York College of Pennsylvania
NASA Student Launch 2017-2018
Critical Design Report

The Aurora Project

441 Country Club Road
York, PA 17403

General Information

Contact Information:

YCP NASA Student Launch Team
York College of Pennsylvania
441 Country Club Road
York, PA 17403

Campus Leader:

Dr. Joseph Merkle (Dean of Student Affairs)
(717) 815-1460
jmerkle@ycp.edu

Adult Educators:

Dr. Tristan Ericson (Professor of Mechanical Engineering)
(717) 815-6523
tericson@ycp.edu

Dr. William Kreiger (Assistant Professor of Earth Sciences)
(717) 815-1379
wkreiger@ycp.edu

Team Leaders:

Kyle Abrahims (Team Captain)
NAR L2 CC: 99631
(717) 698-8566
kabrahims@ycp.edu

Jacob Van Brunt (Team Safety Officer)
jvanbrunt@ycp.edu

Team Mentor:

Brian Hastings
NAR Representative
(717) 586-7166
NAR L3CC: 96571

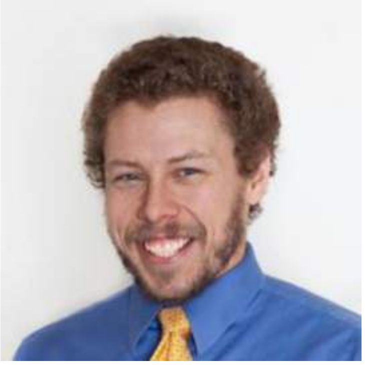
Addressing: For Launch Assistance, Mentoring, and Reviewing our team will be working with the local NAR representatives along with MDRA (Maryland-Delaware Rocketry Association) members for all questions and launches.

Table of Contents

Meet the Team

Advisers

Dr. Tristan Ericson



Dr. Ericson is an assistant professor of mechanical engineering at York College of Pennsylvania. He earned his undergraduate degree from York College of Pennsylvania and his doctorate from Ohio State University in 2012. His research interests include vibrations of multi-body systems, non-linear dynamics, and gear dynamics. He also has had past experience with model rocketry and is excited to work with this group of students. Dr. Ericson currently resides in York with his family.

Dr. William Kreiger

Dr. Krieger is a professor in the life sciences at York College of Pennsylvania. He teaches Earth Science, Earth and Space, and Astronomy courses at the college and has been teaching at York for over 25 years. He is an advocate for future educators and loves to help young students in achieving their goals. Dr. Kreiger resides in York with his family.

Team Lead

Kyle A.

Kyle is a full-time sophomore mechanical engineering major at York College of Pennsylvania who has competed on some of the biggest stages on the national model rocketry circuit. An avid model rocketry builder since age 10, he was a member of the Spring Grove Area High School team from 2011-2015 that competed in both the Team America Rocketry Challenge and the NASA Student Launch Initiative. In 2015, he captained his Team America Rocketry Challenge team to an 8th place national finish out of over 1000 teams nationwide. In 2015, he was also the captain of the Spring Grove Area High School team that won the altitude championship in the high school division of the NASA Student Launch Program. He brings a wealth of knowledge to the team from these previous endeavors and hopes to continue his success at York College.

The Team

Saumil P. (Co-Captain, Recovery System)

Saumil is a sophomore mechanical engineering major from Tremonton, Utah. He is the secretary of the NASA Student launch club here at YCP. He chose mechanical engineering because engineering is in every aspect of our lives and engineering is one of the only fields where failure is not the end. Engineers learn from their failures and the more they fail, the closer they are to the solution. He has always enjoyed learning about aerospace related topics and that is exactly what interested me in this club. He really enjoys learning more about rockets and this club has taught him a lot.

Tanner M. (Co-Captain, Flight Dynamics)

As a student of York College, Tanner is studying mechanical engineering. His extracurricular activities include ultimate frisbee, carpentry, and drawing among other things. The reason Tanner joined the NASA SL club is because for years he has had a fascination with the aerospace industry. When I saw that he could be a part of that community he jumped at the opportunity. Also, he really enjoys building whether it's carpentry or something else, and this is a great experience to do more. Lastly, being an engineering student it gives Tanner the opportunity to practice his skills and develop as a professional.

Eric G. (Payload Lead)

Eric is a senior electrical engineering student at York College of Pennsylvania. He is currently the leading electrical engineer for the payload design and integration. Eric is also the leading electrical engineer on the FSAE team at York College. Apart from school, Eric enjoys riding and working on motorcycles in his free time.

Jacob V.B. (Electronics and Safety Officer)

Jacob is a sophomore student at York College of Pennsylvania studying mechanical engineering. Jacob is the designated safety officer for the club as well. Jacob's previous engineering experience comes from being a member of his high school's First Robotics club where he loved making and building parts. This will be Jacob's first year being a part of a rocket club he hopes to learn as much as he can and be able to use what he learns this year in his future career.

Blake P. (Project Scheduling)

Blake is a freshman majoring in Mechanical Engineering. In his free time, he enjoys reading, driving, working on cars, and computer programming. He has done hobby model rocketry for several years and is excited to learn more advanced rocketry techniques and participate in a high-level competition.

Benjamin S. (Payload Team)

Benjamin is a sophomore mechanical engineering major from Navarre, Ohio. Ben chose to be a mechanical engineer because his uncle and father are engineers. Their careers and their work has always fascinated him and has pushed him into the field of engineering. He chose mechanical for its diversity throughout all the disciplines of engineering and he plans to pursue a career in mechanical design.

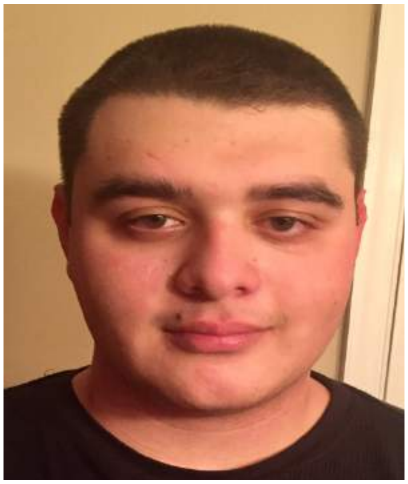
Vincent R. (Rocket Construction)

My name is Vincent Ruggiero and I am going for a major in mechanical engineering. I am from Berlin, New Jersey. I chose mechanical engineering because of a love I have for understanding moving pieces in everyday objects combined with a skill for mathematics. I was in a robotics club in high school so building things from scratch with a goal in mind has always been fun for me, and I'm eager to continue with a harder challenge in college.

