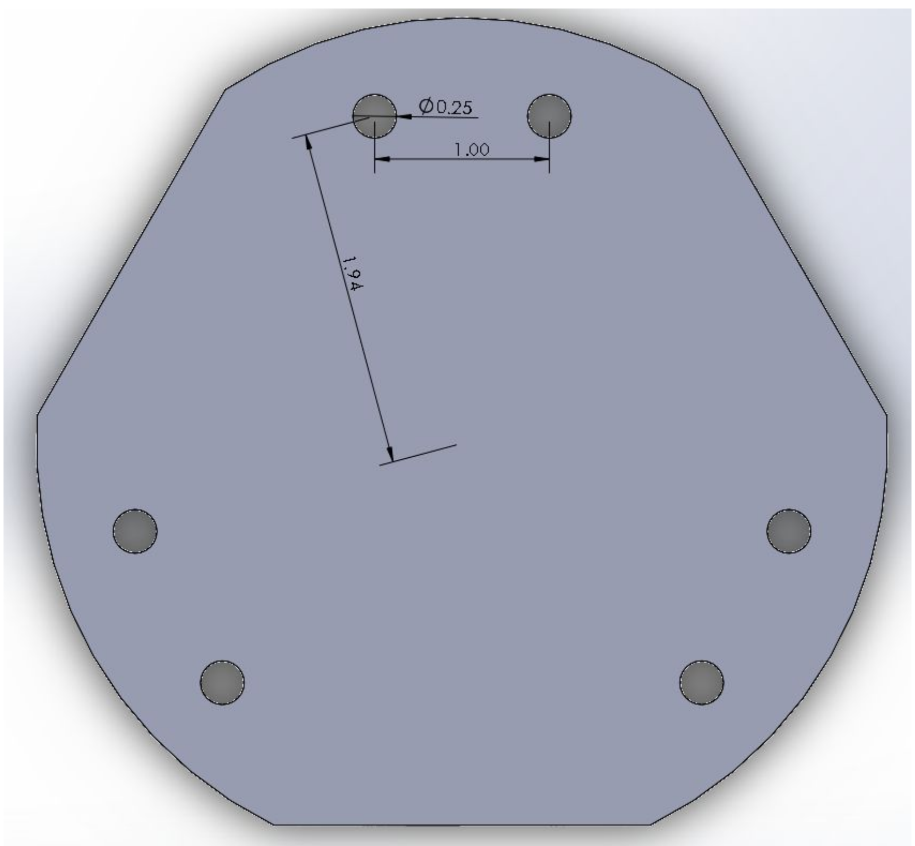

Figure 6.4-9 Camera Housing Top View Dimensions

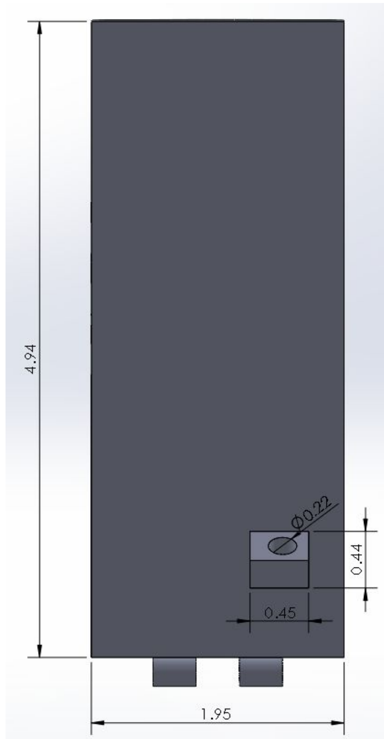

Figure 6.4-10 Stabilizing Leg Front View Dimensions

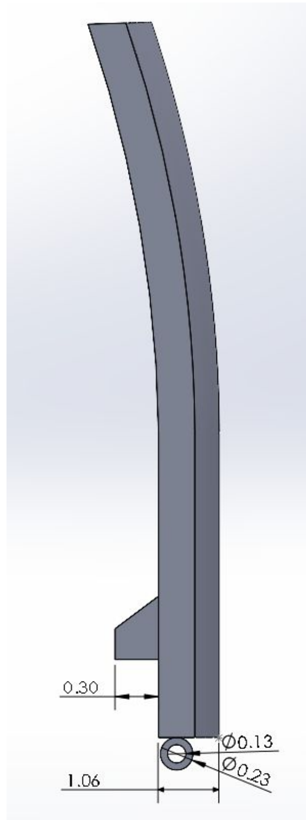

Figure 6.4-11 Stabilizing Leg Side View Dimensions

6.5 Proposed Payload Circuit

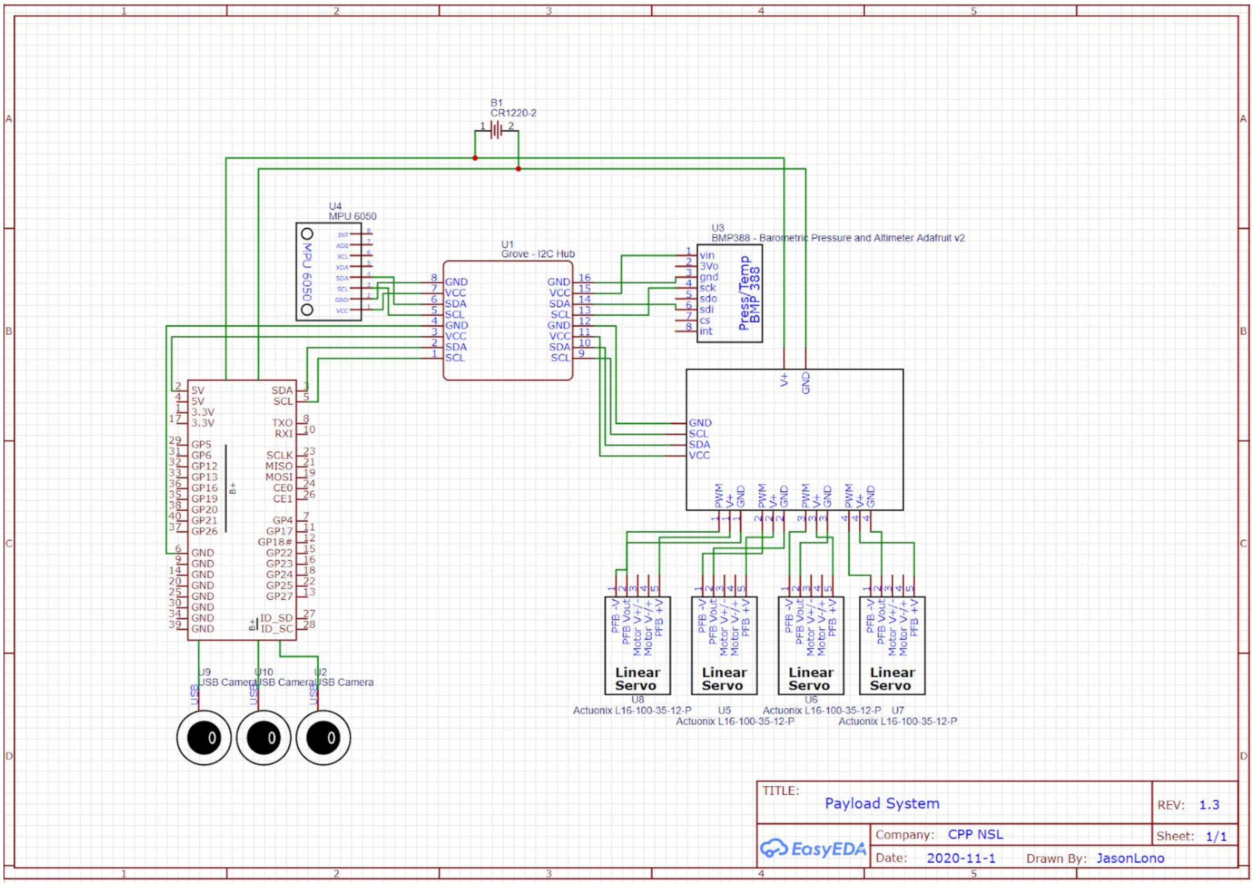

Figure 6.5 - 1 Payload Electrical Design

6.6 Payload Integration System Summary

The payload integration system selected for the mission consists of a nose cone separation at 550 feet followed by a CO2 powered ejection of the payload via the payload barrel. The electronics chosen for the control system include an AT-MEGA 328P powered nano micro-controller, BMP 388 barometric altimeter sensor, 6-axis MPU 6050 gyroscope and accelerometer, Hall effect sensor, 12 volt solenoid valve, 12 volt locking solenoids, and mosfets. Several risk mitigation strategies are to be incorporated into the system code to ensure detection of the deployment altitude window and ensure payload ejection. Success of the system will be determined by the reliability of the nose cone deployment and ability to eject the payload without any catastrophic entanglement or collisions.

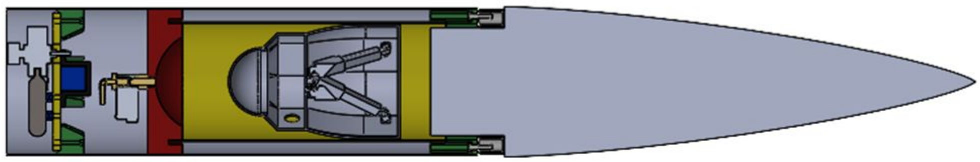

Figure 6.6 - 1 Payload Integration System

Table 6.6 - 1 Payload Ejection Trade Matrix

Payload Ejection Method Selection					
		Option #1		Option #2	
		Spring launch		CO2 ejection	
Criteria	Weight Factor	Utility Value	Weighted Value	Utility Value	Weighted Value
Feasibility	10	6	60	9	90
Aerodynamic forces	9	9	81	8	72
Collision Avoidance	8	7	56	9	72
Entanglement avoidance	9	5	45	8	72
Redundancy	10	1	10	3	30
Moving parts	7	3	21	6	42
Weighted Total		273		378	

Table 6.6 - 2 PLI Nose Cone Ejection Trade Matrix

Nose Cone Ejection System					
		Option #1		Option #2	
		Single Servo Locking Ring		Dual Solenoid & Multi Release Spring Design	
Criteria	Weight Factor	Utility Value	Weighted Value	Utility Value	Weighted Value
Feasibility	10	7	70	9	90
Aerodynamic forces	9	5	45	8	72
Collision Avoidance	8	5	40	9	72
Entanglement avoidance	9	5	45	8	72
Redundancy	10	1	10	2	20
Moving parts	7	3	21	6	42
Weighted Total		231		368	

6.6.1 Payload Integration Retention Design Summary

The payload retention design is built into the payload integration system via the payload barrel. The payload barrel is a multi-functional component in the system as it serves to prevent collisions, entanglement, serve as the payload retention system and is fundamental to the ejection protocol. The payload will sit within the payload barrel in between the nose cone shoulder and its parachute. A 3D printed gas diffuser will be used as a cap behind the parachute to control the flow pattern of the gas during deployment and also limited the travel of the payload along the axis of the rocket.

6.7 Payload Integration Technical Approach manufacturing

The Payload Integration system will be manufactured using 3D printing technology. All the components designed for the integration system were specified to not exceed the manufacturing capabilities of the available 3D printers. A main concern was limiting the amount of support material in builds. This would be beneficial in reducing print times between prototype iterations, decreasing waste material and also minimising the amount of post-print touch up work required. Surface finishes will be accomplished via sanding to ensure minimal frictional forces between the payload and the integration system. Furthermore 3D printed parts will be subjected to heat treatment to ensure layer adhesion and increase stress tolerance. Due to the nature of 3D printing multiple printing parameters will be tested to decrease print time, decrease weight and increase strength. The primary material used will be PLA filament with plans to upgrade structural parts to ABS filament once prototyping is complete.

6.8 PLI System Alternatives

Several payload deployment designs were considered to complete the jettison requirement at the altitude range of 1000 to 500 feet. The primary alternative to CO_2 ejection was a spring loaded ejection mechanism. The spring design called for the use of a piston like component to slide along the fuselage via spring force. The expansion of the spring would ultimately eject the payload. This alternative was abandoned after concerns of the payload parachute being entangled or pinched were presented due to the tolerancing which the available manufacturing machinery could offer.

6.8.1 PLI Microcontroller Alternatives

Multiple micro controller candidates were considered to autonomously operate the payload integration system. The first option was the Arduino Uno which offers plenty of online resources and a vast amount of onboard capabilities. The Adafruit feather modules were also considered due to their small and lightweight configurations. The two vastly different form factors and capabilities required a deeper investigation into the functionality and compatibility with the possible sensors that were being considered for the payload ejection window detection.