Cassidy V. (Educational Engagement)

Cassidy is a freshman mechanical engineering major at York College. She is very excited to be a part of the NASA launch team because she finds aerospace engineering fascinating, and hopes to pursue a career in the field. She feels that engineering is an important job because of the many impacts it has on everyday life. Among other things, she enjoys art, as well as sewing, knitting, and crafting in general. She has also had experience working in a rod shop with her dad.

Joe R. (Mechanical Work)



Joe is a freshman mechanical engineering major from Buena, New Jersey. Joe choose mechanical engineering because he enjoys designing and making parts. In his free time, he enjoys outdoor activities such as fishing, kayaking, and spending time with his family. Being fascinated with rocketry, he has experience with model rockets, and is excited to learn more.

Section 1: Summary of CDR Report

1.1 - Team Summary

All team summary information was included in the general information section of this PDR report. See page 2 of this document for any information needed.

1.2 - Launch Vehicle Summary

Size: 11.50 feet
Mass: 28.49 pounds
Final Motor Choice: *Aerotech L 1150R-PS (3517 N-s)*
Recovery Subsystem:

1. Dual Deployment Via Electronics Bay with added redundancy
2. 24-inch drogue parachute made by Fruity Chutes deployed at apogee
3. 120-inch parachute made by Paramedichutes with Cd of 1.6 to be deployed at 600 feet

Rail Size: 12 ft. 1515 Rail
Milestone Review Flysheet: See attached milestone review flysheet for any additional vehicle information that is needed.

1.3 - Payload Summary

Payload Title: **Sparta Lander**
Payload Summary: Our payload will feature a four-wheeled rover that will have wheels larger than the base plate, which would hold our servos, motors, and sensors. The base plate will hold the necessary components to allow the rover to move forward and clear any obstacles. The rocket design has been analyzed and documented to include a 26-inch payload tube that will be attached to the nosecone via a set number of shear pins that will be determined during testing. The payload tube and attached nose-cone will be ejected from the front body-tube when the main parachute is deployed. This payload tube and nose-cone attachment will be held to the main body of the rocket via shock cord and a U-bolt on its back edge. After landing, the nose-cone will be ejected from the payload tube via a CO2 ejection system, allowing one-side of the body-tube to be open to the environment. After the nose-cone ejection, a gear system will be utilized. This gear system will be located behind the payload and housed within a tubing coupler. This gear system will thread a piece of all-thread out through a bulkhead and push the rover out the top of the payload tube, where the nose-cone was once attached. The rover will exit the payload tube and once fully emerged, will begin its autonomous movement to a distance at least five feet from the rocket's body tube. The rover will be equipped with Arduino programmable boards which will have multiple sensors plugged into them. This will allow for wheel movement as well as the rover to steer around any very large objects that may be in the way of its travel path. See the payload section of this report for more details and drawings.

Section 2: Changes Made from Proposal

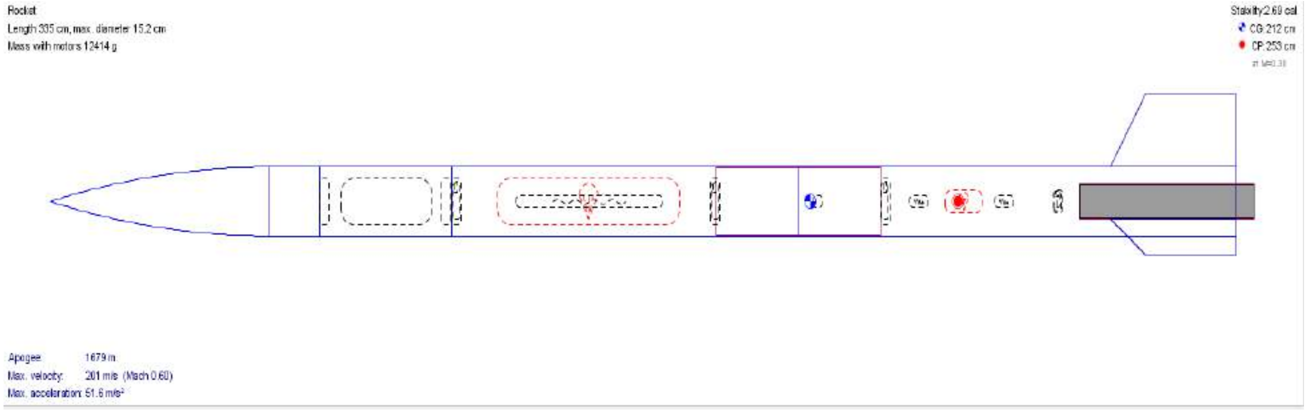


Fig 2.1: Proposed Rocket Design for PDR Report

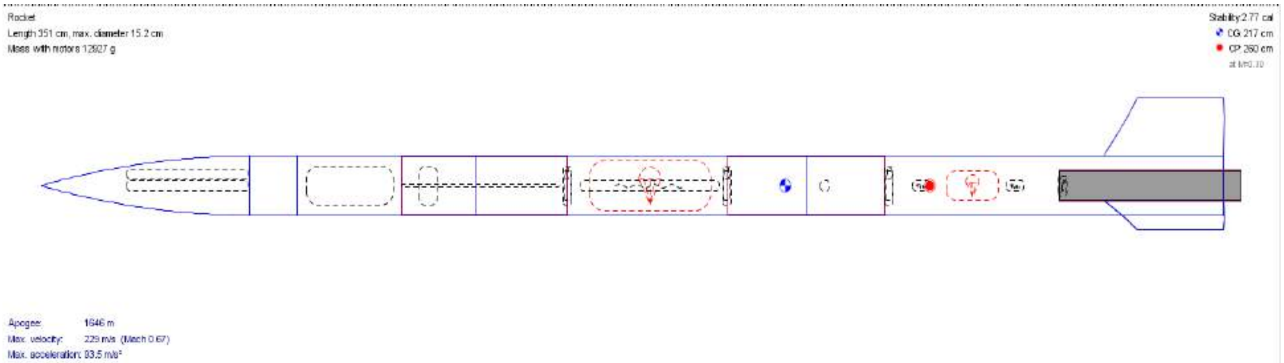


Fig 2.2: Final Rocket Design for CDR Report

Changes Made to Vehicle:

- 4A.3 - The payload tube length has changed from 22 to 26 inches to accommodate new rover sensors and wireless technology to power the gear system (See Sec. 6E)
- 4A.3 – 0.08 pounds has been added to the quick-links in the rocket design due to increase in manufacturing weight
- 4A.3 – 0.50 pounds has been added to the payload mass to accommodate additional sensors needed for the rover and wireless devices to power gear system
- 4A.3 – 0.55 pounds has been added to the coupler section between the payload tube and front body tube to accommodate gear system
- 4A.3 – Fin height has been changed from 17 cm to 15 cm to maintain stability margin of subscale vehicle and previous full-scale vehicle design due to added mass of vehicle
- 4A.3 - Total length of the rocket has now changed from 134 to 138 inches due to payload tube length change
- 4A.3 - Total mass of the rocket has now changed from 27.36 pounds to 28.49 pounds
- 6E – CO2 ejection system will now be used to separate nose-cone from payload tube

Changes Made to Payload:

- 6C – Total payload mass has changed from 3.0 pounds to 3.5 pounds to accommodate additional sensors and wireless devices to power gear system which will push the rover out of the body-tube after flight
- 6C – Updated wiring diagram as well as sensor list to be used on the rover
- 6C – Updated Arduino coding as seen in section 6C
- 6E – Gear system now employed to push rover out after flight which will be controlled wirelessly

Changes Made to Project Plan:

- 7A – Additional tests have been added to be done before full-scale flight
    - Shear Pin Testing – Between nose-cone and payload tube
    - CO2 Ejection Testing – To ensure that nose-cone does not travel further than 10 feet away from launch vehicle
    - Ejection Testing – To ensure the correct amount of black powder charge mass for drogue and main parachute deployment
    - Fin Can Testing – Additional CFD and Wind-Tunnel Testing
- 7C – Team derived requirements updated
- 7D – Educational engagement activities added
- 7E - Line Item Budget Updated

Section 3: Facilities and Equipment

3.1 - Facilities

York College of Pennsylvania Kinsley Engineering Center:

a. Hours: *Shop Access*: Monday through Friday 6 AM to 4 PM
   Computer Labs and Class Rooms: 24-hour access
   i. Room 128:
      1. Agilent Oscilloscope:
         Used to induce a clock in electrical components.
      2. Agilent Dual output DC power supply:
         a. Used to power electrical components while building them.
   ii. Room 133:
      1. Wind tunnel:
         a. Used for testing rocket parts aerodynamics and air flow.
   iii. Room 135:
      1. Dimension Print 3-D printer:
         a. Use for printing plastic computer designed parts.
      2. Tinius Olsen 50ST Structural Stress Analyzer:
         a. Use to test how different materials will handle flight stress.
      3. Instron Compression tester:
         a. Used to test how different materials will compress during launch.
      4. Computers with Microsoft Office and Solidworks' Programs
   iv. Room 138:
      1. Bridgeport manual mill:
         a. Allows the team to mill metal to the appropriate dimensions and tolerances required by design.
      2. HAAS CNC mill:
         a. Gives the team the ability to design parts on the computer and have them cut out of stock.
      3. HAAS CNC lathe:
         a. Used to make circular parts designed on the computer out of stock.
      4. Wilton 20-inch drill press:
         a. Used to put holes in parts or other material.
      5. DoAll Band saw:
         a. Used to cut large pieces of kinds of material.
      6. Hardinge manual lathe:
         a. Used for cutting or milling circular material and treading parts.
      7. Clausing manual lathe:
         a. Used for cutting and milling circular material.

8. DeWalt 16-inch Planer:
    a. Used to smooth large wood planks.
9. Stopsaw 36-inch table saw:
    a. Used for cutting various lengths of wood.
10. DeWalt handheld drills:
    a. Used for putting fasteners into and drilling material.
11. Bridgewood 15-inch bandsaw:
    a. Used for cutting small wood pieces and intricate designs.
12. DeWalt chop saw:
    a. Used for cutting large lengths of wood.
13. Bosch wood CNC machine:
    a. Used for cutting wood parts designed on the computer.

YCP Garage located .2 miles from Campus:

a) Hours: 24-hour access via key entry
b) Used for storage and as workspace
    1. Belt sander:
        a. Used for smoothing wood surfaces and taking small amounts of material off parts.

Description of Computer Equipment:

Every computer in the Kinsley Engineering Center contains Microsoft office, Solidworks, C ++, Python, and Matlab software that can be used for our project.

3.2 - Launch Site:

MDRA Field: Higg's Farm in Price, MD

1. MDRA Launch field will be used for all sub-scale and full-scale testing.

3.3 - Materials/Supplies

1. Supplies will be ordered on an as is needed basis. Basic rockets supplies' such as body tubes, couplers, key switches, and switches have already been ordered and have arrived on campus. The majority of electrical supplies needed such as wire, Arduinos', breadboards, exc., are available for use in the Kinsley Engineering Center. The rest of our supplies will be available and ordered from vendors that Kyle is familiar with such as Animal Motor Works and Apogee Components.

Section 4: Vehicle Criteria

Subsection 4A: Selection, Design, and Rationale of Launch Vehicle

4A.1 - Mission Success Statement and Supporting Criteria

Mission Success / Team Success Statement:

The York College of PA NASA Student Launch Team wants to build the best end product as possible in correlation to the team member's individual skills and also use this project as an opportunity to grow the team's knowledge individually and as a team. We as a team will require that the quality of all components will be created to a maximum factor of safety and created in a timely manner in order to reach the goals set by NASA in this year's competition.

Mission Success Criteria:

1. The vehicle must have an apogee of 5280 feet AGL.
2. The vehicle must be recoverable and reusable.
3. The vehicle will not exceed Mach 1 during flight.
4. The vehicle must maintain stability of 2.5 or more.

4A.2 - System Level Design and Justification

The final structure of the rocket must be capable of withstanding the expected forces during flight, and also be capable of being reused after flight. This means that the rocket overall must be both strong and durable in order to meet those requirements. The rocket was designed by taking these forces into account and also by using lists created by the team to make sure that all needed internal components are able to fit inside the rocket. This includes and is not limited to parachutes, U-bolts, shock cord, electronics, and payload parts and sensors.