6.8.1.1 Arduino Uno

The Arduino Uno microcontroller was the first consideration given its computing power and abundance of online resources. This choice also offers a large selection of compatible sensors which are readily available on the market. Ultimately the Arduino Uno was deemed too large and excessive for this application and abandoned as a favorable option.

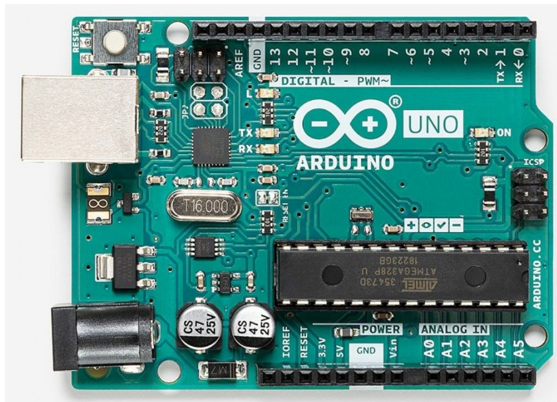

Figure 6.8.1.1 - 1 Arduino Uno

Pros:

- Easy to Use
- Easily accessible documentation
- Lots of add on compatibility
- Lots of Ports

Cons:

- Quite Large Size
- Too many features which are not needed

6.8.1.2 Adafruit feather

The Adafruit feather series boards were compact size and form factor. The ability to have integrated add ons such as bluetooth, wifi, or data logging capabilities were considered as potential benefits but were ultimately deemed unnecessary and a potential roadblock in development. The lack of an onboard 12 volt regulator was also seen as a potential risk due to the mandatory addition of a power regulator into the circuit. This addition increases the potential of failure via disconnection from the circuit due to poor assembly or component failure.

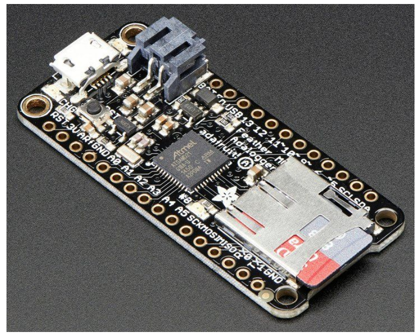

Figure 6.8.1.2 - 1 Adafruit feather M0 data logger

Pros:
- Onboard data storage capabilities
- Small and lightweight

Cons:
- No onboard 12v power regulator
- Lacks processing power

6.8.2 CO2 Cartridge Alternatives

The discharge load of the CO2 cartridge chosen for the application are 12g, 16g, 20g or 25g. All alternatives considered are classified as emergency CO2 tire refills used for cycling and provide quick and powerful delivery of the pressurized gas.

6.8.2.1 12 Gram CO2 Cartridge Alternatives

While at first the 12 gram cartridge looked promising because of its lightweight and minimal volume occupancy. After testing it was noted that the insufficient pressure and inability to use multiple times disqualified this cartridge size.

Figure 6.8.2.1 - 1 12 Gram CO2 Cartridge

Pros:

- Small and Light
- Threaded for easy use

Cons:

- Lacks pressure
- Lacks reusability
-

6.8.3 CO_2 Solenoid Release Valve Alternatives: Brass Gas Solenoid Valve - 12V - 1/2 NPS

The Adafruit solenoid valve was considered for this application due to its availability and power required to operate. The 12 volt power requirement allows for every power distribution which determines our power supply. Due to the microcontroller being 12 volts it was decided that all other electronics operate at this voltage to simplify power distribution and avoid auxiliary components.

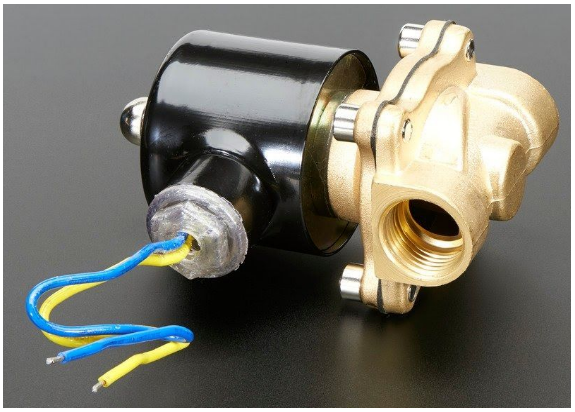

Figure 6.8.3 - 1 Adafruit Brass Gas Solenoid Valve - 12V - 1/2 NPS

Pros:

- 12 volt
- Threaded ½ NPS - female

Cons:

- Large compared to other options
- Heavy compared to other options

6.8.4 System Battery Alternatives: Venom Fly 30C 3S 1300mAh 11.1V LiPo Battery

The need for a power source to power our entire Payload integration system at first led us to go the venom fly lipo battery, because of previous experience with the battery. However the battery did not meet the idle time needed to meet the NASA student handbook lunch site idle time requirement.

Figure 6.8.4 - 1 Venom Fly 30C 3S 1300mAh 11.1V LiPo Battery

Pros:

- Compact size
- Light weight

Cons:

- Lack safety factor for required mAh

6.9 PLI Nose Cone System Alternatives

There were two systems considered that were similar to the selected system. One difference started with the solenoid selection. The other difference for the two options were the methods of locking fuselage and nose cone rings. One contained two solenoids on the nose cone locking ring and the pins of the solenoid would be used to lock fuselage and nose cone rings by entering the inner diameter section of the fuselage ring. These solenoids would push pin into the fuselage rings horizontally and would hold the nose cone with the fuselage similarly to a vault door with pins to lock it in place. This method would use Smalley spring to eject the nose cone off the fuselage once the solenoid pins were pulled. The other option used the solenoids to engage with the fuselage locking ring vertically like the primary design and also had a Smalley spring that would fit into slots on the locking ring. The first method would not be feasible because the nose cone has a solid extrusion that fits into the opening of the payload barrel. The second method issue was the Smalley spring in between the locking rings. The cylindrical shape and thickness of the spring would interfere with the solenoids locking vertically. The chosen design allowed for leading solenoids to fit onto the nose cone locking ring vertically and engage with the fuselage locking ring vertically without spring interference using compression springs.

6.9.1 Horizontally Positioned Medium Push-Pull Solenoid Alternative

The mechanism this solenoid uses is a push-pull pin. The benefit was that it would not require electrical power for the pin to be in an outward position to lock.This option was not possible because the solenoids required to be on the inside of the solid extrusion of the nose cone. The extruded section is needed to enter the payload barrel to encapsulate payload. The solenoids were not useful in other positions. Another drawback was that it consumed a large amount of current to pull the pin towards the solenoid and release. Required a driver for the 800 mA or 1A current draw.

Figure 6.9.1-1 Medium Push-Pull Solenoid

Pros:

- No electrical power needed for pin to push outward
- Cheap solenoid

Cons:

- Large current draw
- Required electrical power for the pin to pull inward.

6.9.2 Smalley Spring Alternative

This spring was considered for the cylindrical shape and the uniform force that it would exert on the locking rings upon release. This spring would ensure that the nose cone would eject evenly and not in an awkward direction. The drawback came from the space the Smalley spring would occupy in between the fuselage and payload barrel. This would occupy space and interfere with the solenoid chosen for the design.

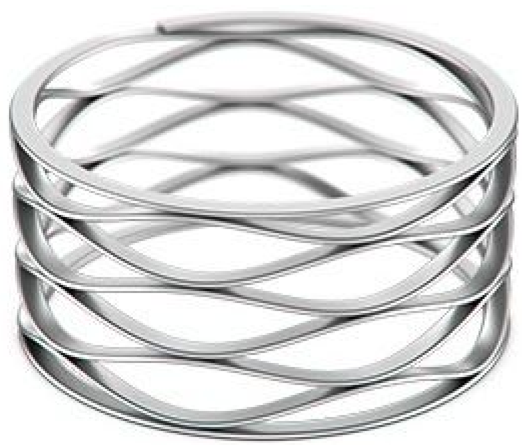

Figure 6.9.2-1 Smalley Spring

Pros:

- Uniform force exerted on surfaces
- Smaller height compared to coil springs

Cons:

- Space occupied is large area
- Interfered with solenoids

6.9.3 Locking Solenoid Alternative

This solenoid was a great option because the latch was simple, its' thin shape seemed useful, and code for Arduino was available for access. The case and the inside components were made of steel, which ensured durability and reliability. In addition, the solenoid had a manual disengage mechanism that had potential for a fail-safe option. The issue came when fitting to locking rings it would occupy too much space and could not be orientated differently to solve the issue

Figure 6.9.3-1 Electric Solenoid

Pros:

- Simple latching design
- Arduino code ready
- All Steel material
- Manual unlock

Cons:

- The dimensions of the solenoid do not allow us to use it in the orientation we need

6.9.4 Relay Alternative

The use of a relay to power our 2 locking nose cone solenoids allows simple yet effect control over both solenoids. However this relay is an electro mechanical system which is susceptible to large vibrations that the rocket will experience at launch. So we ultimately did not choose this relay.

Figure 6.9.4 - 1 Relay

Pros:
- Easy to use

Cons:
- Vibrations may cause loosen wires
- large

6.10 PLI Leading Payload Delivery System

The payload bay location was determined to sit directly behind the nose cone in order to utilize the cross-sectional area of the body tube for payload ejection after nose cone separation. Implementation of a payload barrel was determined to have the least risk of entanglement or jamming when ejecting the payload. In order to ensure the ejection of the payload and nose cone separation from the payload barrel a controlled burst of CO_2 will be used to deploy the payload. The payload deployment altitude window will be detected by a BMP-388 altimeter and an MPU-6050 accelerometer to provide redundancy in the payload ejection protocol initiation.

6.10.1 PLI Leading Components Microcontroller: Lafvin Nano

The Lafvin Nano was chosen to serve as the onboard microcontroller due to its power regulating and computational abilities in a compact and lightweight package. Its use of the ATMEGA328P surface mount chip offers many advantages for the team due to their arduino nano experience.

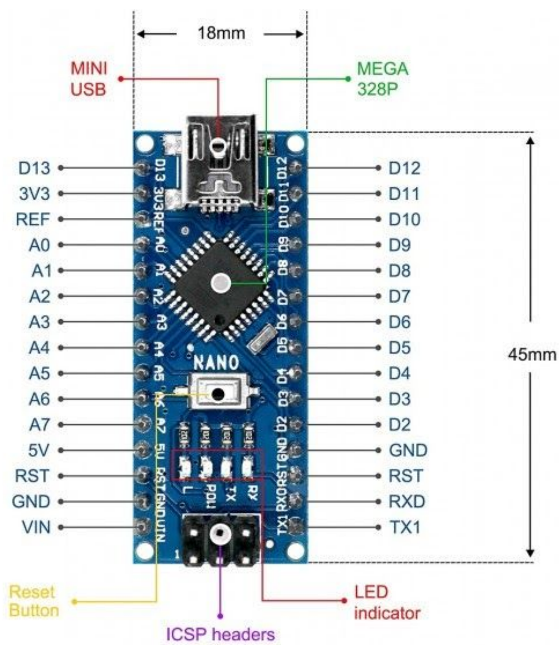

Figure 6.10.1-1 Lafvin Nano Micro-Controller Board

Pros:

- Access to arduino open source
- Inexpensive
- Access to multiple PWM ports
- Clear documentation
- Ability to use I2C and SPI wiring
- Small size

Cons:

- Does not have a 12v power supply

6.10.2 PLI Leading Components Altimeter: BMP388

The altimeter that was chosen is the Adafruit BMP388. This was chosen because of the accuracy of the sensor, the easy calibration method, and the abundance of the clear documentation on how to wire the sensor up. Also the abundance of the code available.

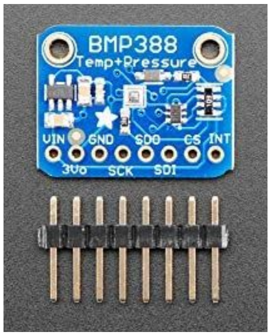

Figure 6.10.2 - 1 BMP388 Altimeter

Pros:

- Accurate to +/- 1 ft
- Inexpensive
- Easy to Calibrate
- Clear documentation
- Ability to use I2C and SPI wiring

Cons:

- Does still require calibration

6.10.3 PLI Leading Components Gyro-Accelerometer: MPU-6050

The leading Gyro-Accelerometer sensor is the MPU-6050. This senso was chosen for its proven accuracy and the team's previous experience with handling this sensor. The easy documentation and calibration method.

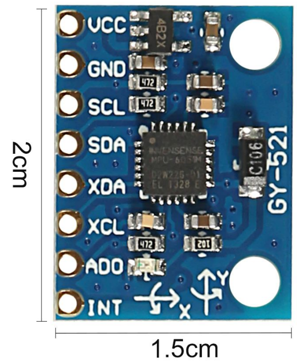

Figure 6.10.3 - 1 MPU6050 Gyroscope and Accelerometer

Pros:

- Inexpensive
- Easy to Calibrate
- Clear documentation
- Ability to use I2C

Cons:

- Does still require calibration

6.10.4 PLI Leading Components CO2 Cartridge: 16 Gram CO2 Cartridge

While at first the 16 gram cartridge was chosen because of its lightweight and more than good enough volume size. After more inspection and some calculations it was noted that the 16 gram cartridge allowed four to five reuses.

Figure 6.10.4 - 1 16 Gram CO2 Cartridge

Pros:

- Small and Light
- Threaded for easy use
- Allows for multiple payload discharges
- Allows for easy reusability

Cons:

- Takes up more space than the 12 g CO2 Cartridge

6.10.5 PLI Leading Components Solenoid Release Valve: CO2 12V NC 2 Way Solenoid Valve

This solenoid valve was chosen due to its compact form factor and 12 volt input power. The advantage of a standardized female thread allows multiple connections to be tested to ensure the most compact and leak proof configuration. The simple rectangular shape also makes the mounting of the valve much simpler than other valves on the market.

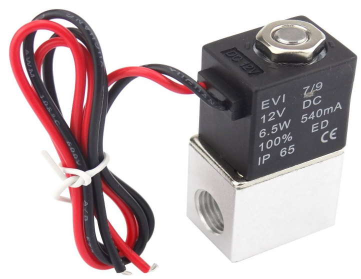

Figure 6.10.5 - 1 CO_2 12v NC 2 way solenoid valve

Pros:

- Small
- Light weight
- 12 volt input power
- Low amperage draw

Cons:

- Flow rate unknown

6.10.6 PLI Leading Components Battery: Tenergy NiMH Battery Pack 12V 2000mAh

This battery was chosen because of its large milliamp hour size of 2000mAh. This larger size allows us to easily meet the idle launch time requirement, while also being more than capable of powering all of our electronic components.

Figure 6.10.6 - 1 Tenergy NiMH Battery Pack 12V 2000mAh

Pros:
- Small
- Enough Mah for application window
- Cost effective

Cons:
- Heavier than other options

6.10.7 PLI Leading Components Mosfet: IRF740 MOSFET

This mosfet was specified because it works and interfaces very well with our microcontroller. It also allows for simple control of our gas valve solenoid. By having a low s

Figure 6.10.7 - 1 IRF740 MOSFET

Pros:
- Small
- Light weight

6.11 PLI Leading Nose Cone System

The nose cone deployment system chosen for the mission is a combination of solenoid locking springs and compressed springs. The locking solenoids will deploy the nose cone based on the input from the onboard altimeter. A hall sensor will identify that the nose cone has seperated and will initiate the payload deployment protocol. The main challenge with a nose cone ejection during flight is obtaining a quick ejection of the nose cone shoulder from the fuselage which will be mitigated by compressed springs.

6.11.1 PLI Leading Compression Spring Component: Coil Spring

These were selected springs because it would take less space in the locking ring and allow solenoids to engage lock. In addition the springs have a spring rate up to 78 lb per inch making the stored potential energy in the compressed spring large enough to exert a strong force that will eject the nose cone. Two springs will be used to evenly eject the nose cone. There was a concern of buckling in compression and expanding in unpredictable directions but that would be easily solved with including a spring seat on the locking rings. In addition the seat will have a pin in the center to help guide the direction of the expansion and force exerted on the locking rings.

Figure 6.11.1 - 1 Coil Spring

Pros:

- Strong spring rate
- Small enough to fit in a locking ring.
- Steel material
- Max load up to 25 lbs

Cons

- Force exerted only on contact surface instead of entire surface
- Linear design may cause buckling and irregular expansion direction

6.11.2 PLI Leading Solenoid Component : HWMATE DC12V Metal Fail Safe Mode Electric Cabinet Lock

This solenoid was chosen because of their shape, material, and capability that allows up to 15 degrees of angle of freedom to attach. The solenoids are an always on system meaning they require power to stay locked allowing for easy emergency release protocol.

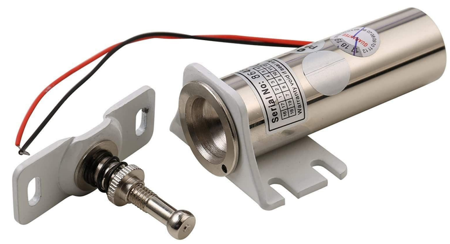

Figure 6.11.2 - 1 HWMATE DC12V Metal Fail Safe Mode Electric Cabinet Lock

Pros:

- Solenoid rated to lock and hold 110 lbs
- Metal material used for entire solenoid
- Fail-Safe mode activated without electrical power

Cons:

- Must have electrical power to lock
- Long solenoid

6.11.3 PLI Leading Hall Effect Sensor component

This type of sensor was selected because of the small size and simple use for determining proximity. It is easy to implement with our electronics and only requires a small magnet.

Figure 6.11.3-1 Hall Effect Sensor

Pros:

- Very small and lightweight
- Easy to implement with electronic system

Cons:

- Require magnet for purpose

6.12 PLI Proposed Payload Circuit

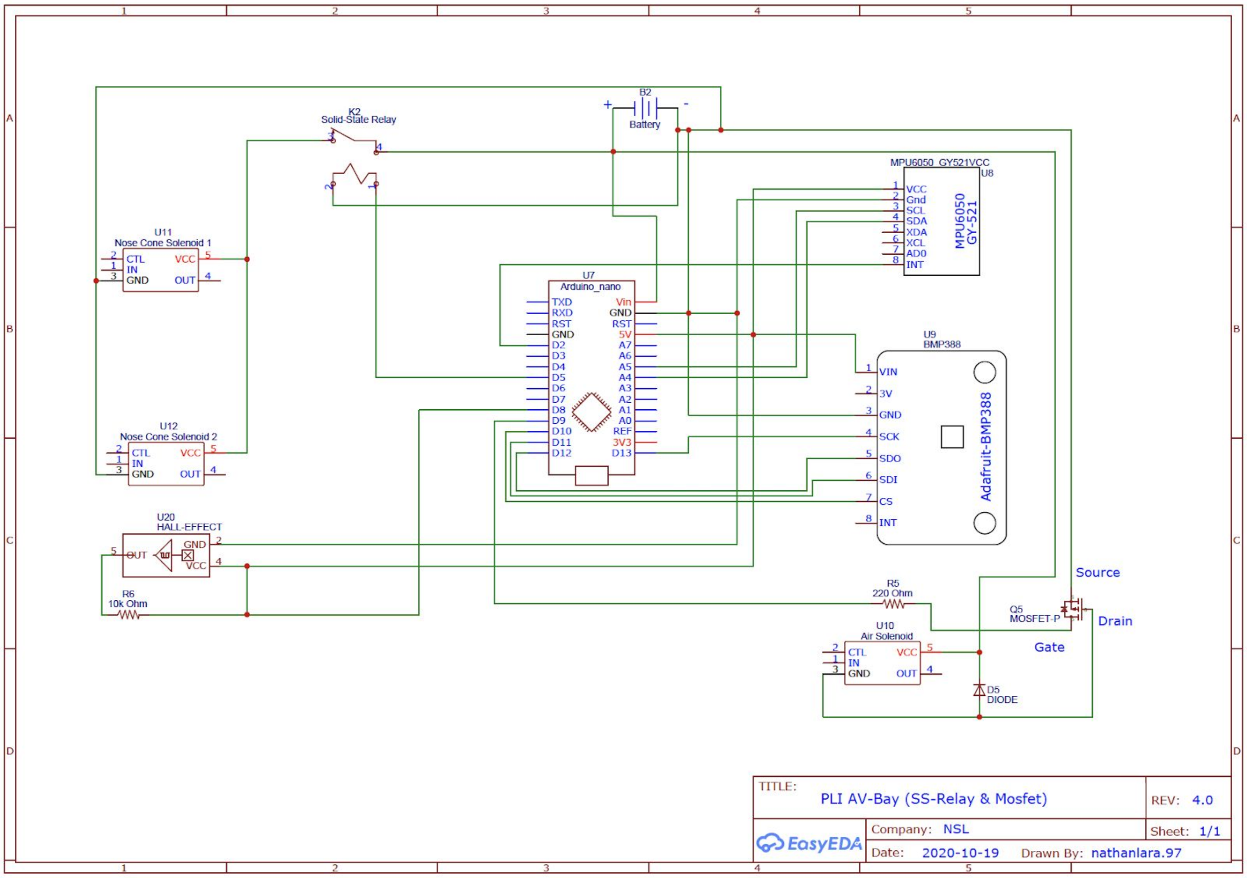

Figure 6.12 - 1 Payload Electrical Design

7.0 Safety

7.1 Safety Plan

Safety Lead Christopher Kinyon and Safety Officer Rukie Shendaj have read through the CDC guidelines for COVID-19 to ensure students do not contract the virus if they are required to meet together physically. The guidelines to be followed for COVID-19 safety can be found at the CDC and University websites. They have made themselves familiar with the codes and guidelines set forth by the National Association of Rocketry (NAR), Federal Aviation Association (FAA), and the National Fire Prevention Association (NFPA) in order to ensure the Cal Poly Pomona NSL team is not in violation of any local, state, or federal laws. The safety lead and safety officer are prepared to hold the Cal Poly Pomona NSL team responsible for maintaining these safety codes and will remain in contact with all team-leads to ensure the entire team understands the safety requirements. Along with obeying all laws and codes related to high-powered rocketry, the safety officers will hold the safety and wellbeing of all team members as the number one concern.

7.2 Safety Officer

The roles and responsibilities of the safety officer will include, but are not limited to:

- The monitoring of sub-teams and remaining up to date on their build or design progress to further provide safety information at each development stage
- Providing appropriate and sufficient safety briefing meetings
- Composing safety briefings for each team on how to safely operate their respective machinery, tools, and handling of substances
- Being present if necessary to ensure safety guidelines are being upheld with each team
- Inspecting launch vehicle and payload for any safety liabilities according to NAR trained-safety officer guidelines, and ensuring construction was completed and safety measures are still in place
- Providing an abundance of safety documents, manuals, pamphlets, and any other sources of safety information to the entire NSL team to minimize risk of misusing machinery/equipment or injuring self or another.

- Communicating with the team mentor to ensure the safe purchase, handling, transportation, and storage of any hazardous materials

7.3 Risk Assessment and Analysis

Risk assessment will be used to identify any hazards or potential threats to the team and the mission's success. It will serve as a proactive accident avoidance system and will provide all team members with the briefing they need to stay safe and keep the mission on track to meet all budgetary and time sensitive milestones. Using risk cubes, as shown in Figure 3.4-1, all threats and risks to the team's success will be analyzed using levels of likelihood and consequences. Green squares show a low risk, yellow illustrates medium or reduced risk, and red shows a high risk. This risk cube will help identify and reduce any risks to the team members, rocket and payload, and assure success in the competition.