Through these requirements, the design of the rocket requires a certain balance between strength and weight based on material and size. In order to help our decision - making process during *The Preliminary Design Review* we used decision matrices to help in our decisions. Ultimately through these charts and through team brainstorming we were able to come up with a solidified design that we feel is capable of having a safe and successful launch and also capable of being reused.

As seen during PDR, we used a decision matrix to help find the proper materials for many of the parts that we planned to use in the full-scale rocket. For CDR, we have chosen our final components to be used on the full-scale rocket based on these decision matrices.

Airframe (Body-Tubes)

The rocket itself is made up of a series of sub-systems, with one of the main ones being the main airframe. This airframe is made up of a series of body tubes. The body tubes are essential to the performance of the vehicle from both a structural strength perspective and also from an aerodynamics perspective. By researching materials and industry standards, the table below was then created to prepare the normalization values which be used within our decision matrix. We decided to leave maximum temperature out of our decision matrix. This is due to the low amount of materials on the rocket that experience extreme temperatures during flight. The motor mount tube and the fins will be discussed later. These two parts have both been specifically designed to use heat resistant materials. This is to help from material malfunction and warping during flight.

Components	Ultimate Strength (KSI)	Weight (lb/in^3)	Max Temperature (F)	Poisson's Ratio
Kevlar	522	0.052	850	0.36
Fiberglass	300	0.055	2030	0.21
Wood (Birch)	5.8	0.024	446	0.40
Carbon Fiber	595	0.047	6332	0.10-0.20
Phenolic	35	0.049	257	0.24
Aluminum	45	0.098	1120	0.33

Fig 4.1: Material Properties

Factors	Score Used in Decision Matrix
Safety	1-6; Highest Safety Material Gets a 1
Weight (Weighted By 2)	1-6; Lightest Weight Material Gets a 1
Cost (Weighted By 2)	1-6; Cheapest Material Gets a 1
Strength	1-6; Strongest Material Gets a 1
Poisson's Ratio	1-6; Lowest Poisson's Ratio Gets a 1

Fig 4.2: Scoring Chart for Decision Matrix

The following decision matrix was then calculated and used to help in the decision process for materials that would be used as part of the rocket's subsystem and main airframe. The following decision matrix is seen below.

Components	Safety	Weight (X 2)	Cost (X 2)	Strength	Poisson	Total
Kevlar	3	8	10	2	5	28
Fiberglass	4	10	6	3	2	25
Wood(Birch)	6	2	2	6	6	22
Carbon Fiber	2	4	12	1	1	20
Phenolic	5	6	4	5	3	23
Aluminum	1	12	8	4	4	29

Fig 4.3: Decision Matrix

According to the decision matrix above, the body tubes should be constructed from carbon fiber. But due to budget constraints, we had to research other cheaper alternatives. The 2nd best material on the decision matrix proved to be phenolic tubing. After speaking with NAR representatives and through previous experience, we found that they make fiberglass wrapped phenolic tubing. Fiberglass wrapped phenolic tubing is strong enough to withstand the high forces put on the airframe during launch with a tensile strength ranging between 440 and 665 ksi depending on the grade of fiberglass used. It is also very heat and fire resistant due to its method of manufacture, and is desirable due to its relatively lower cost compared to carbon fiber tubing (1/2 the cost).

One major concern of the fiberglass wrapped phenolic tubing is that it could increase aerodynamic drag significantly due to its rough outer surface. Because the body tubes comprise the largest surface exposed to the airflow, the aerodynamic properties of the body tubes are highly relevant to the altitude gained by the vehicle. Because aerodynamic flow is disrupted by rough surfaces on the airframe and not so much by the material, the airframe will be sanded to as smooth as possible. By choosing fiberglass wrapped tubing, it should not affect aerodynamic performance compared to the carbon fiber in any significant way. The sanding of the body tube will be more critical to limit aerodynamic disturbance and also help with rocket flight profile.

Additionally, as the largest structure in the rocket, the body tubes represent the largest collection of structural mass in the rocket. Based on our design, the relative mass increase of the fiberglass wrapped phenolic body tubes compared to carbon-fiber tubing does not hurt the stability or our relative projected height. Rather the projected mass of the body tubes is critical in getting our design close to the mile height goal.

Final Airframe Material: Fiberglass Wrapped Phenolic Tubing

Coupler Tubing

The coupler is a component that joins two body tube sections. For any coupler in the airframe, the length will be at least 12 inches. This is based on the theory that the length of coupler into the body-tube, needs to be at least the same length as the diameter of the airframe tubing. This is to ensure structural stability and to ensure that the rocket does not tilt upon launch. These couplers also must be able to withstand forces experienced during rocket ascent to keep the structure of the body attached. This includes shear and torsional stresses from the body tubes during flight as well as axial stress in the electronics bay coupler that holds the electrical components inside.

By using phenolic coupler tubing, we would have a few benefits. It would save us the time of designing and 3-D printing our own couplers. This would reduce construction time of the parts needed to build the completed rocket. The phenolic couplers also provide enough strength for the rocket flight. This has been proven by previous flights done by the team. Because of phenolic's proven track-record, no additional testing would need to be completed on these couplers to ensure flight worthiness.

For these reasons, the team has decided to use phenolic tubing couplers in our final rocket design.

Final Coupler Material: Phenolic Tubing

Bulkheads

Bulkheads are typically flat plates used create airtight spaces in a rocket. This may be done to create a compartment that is unaffected by ejection charges, or to help in the separation of a specific part of the rocket. In our case, the bulkheads are not only used to seal off compartments, but also used as mounting points for U-Bolts to the main airframe. These U-bolts then allow for a quick link to be attached which allows for quick connection and disconnection of shock cord and parachutes to the main airframe.

Both aluminum and wood were considered for the bulkheads within our rocket. Aluminum has a high yield stress which is a big factor in preventing plate and bearing stress failures in the bulkhead due to the U-bolts that are bolted through the material. But aluminum would add additional weight to the airframe as well as be hard to bond to the airframe because it does not have a rough surface. Wood on the other hand is rough and can be bonded to the airframe rather easily. The wood is also light and reduces rocket total weight on the pad. The biggest concern for the wooden bulkhead is to ensure that it is thick enough to ensure that bearing stress failure at the U-bolt does not occur.