Levels of Likelihood:

- **A. Near Certainty** (80-100%) Unpreventable failure and requires mission to be modified
- **B. Highly Likely** (60-80%) Certain failure of a system but can be avoided
- **C. Likely** (40-60%) Will likely occur but can be amended to avoid future setbacks
- **D. Low likelihood** (20-40%) Proper risk assessment will negate majority risks
- **E. Not likely** (0-20%) Basic safety procedures and protocols will negate risks

Levels of Consequences:

1. **Catastrophic-** Almost guaranteed total mission failure. Unacceptable risk and will not meet key program milestones or deadlines. Budget Increase >10%
2. **Critical**- Significant regression of mission goals and may jeopardize milestones and budget limits. Budget Increase <10%
3. **Significant**- Slight reduction on mission performance, will not affect major deadlines but may serve as a significant schedule slip and budget increase. Budget Increase <5%
4. **Moderate**- Minor impact on mission performance goal and deadline, any setback is recoverable with minor schedule and budget impact. Budget Increase <1%
5. **Minimal**- Minimal or no risk to mission performance, schedule, or cost. Budget Increase ~0%

Likelihood	A5	A4	A3	A2	A1
	B5	B4	B3	B2	B1
	C5	C4	C3	C2	C1
	D5	D4	D3	D2	D1
	E5	E4	E3	E2	E1
	Consequence				

Figure 7.3-1 Risk Cube

7.4 Personnel Hazard Analysis

Table 7.4-1 Personnel Hazard Analysis Matrix

Hazard	Cause	Effect	Risk Rating	Mitigation
COVID-19	Contact or exposure to those infected with the virus	Flu-like symptoms, respiratory infection/damage, or death	**A3**	All individuals must maintain 6 feet distance from one another and wear a mask
Workshop tools	Tool negligence or workplace accident	Severe bleeding, loss of limb, cuts, or even death	**A1**	Proper safety guidelines and briefings, PPE, and active work attentiveness
Harmful chemicals	Toxic fumes and strong acidic substances	Light-headedness, lung irritation, skin damage, and chemical burns	**D3**	Respirator or ventilated area and gloves to reduce exposure to body
RSO inspection	Rocket doesn't pass inspection of RSO	Cannot launch rocket, timeline set back	**D2**	Safety and NSL guidelines will be followed and thorough team inspections before RSO inspection
Fiberglass	Very fine dust particles exerted when creating and working with material	Irritation of skin,eyes, throat, and/or lungs	**D2**	Team members working with fiberglass must use proper PPE
Epoxy/ adhesives	Toxic fumes and quick adhering ability	Light-headedness, lung irritation, and skin damage	**A4**	Respirator or ventilated area required with epoxy use, and proper workspace cleaning
Rocket Budget	Project spending is not accounted or tracked properly	Team is unable to purchase necessary materials to complete project	**E1**	Practice proper record keeping and expense reports
Soldering Iron	Team member gets burned while working on circuits	Injured team member may need to receive medical help for burn, may be absent from project during recovery	**E4**	Safety briefings will ensure team members know how to safely operate soldering iron, and team organization ensures other members can take over work

Battery/circuit	Team member shocks themselves or shorts a circuit while working on electronics	Shock can cause severe damage to body and short circuit can render electronic parts unusable	**E4**	Safety briefings will ensure team members know how to safely use batteries and review their circuit orientation before connection
Schools don't cooperate with outreach	Lack of communication or response or unwillingness to cooperate with program	Unable to meet NASA goal of reaching out to 200 students, docked points in competition	**C5**	Contact all possible outreach opportunities to maximize eligible students

7.5 Failure Modes and Effects Analysis

Table 7.5-1 FMEA Matrix

Hazard	Cause	Effect	Risk Rating	Mitigation
Black Powder Charges	Improper magazine storage or excessive heat exposure leading to explosion or fire	Serious injury or burns	**B2**	NFPA guidelines followed and heat sources kept minimum of 25 ft away
Rocket Motor	Motor explodes due to manufacturing error	Destruction of entire rocket and shrapnel to surrounding area	**C1**	Test fires of motor before installation into rocket and sub-scale launches. Team members will follow all launch site safety guidelines to ensure no one is at risk of being harmed in case of explosion
Black powder charge doesn't ignite	Parachute is not deployed	Rocket will sustain heavy damage from fall	**C1**	Perform multiple test fires of charges to ensure ignition success
3D Printer	Axis are set up improperly or other technical error and prints improper size or fractured part	Printed part does not fit in rocket or does not withstand stresses of launch and break	**D2**	All 3D printed parts will be inspected thoroughly before implementation into rocket

Payload malfunction	Payload legs don't extend due to actuator or electronic malfunction	Picture can't be taken for competition guidelines, lose points	**D3**	Multiple drop tests will be performed to ensure the payload will be able to function after landing
Damaged payload	Payload part(s) are damaged during launch or landing	Not able to function properly and take a picture or send picture, lose points in competition	**D3**	Every function of payload will be tested to ensure it can take and send pictures to team after surviving drop tests
Fin separation	Fins snap off or crack during launch	Rocket stability is decreased and rocket may go off course, or crash	**D1**	Fin strength and attachment will be checked before launch
Can't buy altimeter	Desired altimeter is out of stock	Unable to implement vital piece of rocket, can't coordinate ejections	**C2**	Trade study to identify replacements to order if altimeter can't be acquired
Fuselage doesn't arrive in time	Shipping delays or lack of inventory from vendor	Unable to construct rocket in time for launch, timeline set back	**D1**	Source rocket parts from local company to reduce travel time and have replacements ready to order
Payload gets tangled after ejection	Payload and launch vehicle cords become tangled	Parachutes are rendered inoperable, payload and rocket will suffer heavy damage from fall	**D1**	Ejection of parachute and payload will be staggered to increase distance between objects before deployment
Black powder charge doesn't ignite on time	Parachute deploys at wrong altitude due to system error or lag	Rocket misses target altitude for chute deployment, team loses points and rocket may sustain damage or drift away from landing zone	**E1**	Perform multiple test fires of charges with ignition switches and appropriate systems to prevent chance of misfire or duds

7.6 Environmental Hazard Analysis

Table 7.6-1 Environmental Hazard Matrix

Hazard	Cause	Effect	Risk Rating	Mitigation
Launch site fire	Motor blast isn't shielded properly or motor explodes	Surround area is scorched and any flammable material may turn into wildfire	**C1**	Blast shields will be used for any motor firing and surrounding area from launch will be cleared a minimum of 10ft, all NFPA guidelines will be followed
Wind blows payload off course	Strong wind blows payload away from landing zone	Payload is unrecoverable or difficult to locate	**C2**	Team will research wind patterns to determine best time to launch and weighted bottom will help prevent sway
Weather-Rain	Launch site is flooded from rain	Unable to launch sub-scale rocket and gather vital data, timeline pushed back	**A4**	Team will research weather before scheduling a launch and have multiple backup dates
Weather-Strong wind	Winds 15mph+ during launch	Unable to launch due to unsafe conditions, rocket would be flown off course	**A4**	Team will research weather before scheduling a launch and have multiple backup dates

7.7 Risk Mitigation Quantification

Table 7.7-1 Risk Mitigation Quantification Matrix

Risk	Mitigation	Quantification
COVID-19 Infection	Practice social distancing and reducing time spent together working on project	Buying parts rather than manufacturing them increases construction costs
Budgetary overage	Confirm with project lead each purchase and contact ASI for reimbursement.	Slow reimbursement processes may discourage members from purchasing vital

		components until the last second, timeline is shortened until part is received.
Rocket motor malfunction	Multiple test fires of motor before installation into rocket	Budget increases each time a motor is fired, malfunction while in rocket leads to entire new rocket needing to be built
Bad weather at launch site	Plan for multiple launches if weather causes launch to be scrubbed	Postponing launch allows for less time to analyze data and incorporate into appropriate report
Payload not ejected	Include numerous redundancy methods to ensure payload is ejected if initial system fails	Budget is increased for each test ejection and launch where C02 gas redundancy method is included.
Desired altimeter out of stock	Identify replacements in case altimeter can't be bought	Timeline will be set back until altimeter is received, replacements have less functions and will require more time to replicate functions
Team member injury while working on rocket	Safety briefings before every workshop day	Additional time is required to stay safe while constructing rocket, additional days may be required, medical costs of injured student in event of accident
Cal Poly Pomona campus and laboratories closed due to COVID-19	Locate additional workshops that can accommodate rocket construction	Alternate location requires additional travel time and gas usage for team

8.0 Requirement Compliance

8.1 Derived Requirements

The team created derived requirements during the design process to help each subteam understand what is required from the system. Each derived requirement was established with a measurable value or constraint so progress could be checked during the various tests the team plan to carry out for the Critical Design Review. It was essential to make each requirement formatted this way to help finalize the launch vehicle and payload design.

Table 8.1-1 Launch Vehicle Derived Requirements

Derived Req. #	Related Req. #	Statement	Verification Method	Verification Plan	Status
D2.1	2.1	The vehicle will deliver the payload to an apogee of 4,000 feet	Testing and Analysis	The team will utilize Rocksim to simulate the rocket's trajectory along with a subscale launch to confirm that the simulations are accurate	In Progress
D2.2	2.14	The Launch Vehicle will have a minimum rail exit stability of 2.1	Analysis	Rocksim model will have a minimum of 2.1 stability to ensure rail exit velocity is above 2.0	In Progress
D2.3	2.5.1	Coupler that is used at an in-flight separation point will be at least 7.5 inches in length	Analysis and Inspection	The coupler will be machined or manufactured to meet the 7.5 in length requirement	In Progress
D2.4	2.5.2	The shoulder that we will be purchasing will have a minimum shoulder length of 3.76 ± 0.1 inches	Analysis and Inspection	The shoulder length will be manufactured to meet the 3.76 in length requirement	In Progress
D2.5	2.16	The launch vehicle will accelerate to a velocity of 55 ft/s rail velocity to ensure launch velocity requirement of 52 ft/s	Testing and Analysis	A full-scale test of our launch vehicle will confirm that our rail exit velocity will be greater than 52 ft/s	In Progress
D2.7	2.13.1	An in-flight Factor of Safety of 4:1 will be used for expected loads applied to the airframe.	Analysis	Use stress analysis and strength tests to ensure that the fuselage provides enough strength to include a Factor of Safety of 4	In Progress
D2.8	2.22.6.	Maximum speed of the launch vehicle will not exceed Mach 0.5	Testing	A test of our full scale shall prove that our full scale flight will not exceed Mach 0.5	In Progress

Table 8.1-2 Recovery Derived Requirements

Derived Req. #	Related Req. #	Statement	Verification Method	Verification Plan	Status
D3.3	3.3	The heaviest section will have a weight of 27.63 lb and a calculated descent velocity of 13.18 ft/s Which yields 75 ft-lbf of KE	MATLAB	The team shall use MATLAB code to calculate the descent velocity	Complete
D3.4	3.4	The single (1) redundant altimeter, StratoLogger CF, must be tested to work just like the primary altimeter.	Testing	The altimeter shall be tested in our pressure bowl to ensure their reliability	In Progress
D3.6	3.6	Battery supply will last 4 hours long, to await launch time.	Testing	The batteries will be charged fully then connected to ensure that power supply will last 4 hours	In Progress

D3.11	3.11	The main parachute is set to deploy at an altitude of 600 ft which brings descent time to 86 seconds.	Testing	The Jolly Logic has a built in altimeter that will be tested in our pressure bowl to ensure it deployed the parachute at the right altitude	In Progress

Table 8.1-3 Payload Derived Requirements

Derived Req. #	Related Req. #	Statement	Verification Method	Verification Plan	Status
D4.2	4.2	The 3D printed material used for the payload walls must able to withstand an impact force of 2.64 Joules from landing at 7.92fps using a 60" diameter parachute.	Testing and Analysis	Various filaments with different impact strength properties vs. density will be tested to determine the best strength to weight ratio that will suit the payload's needs.	In Progress
D4.3.2.1	4.3.2	Landing system will use raspberry pi to autonomously control linear actuators to level according to MPU 6050.	Testing	Upload code to raspberry pi and run auto leveling command with linear actuators connected to frame and raspberry pi.	In Progress
D4.3.2.2	4.3.2	Using the designated linear actuators, the center of gravity needs to be around 3 inches from the bottom of the payload in order to push the payload upright from its side.	Testing	Linear actuators will be tested on a payload that will prototype the center of gravity and moments.	In Progress
D4.3.2.3	4.3.2	An onboard altimeter used in conjunction with an accelerometer will verify that the payload has touched down before starting the linear actuation of the legs.	Testing	The altimeter and accelerometer will be tested for proper raspberry pi readouts at different altitudes and motion sequences. The payload will also be flown in a test flight to verify functionality.	In Progress
D4.3.3	4.3.3	MPU 6050 will need to be tested for accuracy of +-1degree , then be able to gather the data on the raspberry pi.	Testing	Calibrate MPU 6050 until given accurate readings and then enter reading into a variable in the raspberry pi.	In Progress
D4.3.3.2	4.3.3.2	Raspberry pi will gather readings from MPU 6050 before and after the auto leveling command.	Testing	Test pre-level, auto level, and post-level command on raspberry pi altogether to check for recorded angles.	In Progress
D4.3.1	4.3.1	Payload integration will jettison the payload out of the fuselage at an established altitude of 550ft.	Testing and Demonstration	Vertical test stand will hold the fuselage to allow payload ejection via CO2 burst	In Progress
D4.3.1.1	4.3.1	The roof of the payload will be able to withstand the force of the parachute opening.	Testing and Analysis	Shock tests will be conducted on an overweight payload to ensure a margin of safety in the roof structure	In Progress

9.0 Budgeting and Timeline

9.1 Bill of Materials

Cal Poly's NASA Student Launch Team is composed of several subteams, with three main systems that take care of the overall design of the launch vehicle and payload. The Payload Integration and Payload subteams under the Payload System created separate bills of materials, **Table 9.1-1** and **Table 9.1-2**, that include available shipping and tax information. The same can be said for the Avionics and Parachute Analysis subteams. **Table 9.1-4** and **Table 9.1-5** summarize their respective bill of materials that include available shipping and tax information for the Recovery System. The Launch Vehicle Team combined their bills of materials for the Structures and Analysis subteams, which is shown in **Table 9.1-3**.