Based on prior experience using bulkheads and through testing done in the laboratory, wooden bulkheads that are ½” thick for this application are able to withstand the bearing stresses placed on them. We found that ½” thick wooden bulkheads are able to withstand forces upward of 2,000 pounds before they begin to rip through the wood. We as a team have decided to use wooden bulkheads due to their reliability, strong testing results, and for cost saving measures.

Final Bulkhead Material – ½” thick wood / lumber pieces

Centering Rings

The purpose of a centering ring is to center a smaller cylindrical body or tube inside a larger diameter one. The team has chosen to use 3 centering rings in the rocket on the motor tube. This will ensure that the motor tube is centered and will not change orientation during flight.

Our centering rings will be made with fiberglass that will be cut using a band-saw and various hole-saws till we reach the desired dimensions. The general dimensions of the centering rings include an outer diameter of 6 inches with an inner diameter of 75 mm. The thickness of each ring will be approximately 0.25 inch.

Fiberglass was chosen for our centering rings because of its availability, relative strength, and weight. Overall our design calls for 3 centering rings to be used for the motor mount of our rocket. With 3 centering rings used instead of 2, that reduces the amount of force taken on by each centering ring. Based on our calculations, ¼” thick fiberglass centering rings will be strong enough to withstand the forces of the motor. Fiberglass is also easy to work with as long as safety measures are taken making it nice for some of our younger members.

Final Centering Ring Material - Fiberglass

U-Bolts

For the rocket, we will use ¼” thick steel U-bolts throughout. This was determined by finding the stress/force put on the U-bolt by the quick link and shock-cord during flight. We found that during dynamic ejection events, upwards of 2000 pounds of force could be placed on the U-bolt. By finding this, we compared that number to the maximum shear stress allowable for the steel quick link with a factor of safety of 2.0. The steel U-bolt was the lightest and cheapest option that also maintained the maximum shear strength needed to completely maintain its elastic strength during flight.

Final U-Bolt Material and Size: Steel / ¼” thick

Fin Design

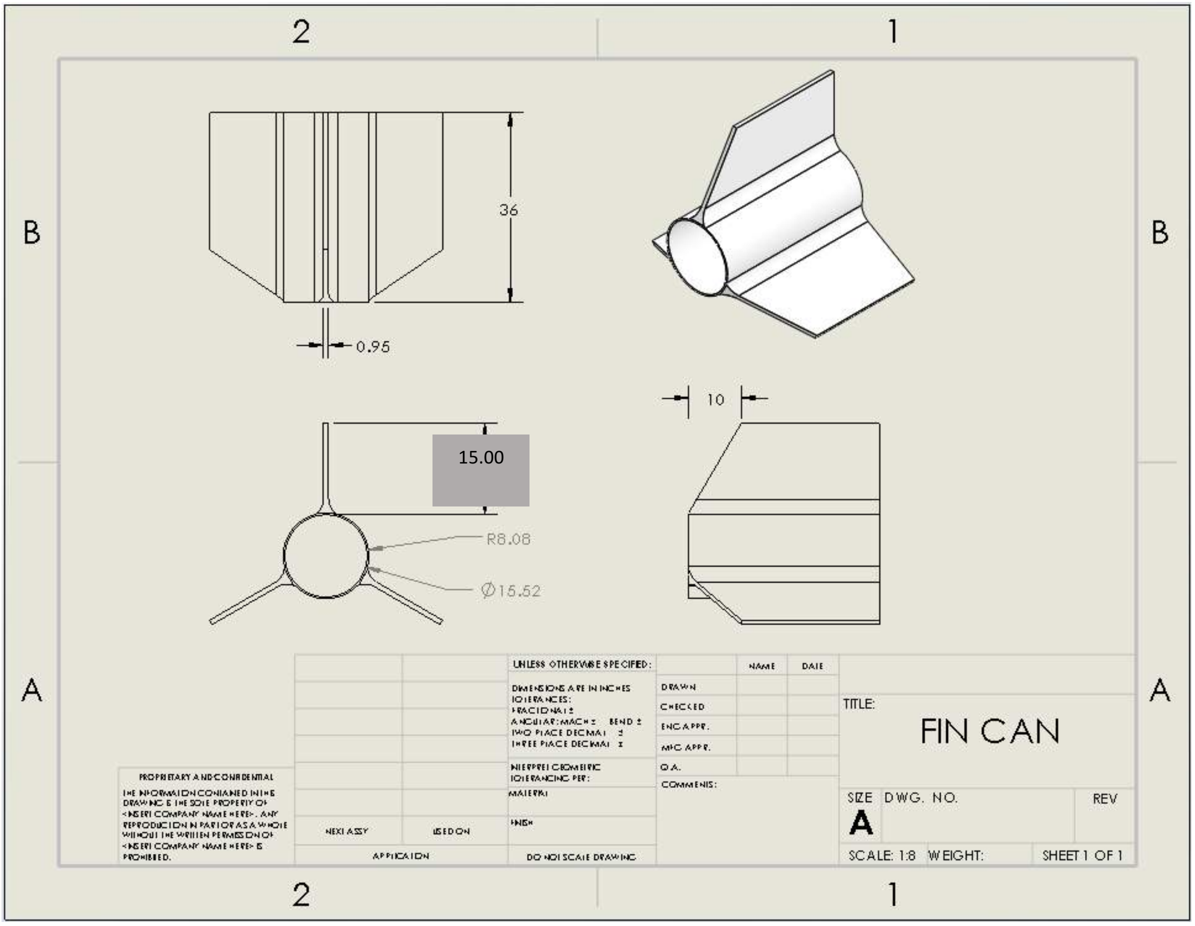
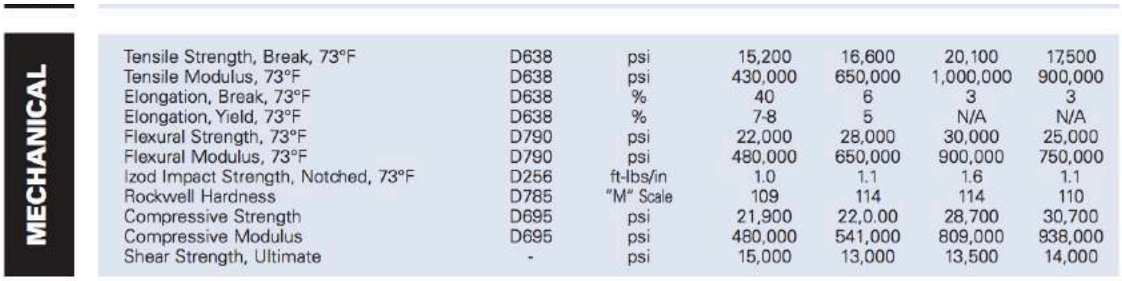