Table 9.1-1 Payload Integration's Bill of Materials

Product Name	Quantity	Price	Shipping + Tax	Total
Arduino nano	pack of 3	$13.99	$1.08	$15.07
prototype board	6 pack	$9.99	$0.77	$10.76
lipo charger	1	N/A	N/A	N/A
through hole terminal block	70 pcs set	$10.99	$0.85	$11.84
MPU-6050	3 pack	$12.00	$0.93	$12.93
JST SM 3pin connector	20 pack	$9.88	$0.77	$10.65
BMP388	3	$29.85	$12.56	$42.41
12v locking solenoids	2	$47.00	$3.64	$50.64
12 V 1/4 in solenoid valve	1	$14.00	$1.09	$15.09
hall effect sensor	3	$10.00	$0.78	$10.78
mosfets 12v 1.5A	20	$12.99	$1.01	$14.00
1 kg filament spool	4	N/A	N/A	N/A
16g CO2 cartridges	7	$18.15	$1.41	$19.56
CO2 regulator	1	$34.50	$2.67	$37.17
pneumatic hose	1 pack	$12.99	$1.01	$14.00
solenoid brass fittings	2	$10.00	$0.78	$10.78
m2 nylon standoffs	100 pcs set	$9.99	$0.77	$10.76
#8 x 1/2" screws	50 pcs	$6.87	$0.53	$7.40

jb weld	1	N/A	N/A	N/A
			Total	**$293.84**

Table 9.1-2 Payload's Bill of Materials

Product Name	Quantity	Price	Shipping & Taxes	Total
Planetary Lander Components				
Raspberry Pi 4 B 2GB	1	0 (Already Owned)	0	$0.00
MPU 6050	1	0 (Already Owned)	0	$0.00
Adafruit BMP388	2	$15.99	$2.24	$34.22
L12-R Micro Linear Servo	4	$70	$2.24	$282.24
180 degree fisheye lens	3	$45	$2.24	$137.24
2 cell Lipo battery	1	$29.99	$2.17	$32.16
PWM Driver with I2C Protocol	1	$20.4	$2.24	$22.64
4G LTE Base Hat	1	$75.09	$7.69	$82.78
M4 Phillips Flat Heat Screws, 8mm	1	$3.45	$0.25	$3.70
M4 Phillips Flat Heat Screws, 14mm	1	$4.4	$0.32	$4.72
M4 Hex Nut	1	$2.26	$0.16	$2.42
Aluminum Screw-to-Expand Insert for Plastic (1 set of 25 pcs.)	1	$6.41	$0.46	$6.87
Overture TPU Filament 1kg	1	$26.99	$1.96	$28.95
Hatchbox PLA Filament 1kg	1	$22.99	$1.67	$24.66
Ziro Carbon Fiber PLA Filament 1.76lbs	1	$28.99	$2.10	$31.09
Breadboard wires	1	$6.98	$0.51	$7.49
Parachute	1	$29.79	$2.16	$31.95
Jolly Logic	1	$129.95	$9.42	$139.37
			Total	**$872.50**

Table 9.1-3 Launch Vehicle's Bill of Materials

Product Name	Quantity	Price	Shipping & Taxes	Total
Full Scale Rocket Motor Components				
Cesaroni 3-Grain Casing Kit	1	$388.42	$12.87	$401.29
Cesaroni Spacer	1	$33.42	$6.49	$39.91
Cesaroni Rocket Motor	2	$500	$0	$500.00
CR-7.5-2.1 Centering Rings	3	$25.17	$12.95	$38.12
Fasteners		$20		$20.00
Full Scale Rocket Fuselage				
Fuselage	2	$600	$14.26	$614.26
Nose Cone	1	$168	$11.79	$179.79
Fins G-10 fiberglass fins	4	$50	$12.95	$62.95
G-12 Fiberglass coupler	1	$132	$26	$158.01
Slow-Cure Epoxy	2	$19.25	$14.67	$33.92
Bulkheads	2	$14.60		$14.60
Sub-Scale Rocket				
4-inch fiberglass fuselage	1	$71	$16.42	$87.42
Cone	1	$79.95	$15.70	$95.65
G-12 Fiberglass coupler	1	$22	$9.43	$31.43
Motor	1	$150		$150.00
Centering Rings	3	$15	$6.01	$21.01
Motor Casing	1	$150		$150.00
Fasteners		$20		$20.00
Slow-Cure Epoxy	1	$20	$14.67	$34.67
Bulkheads	2	$8.16	$4.51	$12.67
			Total	**$2,665.70**

Table 9.1-4 Avionics' Bill of Materials

Product Name	Quantity	Price	Shipping & Taxes	Total
Telemetrum V3	1	$300.00	$5.00	$305.00
StratologgerCF	1	$54.95		$54.95
HTRC LiPo Charger	1	$13.97	$1.14	$15.11
TeleDongle Starter Kit	1	$175.90	$12.08	$187.98
Perfect Flite	1	$24.95		$24.95
McMaster Carr Aluminum screw to expand for plastic	1	$6.69		$6.69
Venom Fly 1300	1	$18.99	$1.14	$20.13
Polycarbonate (PC) Sheet, Transparent Clear, Standard Tolerance, ASTM D3935, 1/2" Thickness, 12" Width, 12" Length	1	$28.94		$28.94
Pittsburgh Air Powered Vacuum Pump	1	$17.99		$17.99
			Total:	**$661.74**

Table 9.1-5 Parachute Recovery's Bill of Materials

Product Name	Quantity	Price	Shipping & Taxes	Total
Gorilla Tape, Black Duct Tape, 1.88 in. x 12 yd., Black, (Pack of 1)	1	$6.81	$0.54	$7.35
hyStik 1 in. x 60 yds. Blue Painters Masking Tape	1	$4.85	$7.32	$12.17
E-match starter kit (makes 80 starters)	1	$83.46	$18.28	$101.74
1/4" U-Bolt. Stainless Steel	2	$3.00	$7.43	$13.43
SW- 350	2	$1.50	$7.99	$10.99
1/4" QUICK LINK	4	$4.26	$11.06	$28.10
Nylon Shear Pins - 20 pack	1	$5.56	$12.00	$5.56
Jolly Logic Chute Release	2	$129.95	$23.39	$283.29
Jolly Logic Chute Release Protector	2	$9.95	$3.56	$23.46
2 3-gram Aluminum Charge Wells	1	$14.95	$6.20	$21.15
2 in. Copper Pressure Tube Cap Fitting	2	$10.98	$3.85	$25.81
120" Iris Compact parachute (w/15% disc)	1	$460.68	$57.78	$449.36
Classic Elliptical Compact 24" (w/15% disc)	1	$61.23	$21.14	$73.18
			Total	**$1,055.60**

9.2 Budget

The fundraising goal for the year was set on the initial bill of materials that was created by the individual subteams. As the design phase progressed, different choices of materials were down selected causing the budget to decrease from its initial value. The allocation amounts can be seen in **Table 9.2-1** along with a visual representation of the allocated amounts in **Figure 9.2-1**. This budget takes into account the discounts acquired from various companies as well.

Table 9.2-1 Allocation of Budget

System	Amount Allocated
Payload System	$1,166.34
Launch Vehicle System	$2,665.70
Recovery System	$1,717.34
Manufacturing	$500.00
Outreach	$1,250.00
Safety	$250.00
Merch	$1,090.00
Travel	$9,306.00
Total	**$17,945.38**

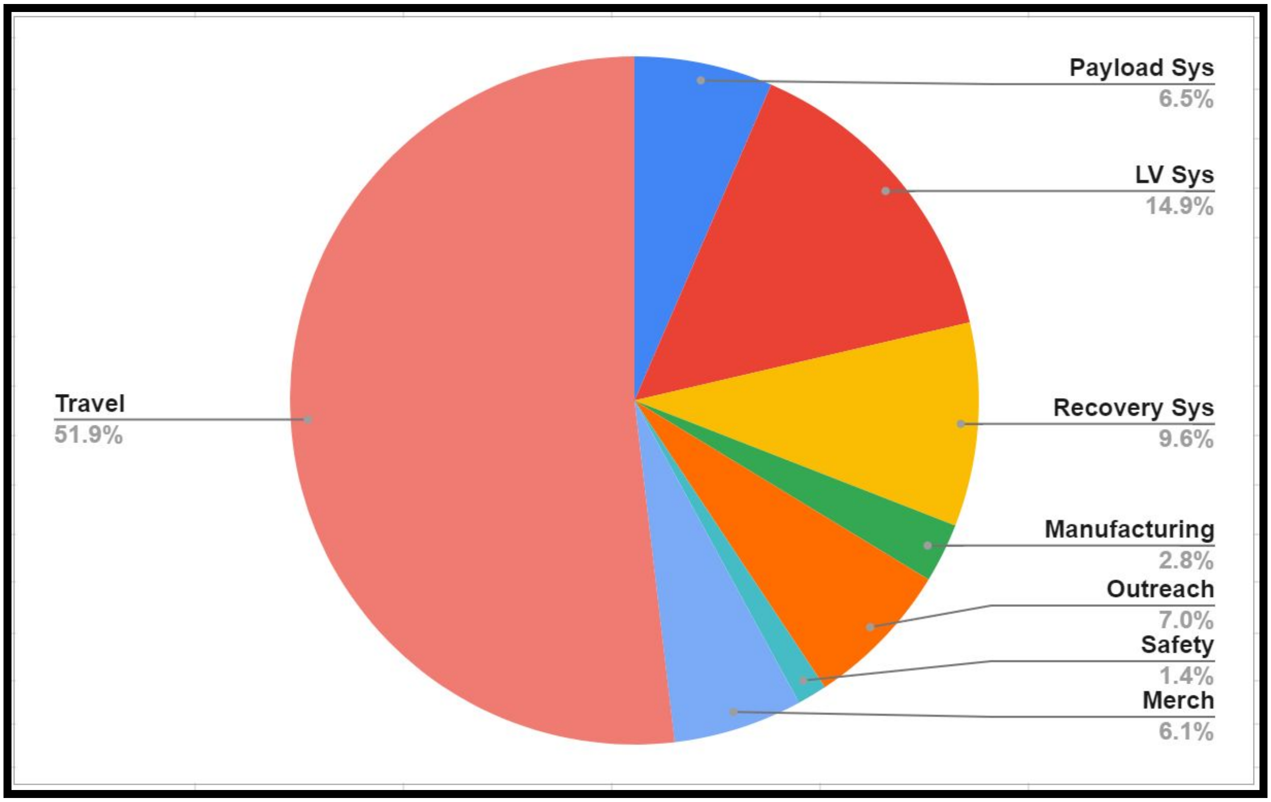

Figure 9.2-1 Allocation of Budget Pie Chart

Due to the uncertainty of COVID-19, the team has also created a budget that takes into account a decision if the team decided to not travel to Huntsville, Alabama and launch locally at a NASA-approved site. If the team decides to not travel, the budget for team merchandise will be increased, which would help advertise NASA Student Launch and also affect Outreach. With the increased budget in merchandise, the team plans to buy official Team collared, jackets, stickers, and more. The Outreach Team also received a large allocation of the budget to prepare for the STEM Engagement activities. However, in Southern California majority of the schools are still practicing virtual instruction so it is fairly difficult to plan activities for these events. The budget will be available if kits can be provided but it is also possible to allocate these funds for other needs if the kits seem impossible to distribute.

9.3 Funding Sources

Funding sources, as mentioned in the proposal, will still come from the university, businesses, and donations from individuals. The following table shows funds that have been secured.

Table 9.3-1 Funding Sources

Funding Source	Support
Cal Poly Pomona Associated Students, Incorporated Grant	$5,000.00
Undergraduate Missiles and Ballistics and Rocketry Association	$1,600.00
Lockheed Martin Sponsorship	$3,000.00
GoFundMe	$3,040.00
Bronco Launchpad	TBD
Total	$12,640.00

The Outreach team still plans to do a significant amount of work in branching out to the community to reach out to as many people as possible in order to receive support in regards to funding. Also, the NSL team has two active fundraisers through GoFundMe and Bronco Launchpad, which goes to the team directly and to UMBRA who will give a portion of the funds raised, respectively. Team members will purchase parts, personally, and then go through a reimbursement process that involves the UMBRA treasurer and Associated Students, Incorporated.

To receive even more support from companies, the team also plans to send sponsorship packets via email. The following is a list of potential companies that will be sent an email, which will continue until March 2021: *SpaceX, RocketLab, Northrop Grumman, Slingshot Aerospace, Boeing, and Smartplane.*

9.4 Timeline

Figure 9.4-1,2,3,4,5,6,7 describe the current project plan that our team is following. With November 21 being our ideal launch date for the subscale, components have been ordered to begin the manufacturing process. **Figure 9.4-7** illustrate our current manufacturing schedule assuming we are only capable of using the donated workspace at Paragon Airways, which was described in our Proposal. The team is currently doing their best to meet to manufacture with the given conditions, hence the small restricted schedule. Decisions are pending on whether to continue the manufacturing process at other locations.

The Outreach team has missing events in the plan due to the current pandemic. It has been fairly difficult to reach out to schools to schedule events but the Outreach Lead has made contact with several schools and are awaiting confirmation for specified dates and event descriptions.

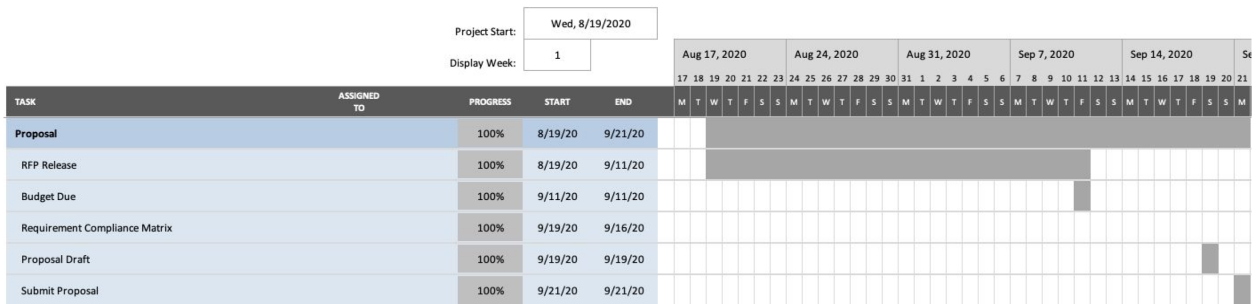

Figure 9.4-1 Gantt Chart: Proposal

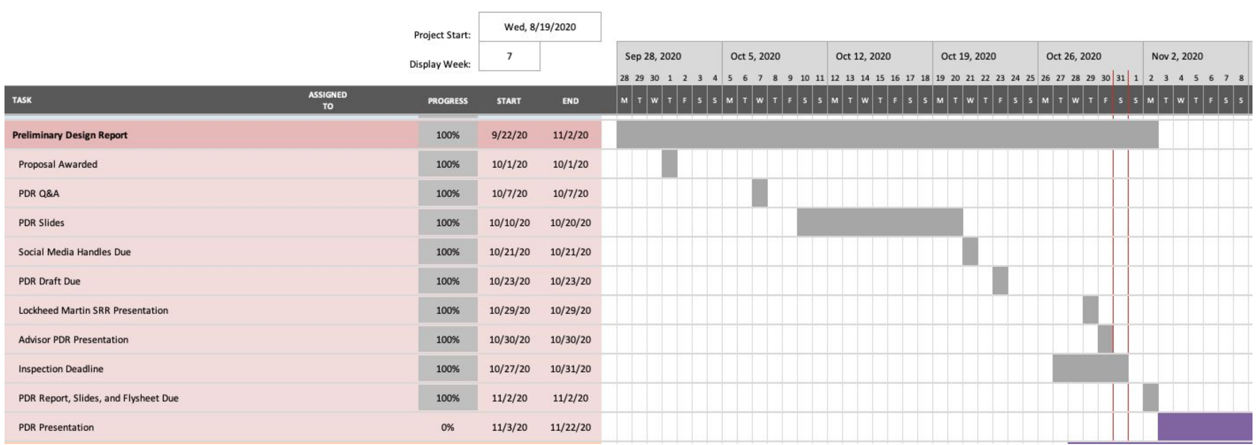

Figure 9.4-2 Gantt Chart: Preliminary Design Report

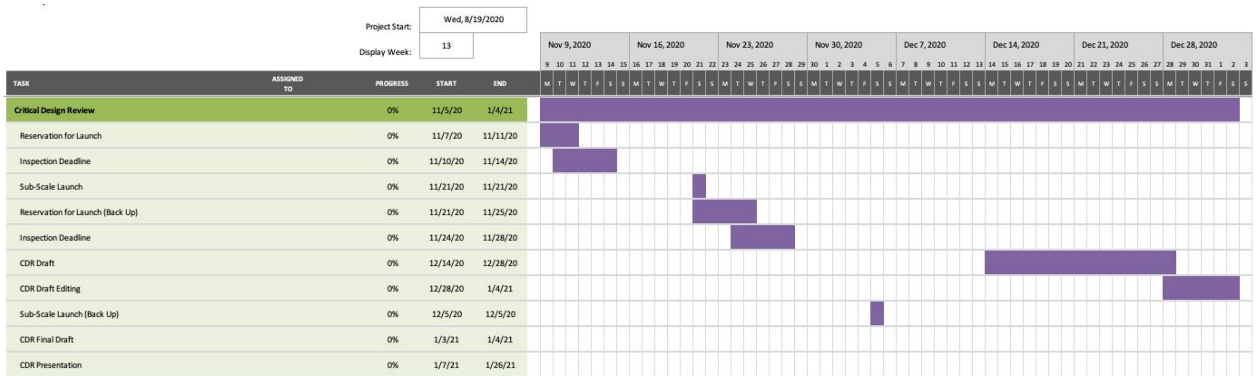

Figure 9.4-3 Gantt Chart: Critical Design Review

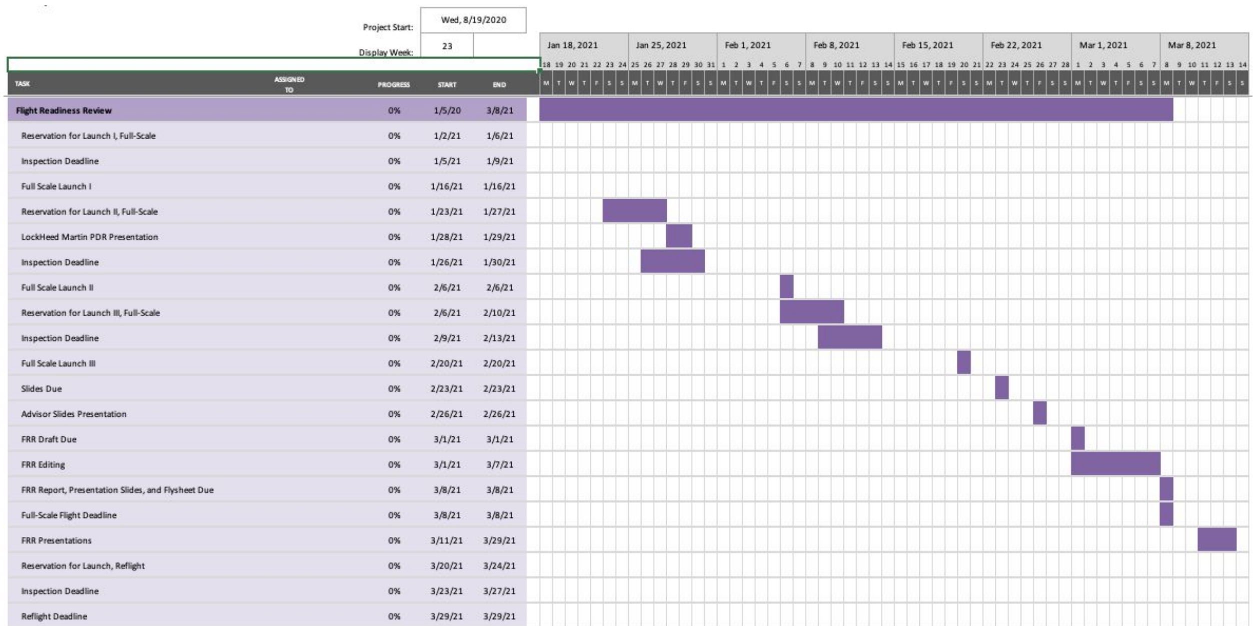

Figure 9.4-4 Gantt Chart: Flight Readiness Review

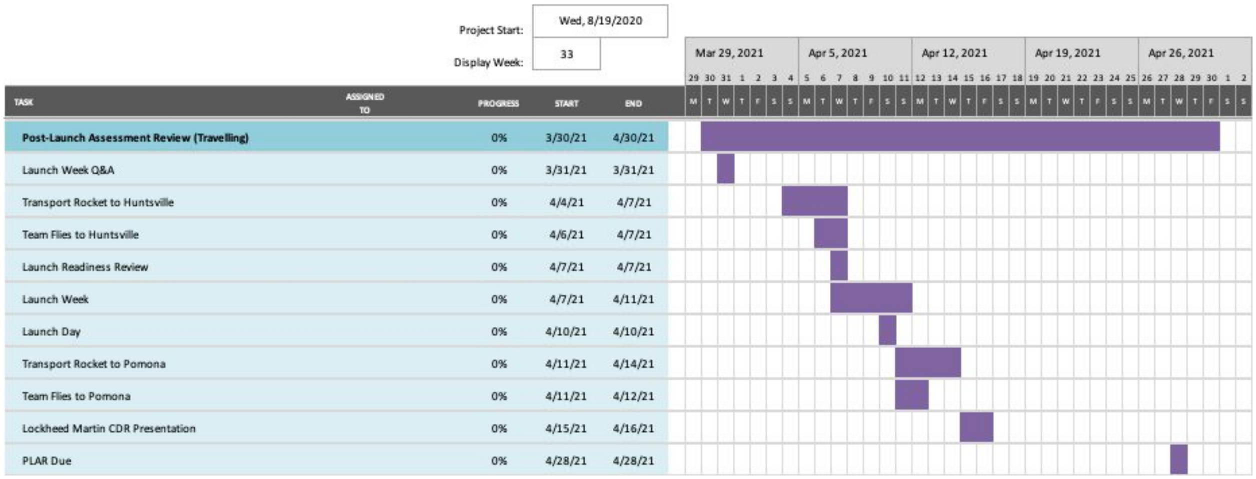

Figure 9.4-5 Gantt Chart: Post-Launch Assessment Review (If Travelling)

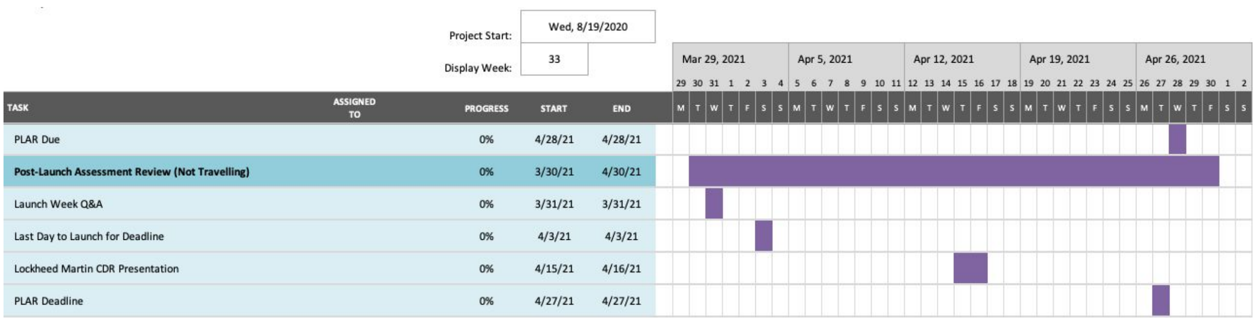

Figure 9.4-6 Gantt Chart: Post-Launch Assessment Review (If Not Travelling)