Fig 4.4: Fin Can Design

As discussed in the PDR, we plan on using a 3-D printed fin can system. The proposed rocket has three fins that are 120 degrees from each other, each with a trapezoidal design that stretches 36 centimeters long by 15 centimeters tall with a diagonal. This creates a total surface area of 465 square centimeters. The base will be around 0.25 inches thick and made to a curvature at the front and rear to decrease drag. The fins will be made to fillet with the cylinder and will be one connected piece that is attached to the base. The fin can system is shown above in figure 3.4, which is an accurate drawing to represent the exact dimensions of the fin can system that will be 3-D printed. The component continues to be worked on and designed to ensure the utmost accuracy as well as to ensure that no problems will occur with the tolerances of the fillets during printing.

When considering materials for our fin-can, we were recommended to use Ultem plastic. Ultem is valued and used because of its cost efficiency and relative strength and ability to hold up to physical stresses; tensile strength in particular. For its high tensile strength, high durability, and ability to withstand high temperatures we have chosen to use Ultem plastic material when making our 3-D printed fin-can.



MECHANICAL	Tensile Strength, Break, 73°F	D638	psi	15,200	16,600	20,100	17,500
	Tensile Modulus, 73°F	D638	psi	430,000	650,000	1,000,000	900,000
	Elongation, Break, 73°F	D638	%	40	6	3	3
	Elongation, Yield, 73°F	D638	%	7-8	5	N/A	N/A
	Flexural Strength, 73°F	D790	psi	22,000	28,000	30,000	25,000
	Flexural Modulus, 73°F	D790	psi	480,000	650,000	900,000	750,000
	Izod Impact Strength, Notched, 73°F	D256	ft-lbs/in	1.0	1.1	1.6	1.1
	Rockwell Hardness	D785	"M" Scale	109	114	114	110
	Compressive Strength	D695	psi	21,900	22,0.00	28,700	30,700
	Compressive Modulus	D695	psi	480,000	541,000	809,000	938,000
	Shear Strength, Ultimate	-	psi	15,000	13,000	13,500	14,000

Fig 4.5 – Material Properties of Ultem Plastic
(http://www.sdplastics.com/ensinger/ultem.pdf)

The fin can system will be one solid piece that is printed in one session. The fin can system will also be the exact diameter of the outside of the body tube. This will help create a friction fit between the body tube and the fin can system. For additional strength, screws will also be placed in between the fins to help secure the fin-can to the body tube.

For printing, *Hoosier Pattern Incorporated* out of Decatur, Indiana will be completing our 3-D printing. This company has offered us a discount for its services and also has large enough 3-D printers to be able to print our fin can as 1 solid piece.

A scaled fin can was 3-D printed and used on our subscale rocket. During the subscale flights, the fin-can worked and functioned as designed. The fin-can held up to the forces of flight and also the impact forces that were generated during landing. The fin-can was inspected after flight and showed no signs of zippering or cracking. From these results, we concluded that our fin-can system will work and also have the strength to withstand a full-scale flight test. Testing of our full-scale 3-D printed fin can system will also be done in the scaled wind tunnel machine located at York College of Pennsylvania. Because of the design parameters, we will continue testing work to ensure aerodynamic flow and structural integrity before it is launched on the full-scale rocket before FRR.

Final Fin-Can Material: Ultem Plastic

Nose-Cone

When designing the rocket, we chose to design the airframe first and choose a nosecone last when designing the assembled rocket. This was done for a specific reason. The main reason being that we were able to simulate different nose-cone drag values based on the shape of the nose cone. By being able to simulate different nose-cones, we could choose different shapes to help us get closer to our 5,280 feet apogee goal.

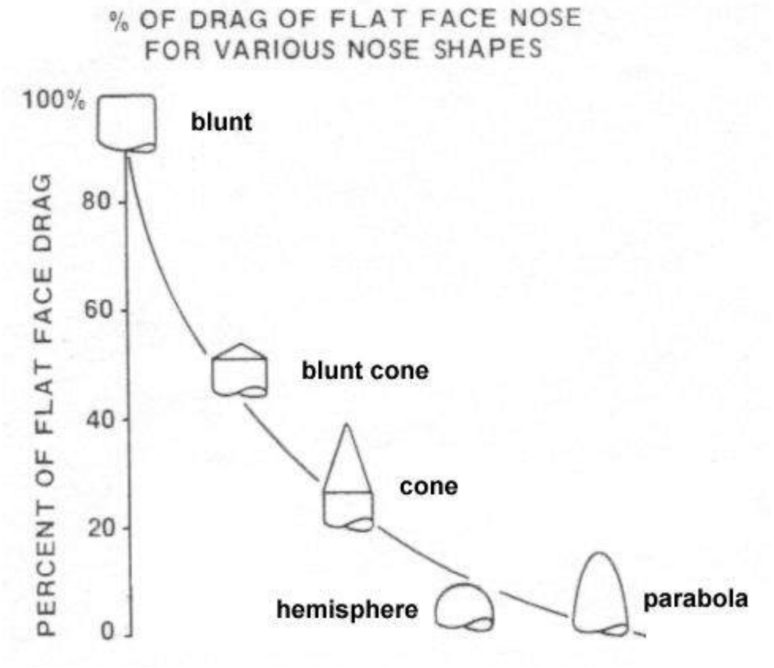


Fig 4.6: Rocket Nose Percent Drag Calculations Based on Nose-Cone Shape
(http://www.aerospaceweb.org/question/aerodynamics/q0151.shtml)

Based on our initial mass calculations, we came up with an ideal motor that we wanted to use for our final rocket design. After calculating thrust values, we began to look at different nose-cone shapes and how they would affect the apogee that the rocket would reach. Based on figure 3.6, we can see that a parabolic nose-cone has nearly 20 percent less drag that a conical nose-cone. Through simulation techniques on OpenRocket, we found that a parabolic nose-cone gave us an apogee height of 5,650 feet. By replacing the parabolic nose-cone with a conical nose-cone, we decreased the height of our rocket by nearly 250 feet to around 5,400 feet. This was a value that we felt comfortable with and that is why we selected a conical nose-cone for our proposed rocket design. We then chose the 6.00” fiberglass nosecone from Public Missles Limited based on the cost and relative strength of fiberglass compared to 3-D printing our own nose-cone.