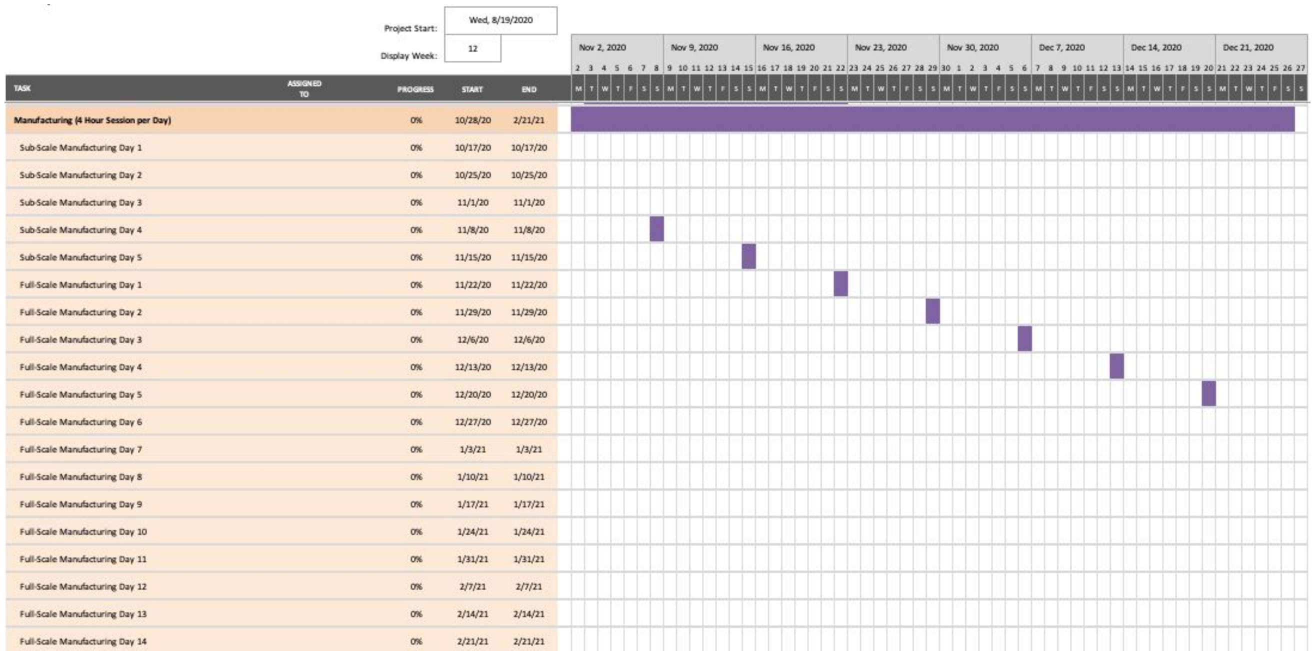

Figure 9.4-7 Gantt Chart: Manufacturing Schedule (4 Hours/Week, Sunday)

Appendix A - Team Hour Log Sheet

Week 5 September 20 - September 26

First Name	Last Name	Major	Time (hours)	Description
Alex	Djansezian	Aerospace Engineering	9	General meeting, design meeting, subteam meeting, reasearch on ham radio license and subscale AV bay
Andres	Ruiz	Electromechanical Systems Engineering Technology	6	General, payload, design meeting, and electronics with Jason
Charles	Kalis	Aerospace Engineering	-	-
Arbi	Khodaverdian	Mechanical Engineering	3.5	Attended general, design, and payload team meetings
Benjamin	Madrigal	Aerospace Engineering	3	-
Brooks	Blenker	Aerospace Engineering	2.25	General Meeting, Design meeting.
Bulmaro Jr.	Sanchez	Aerospace Engineering	7	Design meeting, general meeting, subteam meeting, preperations of pdr
Carlos Armando	Barrios	Mechanical Engineering	7	meetings, design, team progress review
Christopher	Kinyon	Aerospace Engineering	4	general meeting, design meeting, team lead meeting
Daniel	Castaneda	Aerospace Engineering	10	Design meeting, general meeting, advisor meeting, presentation prep
Garrett Arian	Arian	Aerospace Engineering	8	PDR research, subteam meetings, design meetings, general meetings
Iganus	Bala	Aerospace Engineering	11.2	General meeting, launch vehicle meeting, analysis meeting, reviewed rocket loads, solid works course
Jacob	Swenke	Computer Engineering	7.75	2 design meetings, AV meeting, team meeting, research on AV electronics
Jason	Lono	Mechanical Engineering	3	General and Payload meetings, electronics research
Jessica	Hernandez	Aerospace Engineering	3	organized outreach folders in drive and edited documents, general team meeting
Josepf	Amador	Aerospace Engineering	2.5	General, launch vehicle and analysis meeting
Justin	Diaz	Aerospace Engineering	6.4	Organized team meetings. general meetings. 3D modeled rockeeet components. Downloaded software.
Katarina	Aguayo	Aerospace Engineering	6	general meeting, lead meeting, design meeting, pdr prep
Khai	Phan	Aerospace Engineering	4	General meeting and weekly parachutes meeting
Mary	Boddy	Aerospace Engineering	3	Sub Scale model, general meeting
Naethan	Mallari	Mechanical Engineering	5	design meeting, lead meeting, general meeting, last minute changes to the proposal
Nathan	Lara	Aerospace Engineering	8	Design meeting, general meeting, subteam meeting, reserch on electrical compnents wiring set up, working on PLI-E-Bay schematic
Noah	Serio	Mechanical Engineering	12	Meetings, Proposal Writing
Rukie	Shendaj	Aerospace Engineering	3	Meetings, Research, Proposal Writing
Samantha	Guerrero	Physics	4	Team meetings, design meeting
Samy	Ousman	Aerospace Engineering	5	Design meeting, general meeting, team meeting, proposal look over
Sobhan	Akhtar	Aerospace Engineering	6.12	General meeting, launch vehicle team meeting, analysis team meeting, reviewed PDR requirements in NASA handbook, looked over previous Rocksim and made various adjustments to mass and tried different motors to see how the altitude would change, went over stress analysis done prior to see how to redo for new dimensions from current Rocksim model
Tommy	Fuentes	Aerospace Engineering	9.15	team meeting, design meeting, general meeting, PLI locking ring components cad modeling and research
Yosuf	Mayar	Mechanical Engineering	11.25	design, general, and avioncis meetings, research, modelling avbay in sw
Zachary	Smith	Mechanical Engineering	12	Design and general meetings, payload model redesign
		Total Team Hours	182.12	

Figure A-1: Week 5 Hour Log Sheet for the Team

Week 6	September 27 - October 3			
First Name	**Last Name**	**Major**	**Time (hours)**	**Description**
Alex	Djansezian	Aerospace Engineering	6.5	Hosted Subteam meeting, attended design meetings, general team meeting, ham radio study
Andres	Ruiz	Electromechanical Systems Engineering Technology	5	General, payload, and meeting with Jason for electronics
Charles	Kalis	Aerospace Engineering	-	-
Arbi	Khodaverdian	Mechanical Engineering	2.5	Attended general, design, and payload team meetings
Benjamin	Madrigal	Aerospace Engineering	3.15	
Brooks	Blenker	Aerospace Engineering	1	General Meeting
Bulmaro Jr.	Sanchez	Aerospace Engineering	7	General meeting, subteam meeting, research for kenetic energy and parchute sizing
Carlos Armando	Barrios	Mechanical Engineering	8	design, meetings, team progess review
Christopher	Kinyon	Aerospace Engineering	4	general meeting, design meeting, team lead meeting
Daniel	Castaneda	Aerospace Engineering	8.5	Design meeting, presentation prep, inputting grades, meeting handoff
Garrett Arian	Arian	Aerospace Engineering	8	Research into the amount of material needed for the fuselage, Launch vehicle meeting and general meetings
Iganus	Bala	Aerospace Engineering	10.05	General meeting, launch vehicle meeting, analysis meeting, reviewed design changes, articles on rocket stress analysis, solidworks course
Jacob	Swenke	Computer Engineering	5	AV meeting, team meeting, recovery meeting, research on vaccum chamber
Jason	Lono	Mechanical Engineering	5	Payload meeting, General meeting, disucsion for paylaod electronics
Jessica	Hernandez	Aerospace Engineering	2	general teaming meeting, emailed more schools
Josepf	Amador	Aerospace Engineering	4.5	research, solidworks, meeting: launch vehicle team and analysis team
Justin	Diaz	Aerospace Engineering	7.8	Researched fiberglass material. general meetings. Organized team meetings. 3D modeled new fuselage. Downloaded software.
Katarina	Aguayo	Aerospace Engineering	6	general meeting, pdr prep, meetings with subteams
Khai	Phan	Aerospace Engineering	-	-
Mary	Boddy	Aerospace Engineering	5	PDR, rocket sim, stress analysis
Naethan	Mallari	Mechanical Engineering	7	design, lead meeting, presentation prep for general meeting
Nathan	Lara	Aerospace Engineering	6.5	sub team meeting, worked on schematic revision, reserched code for arduino
Noah	Serio	Mechanical Engineering	10	Meetings, PDR Discussion
Rukie	Shendaj	Aerospace Engineering	3	Meetings, Research, Proposal Writing
Samantha	Guerrero	Physics	4	team meeting, design meeting
Samy	Ousman	Aerospace Engineering	8	design meeting, general meeting, parachute meeting, recovery meeting, research for pdr calculations
Sobhan	Akhtar	Aerospace Engineering	7.16	Launch team meeting, design meeting with team leads, analysis team meeting, design team meeting with launch vehicle team, Rocksim model had been adjusted by Garrett, looked into how to make our fins larger and more effective, needed to cut weight for rocket, I made adjustments to our Rocksim model based off constraints given by Garrett and ended with two different models with two different motors L3150VM and L1350CS, general team meeting
Tommy	Fuentes	Aerospace Engineering	7.5	PLI locking ring components cad modeling , team meeting, design meeting, and general meeting
Yosuf	Mayar	Mechanical Engineering	10.75	PDR draft, avionics meeting, design meeting, research, meeting with kat, sw model, designing vacuum chamber
Zachary	Smith	Mechanical Engineering	8.25	General meetings, solidworks updates
		Total Team Hours	171.16	

Figure A-2: Week 6 Hour Log Sheet for the Team

Week 7 October 4 - October 10

First Name	Last Name	Major	Time (hours)	Description
Alex	Djansezian	Aerospace Engineering	8	Hosted subteam meeting, attended general and design meeting, KE calculations for parachutes, studying for ham radio test
Andres	Ruiz	Electromechanical Systems Engineering Technology	3	General meeting and payload meeting
Charles	Kalis	Aerospace Engineering	-	-
Arbi	Khodaverdian	Mechanical Engineering	8	Hosted payload team meeting, attended design meeting, and worked on the payload CAD model redesign
Benjamin	Madrigal	Aerospace Engineering	4	General Meeting, Launch Vehicle design meeting, Modeling in SolidWorks
Brooks	Blenker	Aerospace Engineering	2.5	General Meeting, design meeting, scouring the hangars for a tap and die set
Bulmaro Jr.	Sanchez	Aerospace Engineering	8	General meeting, design meeting, subteam meeting, research and calculations of kenetic energy and parachute sizing
Carlos Armando	Barrios	Mechanical Engineering	18	PLI locking rings & hardware design/ modeling, meetings, team progress review
Christopher	Kinyon	Aerospace Engineering	3	general meeting and design meeting
Daniel	Castaneda	Aerospace Engineering	11.75	Kick off meeting, design meetings, general meetings, leads meeting, picking up and delivering filament
Garrett Arian	Arian	Aerospace Engineering	12	Launch vehicle meetings, created Von Karmen solidwork model, updated the Rocksim model with latest dimensions and weights, Motor casing research
Iganus	Bala	Aerospace Engineering	13.5	More stress analysis on rocket posted to analysis research folder, fin design changes, motor casing research, and team meetings
Jacob	Swenke	Computer Engineering	6	shopping for vacuum chamber parts, general meeting, design meeting
Jason	Lono	Mechanical Engineering	3	General and Payload meetings, Microcontroller research and compatibility
Jessica	Hernandez	Aerospace Engineering	7	general meeting, finalized outreach options for schools to consider, made outline of the options
Josepf	Amador	Aerospace Engineering	5.6	Research: soldiworks, testing design, Meeting: analysis, launch vehicle general
Justin	Diaz	Aerospace Engineering	5.2	Research fiberglass material. Testing solution research. CAD models. general meetings
Katarina	Aguayo	Aerospace Engineering	12	wrote code for calculations, one on one meetings, organize meetings, general meeting, team meeting, design meeting
Khai	Phan	Aerospace Engineering	4	general meeting, parachute KE, sizing calculations
Mary	Boddy	Aerospace Engineering	6	general meeting, PDR
Naethan	Mallari	Mechanical Engineering	8	general, design, lead meeting, sketch/designing logo, learnign adobe illustrator
Nathan	Lara	Aerospace Engineering	8	sub team meeting, Design team meeting, updated electrical schematic
Noah	Serio	Mechanical Engineering	10	-
Rukie	Shendaj	Aerospace Engineering	3	Meetings, Research, Report Writing (PDR)
Samantha	Guerrero	Physics	5	design meeting, subteam meeting, research into centering ring material and fin material (still in process)
Samy	Ousman	Aerospace Engineering	9.75	meeting with Kat, general meeting, parachute team meeting, design meeting, research for calculations, sizing estimates for launch team, fruity chutes call
Sobhan	Akhtar	Aerospace Engineering	12.25	Design team meeting for Launch Vehicle team, going with the L1350CS motor for our rocket, looking for motor casing and based off of research we'll be needing to use a 3 Grain casing, worked with Bala to research on fin cans and to correct the analysis done on the fuselage, analysis team meeting, design meeting with launch vehicle team, general team meeting, update to Rocksim model dimensions and margin, worked on finding bending stress for fuselage
Tommy	Fuentes	Aerospace Engineering	11.83	test 3D printing with 1.0 mm nozzles, CAD modeling of locking rings, components, and finalizing arrangement,General meeting, team design meeting.
Yosuf	Mayar	Mechanical Engineering	12.15	recovery, design, avionics, and general meetings, KE and parachute calculations, working on making calc with sheets, and shopping for parts
Zachary	Smith	Mechanical Engineering	8	General meetings, CAD updates, hardware research (hinges, screws, u-bolts)
		Total Team Hours	228.53	

Figure A-3: Week 7 Hour Log Sheet for the Team

Week 8 October 11 - October 17

First Name	Last Name	Major	Time (hours)	Description
Alex	Djansezian	Aerospace Engineering	8	General meeting, hosted subteam meeting, design meetings, PDR preparations, work on SRR
Andres	Ruiz	Electromechanical Systems Engineering Technology	5	General meeting, Payload meeting, Design meeting, and taking materials to Jason
Charles	Kalis	Aerospace Engineering	-	-
Arbi	Khodaverdian	Mechanical Engineering	7	Payload team meeting, general meeting, design meeting, and testing/adding new parts on payload CAD model
Benjamin	Madrigal	Aerospace Engineering	3.5	Meetings and SolidWorks modeling
Brooks	Blenker	Aerospace Engineering	-	-
Bulmaro Jr.	Sanchez	Aerospace Engineering	11	General meeting, subteam meeting, recovery meeting, sizing calc verifications with Kat, pdr prepartions
Carlos Armando	Barrios	Mechanical Engineering	12	
Christopher	Kinyon	Aerospace Engineering	8	General Meeting, Lead Meeting, design meeting, PDR safety research
Daniel	Castaneda	Aerospace Engineering	13	SRR, ConOps, Leads Meetig, Crowdfunding Page set up, Budgeting
Garrett Arian	Arian	Aerospace Engineering	15	SRR, ConOps, Meetings, Solidworks models, Rocksim modeling, Trade Studies
Iganus	Bala	Aerospace Engineering	12.33	Team meetings, fin design and drag characteristics, solid works course, uploaded research to drive folder
Jacob	Swenke	Computer Engineering	6	design meeting, general meeting, vaccum chamber construction
Jason	Lono	Mechanical Engineering	6	General, design, and payload meetings, electronics testing
Jessica	Hernandez	Aerospace Engineering	6	General meeting, school contacting
Josepf	Amador	Aerospace Engineering	4	Meeting, Solid Works research
Justin	Diaz	Aerospace Engineering	7	Continued work on CAD models, team meetings, pdr/srr risk analysis and work
Katarina	Aguayo	Aerospace Engineering	12	matlab code for calculations, research for calculations, general meeting, design meeting, prepare pdr, derived requirements
Khai	Phan	Aerospace Engineering	2	general meeting, parachute sizing calculations
Mary	Boddy	Aerospace Engineering	6	General Meeting, PDR, Sub Scale model
Naethan	Mallari	Mechanical Engineering	8	Gantt chart, design/lead/general meeting, worked on logo
Nathan	Lara	Aerospace Engineering	8	sub team meeting, general meeting, Design team meeting, updated the ardunio code,
Noah	Serio	Mechanical Engineering	6	Meetings, Payload ConOps, Armenian Relief, Team Coordination
Rukie	Shendaj	Aerospace Engineering	3	Meetings, Research, Report Writing (PDR)
Samantha	Guerrero	Physics	6.05	all meetings and research into centering rings, fin material, and conops
Samy	Ousman	Aerospace Engineering	10.5	calculations (parachute size, kinetic energy, descent time), pdr prep, team meeting, parachute meeting, design meeting, meeting with Kat, risk mitigation,
Sobhan	Akhtar	Aerospace Engineering	13.05	Launch vehicle team meeting, launch vehicle design meeting, calaculated Max bending stress for our rocket, NSL design meeting, Analysis team meeting, fin
Tommy	Fuentes	Aerospace Engineering	16	3D printing and making adjustments to prints of components of CO2 ejection system, research of dismantled solenoid, redesign of locking rings and arrangement of solenoids, general meeting, team design meeting
Yosuf	Mayar	Mechanical Engineering	12.5	Avionics, Recovery, and General meetings, research and designing AvBay and pressure bowl in SW
Zachary	Smith	Mechanical Engineering	15.25	Payload, Design, and General meetings, solidworks model changes and fine details added, hardware selection
		Total Team Hours	242.18	

Figure A-4: Week 8 Hour Log Sheet for the Team

Week 9	October 18 - October 24			
First Name	**Last Name**	**Major**	**Time (hours)**	**Description**
Alex	Djansezian	Aerospace Engineering	12	General meeting, hosted subteam meeting, SRR powerpoint, PDR report editing
Andres	Ruiz	Electromechanical Systems Engineering Technology	10	Payload meeting, PDR, SRR, General meeting
Charles	Kalis	Aerospace Engineering		
Arbi	Khodaverdian	Mechanical Engineering	12.5	Payload team meeting, general meeting, design meeting, working on ways to design a new hinge concept model for payload support arms, hinge hardware research, working on PDR
Benjamin	Madrigal	Aerospace Engineering	2.5	General meeting and launch vehicle design meeting
Brooks	Blenker	Aerospace Engineering	1	General Meeting
Bulmaro Jr.	Sanchez	Aerospace Engineering	12	General meeting, subteam meeting, SRR presentation and edits, pdr report writing
Carlos Armando	Barrios	Mechanical Engineering	10	
Christopher	Kinyon	Aerospace Engineering	5	SRR , team lead meeting
Daniel	Castaneda	Aerospace Engineering	13	SRR presentation edits, leads meeting, general meeting
Garrett Arian	Arian	Aerospace Engineering	15	SRR, Meetings, sub-scale research/Purchses, Rocksim model
Iganus	Bala	Aerospace Engineering	20.5	Team meetings and worked on the PDR. Ran multiple simulations and hand calculations to determine official launch day altitude, and decent times for the rocket and payload.
Jacob	Swenke	Computer Engineering	6	design meeting, general meeting, vaccum chamber construction
Jason	Lono	Mechanical Engineering	7	General and payload meetings, circuit wiring for payload system, PDR writting
Jessica	Hernandez	Aerospace Engineering	8	general meeting, social media site set up, outreach event organizing, supply researching
Josepf	Amador	Aerospace Engineering	23	PDR, Rocket apogee equations derivations and analysis
Justin	Diaz	Aerospace Engineering	9	CAD modeling, SRR risk analysis, team meeetings, Report help
Katarina	Aguayo	Aerospace Engineering	10	SRR, PDR, team meetings, general meeting
Khai	Phan	Aerospace Engineering	6	general team meetings, SRR risk mitigation and test plan ,PDR
Mary	Boddy	Aerospace Engineering	5	PDR, Mass and Wind variations calcs
Naethan	Mallari	Mechanical Engineering	10	SRR, Functional WBS, Product WBS, PDR report writing
Nathan	Lara	Aerospace Engineering	15	sub team meeting, general meeting, Design team meeting, worked on SRR, finialized the PLI electrical shcematic, formated and worked on PLI PDR draft
Noah	Serio	Mechanical Engineering	8.25	Payload Meeting, PDR, SRR, ConOps, GoFundMe, Solidworks Modeling, Derived Requirements
Rukie	Shendaj	Aerospace Engineering	3	Meetings, Research, Report Writing (PDR)
Samantha	Guerrero	Physics	10.2	design meetings, general meetings, PDR, research
Samy	Ousman	Aerospace Engineering	9.25	risk mitigation, test plan, parachute team meetings, con ops, calculations, ssr, pdr, general meeting
Sobhan	Akhtar	Aerospace Engineering	13.51	Launch vehicle PDR and SRR work, reupdated fin designs,trade matrices for fins and motor. Made plots for flight simulations at different wind speeds.
Tommy	Fuentes	Aerospace Engineering	16.45	PLI team meeting, SRR slides work and adding PLI CAD model pictures, adjustment to design to ensure nose cone will fit along with locking ring wall design made to fit flush with rocket outer wall, Continuation of printing components for ejection system, General meeting, team design meeiting, PDR drafting
Yosuf	Mayar	Mechanical Engineering	12	Worked on Vacuum chamber, finished test manual, finished printable sw model of AV bayfinished sw model of vacuum chamber, worked on SRR, subteam meeting, general meeting
Zachary	Smith	Mechanical Engineering	13	General and Subteam meetings, pdr writing and cad model changes
		Total Team Hours	298.16	

Figure A-5: Week 9 Hour Log Sheet for the Team

Week 10	October 25 - October 31			
First Name	**Last Name**	**Major**	**Time (hours)**	**Description**
Alex	Djansezian	Aerospace Engineering	9	-
Andres	Ruiz	Electromechanical Systems Engineering Technology	5.5	-
Charles	Kalis	Aerospace Engineering	7	PDR Edits
Arbi	Khodaverdian	Mechanical Engineering	7	Working on PDR, attending PDR writing meeting , payload team meeting
Benjamin	Madrigal	Aerospace Engineering	4.5	General meeting, SolidWorks modeling, and working on the PDR
Brooks	Blenker	Aerospace Engineering	1	
Bulmaro	Sanchez Jr.	Aerospace Engineering	10	Subteam meeting, general meeting, design meeting, updated BOM with shippig and taxes, PDR report and editing
Carlos Armando	Barrios	Mechanical Engineering	9	-
Christopher	Kinyon	Aerospace Engineering	10	design meeting, safety matrix work, LM presentation, gen meeting
Daniel	Castaneda	Aerospace Engineering	15.5	PDR draft, LM presentation, SRR prep
Garrett Arian	Arian	Aerospace Engineering	15	PDR writing, meetings, SRR and SRR presentations, PDR slides
Iganus	Bala	Aerospace Engineering	13.5	Reiterated official lauch day altitude and decent times using a more accurate model. Worked on PDR doc. Included stress analysis for rocket under expected max loads and results in PDR doc. Team meetings
Jacob	Swenke	Computer Engineering	7	design meeting, general meeting, vaccum chamber construction
Jason	Lono	Mechanical Engineering	8	-
Jessica	Hernandez	Aerospace Engineering	8	Social media site management, gengeral meeting, outreach organization, replying and corrdinating outreaches with schools
Josepf	Amador	Aerospace Engineering	9	Meetings, PDR, PDR Slides, Calculations
Justin	Diaz	Aerospace Engineering	8	team meetings, PDR work, BOM work, CAD models
Katarina	Aguayo	Aerospace Engineering	10	presentation practice, Lockheed presentation, writing SRR, writing PDR,
Khai	Phan	Aerospace Engineering	1	general team meetings
Mary	Boddy	Aerospace Engineering	6	Sub Scale model, rocket sim
Naethan	Mallari	Mechanical Engineering	9	SRR, PDR, Gantt Chart, general meeting
Nathan	Lara	Aerospace Engineering	16	SRR, PDR, Team meetings, Design/Drafting meeting, PDR review
Noah	Serio	Mechanical Engineering	12	SRR Edits, SRR Presentation, PDR Edits, Meetings
Rukie	Shendaj	Aerospace Engineering	-	-
Samantha	Guerrero	Physics	7	meetings, PDR ppt, research
Samy	Ousman	Aerospace Engineering	8.5	working on srr, working on pdr, drift entry, descent entry, meeting, BOM weights research and entry, editing
Sobhan	Akhtar	Aerospace Engineering	8.42	PDR work, Fixing flight simulations, developed various plots from Rocksim, found wind drifts at different wind speeds, NSL Team Meeting, PDR slides
Tommy	Fuentes	Aerospace Engineering	12.5	PDR drafting, meetings, 3D printing test locking rings,
Yosuf	Mayar	Mechanical Engineering	9.5	Building vacuum chamber, worked on PDR draft and sponsorship package, and general/subteam meetings
Zachary	Smith	Mechanical Engineering	11	General and Design meetings, finalizing solidworks design, pdr writing
		Total Team Hours	257.92	

Figure A-6: Week 10 Hour Log Sheet for the Team