Final Nose-Cone Material and Manufacturer: Fiberglass / Public Missiles Limited

4A.3 – Final Vehicle Design

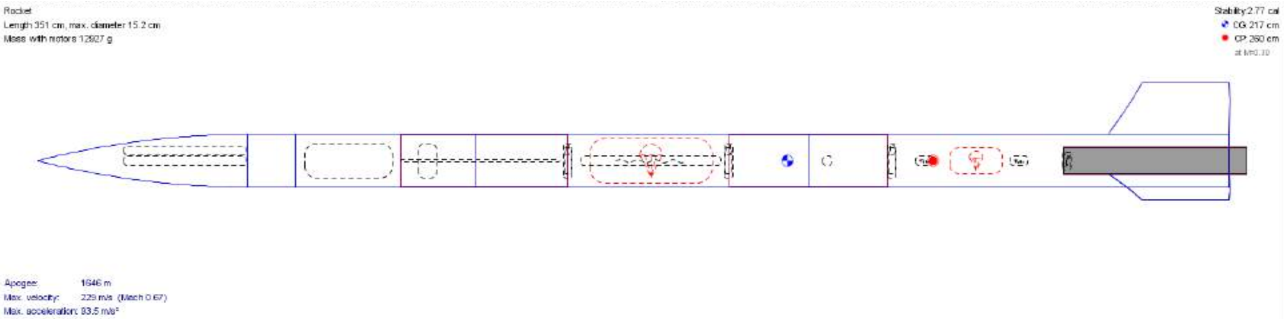


Fig. 4.7: Final Vehicle Design for CDR Report with Loaded Motor Mass

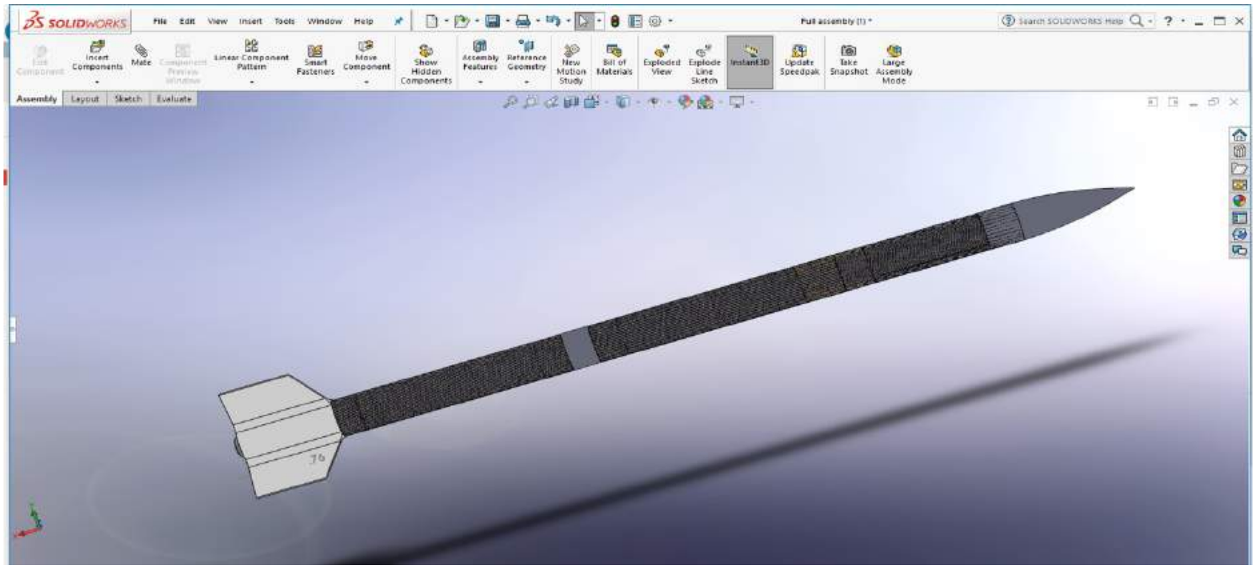


Fig 4.8: 3D CAD Rendering of Full-Scale Rocket

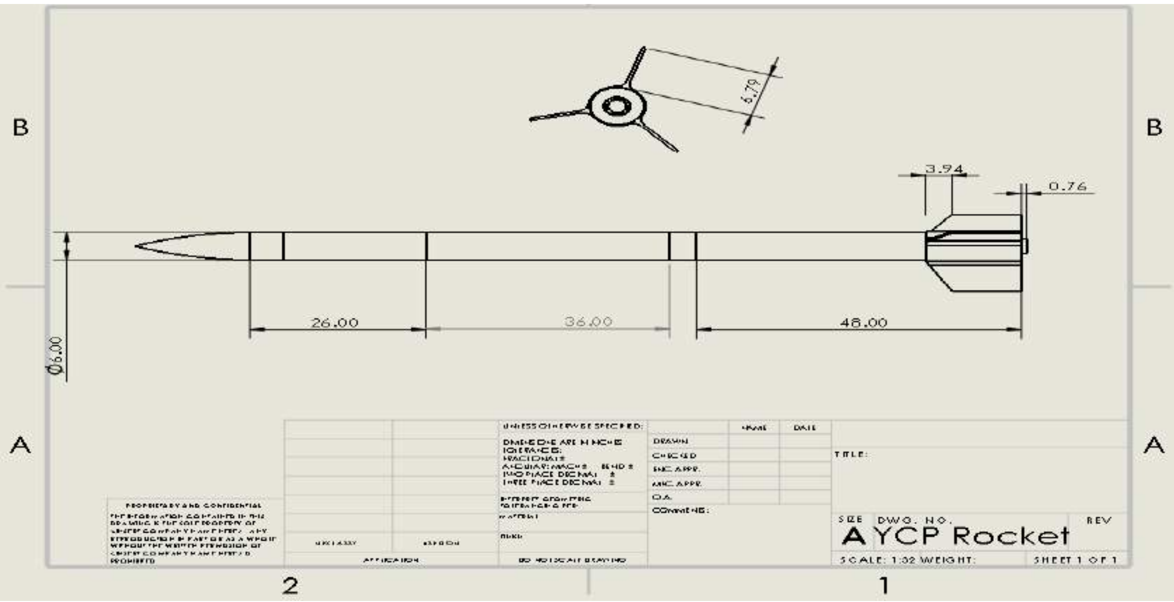


Fig 4.9: 1:32 Scale Drawing of Full-Scale Rocket

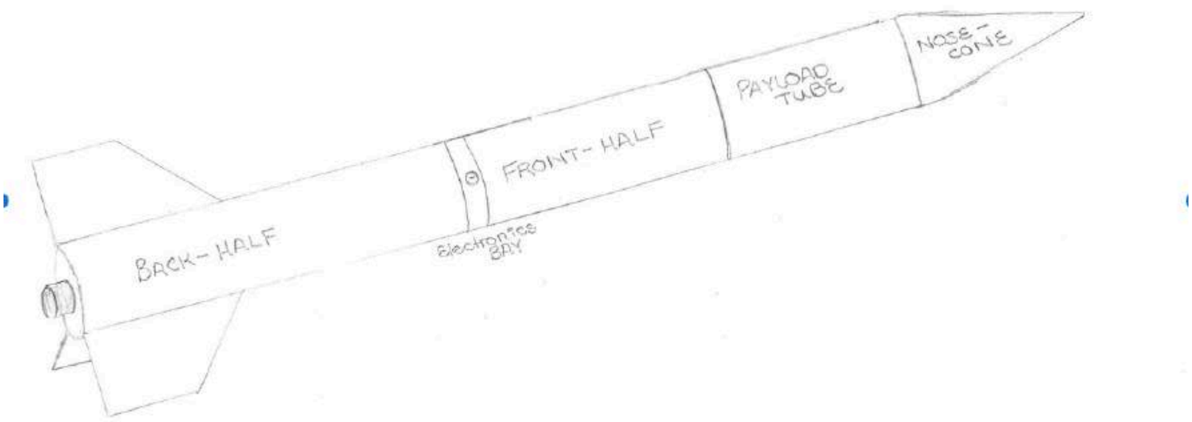


Fig 4.10: Full-Scale Rocket Diagram with Labeled Airframe Components

Overall Vehicle Design
The proposed rocket will be 138 inches in length counting the nose cone. The planned mass of the rocket will be 12,927 grams or just over 28.49 pounds with our proposed engine, The Aerotech L-1150 Red, loaded in it. The static stability margin of the rocket is calculated to 2.77 cal, which was verified via OpenRocket simulation as well as through hand calculations. Our design goal has our margin of stability being over 2.5 and less than 3.5. This stability margin is slightly over stable, but falls with the team's acceptable range. See Figure 3.7 for more information.

Drag Reduction
The team will also focus a significant amount on drag reduction. In our case, we are dealing with parasite drag, also known as non-lifting drag. It is known that as velocity increases, the stagnation pressure and the rear pressure due to the momentum of air all increase. To reduce drag on our rocket, we are going to maintain as streamline as design as possible to reduce unnecessary drag. We are planning to work extremely hard to reduce surface drag by sanding all surfaces really well and also making sure to not affect the streamline flow of air over the rocket's airframe.

Rocket Design
On the rocket airframe, there are a total of three PML body tubes with an inner diameter of 6.007 inches. The payload tube is going to be 26 inches in length, which will house our payload, "The Sparta Lander". The middle body tube will be 38" long and house the main parachute which will be ejected from the rocket at a height of 600 feet on its' descent. The bottom tube is going to be 48 inches in length and will house the drogue parachute, the motor, and also securely hold the fin can system. In between the front tube and the bottom tube will be a small 2.0-inch ring that is part of the electronics bay which will have the key switches on it.

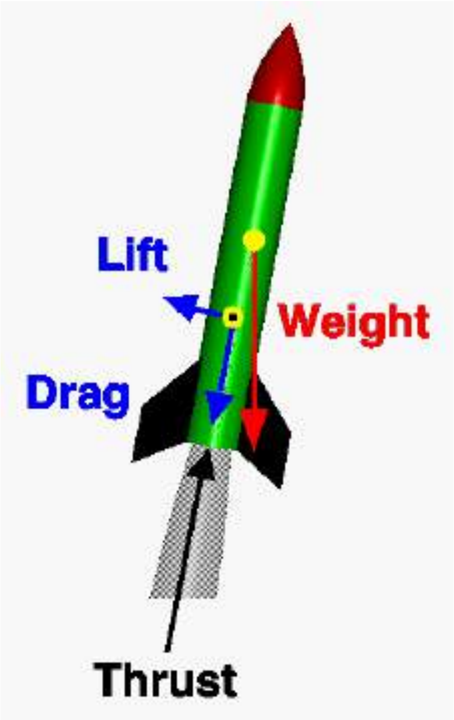


Fig 4.11: FBD of Rocket in Flight

Airframe

We plan on buying our Body Tubes from Public Missiles Ltd. The part number for this tube is FGPT-6.0. This tube is a fiberglass wrapped phenolic tube that they produce for high speed model rockets. This tube is a very strong tube; making it much stronger than cardboard. The Public Missiles Ltd. body tube was chosen because it can withstand high velocities. This was done through calling numerous companies and also consulting with our team mentor, Mr. Brian Hastings. Mr. Hastings suggested that we use this tubing as our primary option. The reason that we have decided to purchase tubes, rather than make our own body-tubes is due to lack of experience with the faculty here, and also to decrease the amount of parts that need to be ordered. By purchasing our tubes from Public Missiles Limited, the fiberglass wrapped phenolic body tubing will also help prevent zippering when the parachute is deployed. Zippering is when the rocket is going too fast, and as a result the shock cord cuts through the body tube.

Nose-Cone

The nose cone will also be purchased from Public Missiles Limited for the same reason as mentioned above. As a first-year team, we do not have the resources in place yet to build or design our own nose-cones. It is cheaper for us to purchase parts such as this nose-cone from a supplier rather than build it ourselves.

Shock Cord

The shock cord used will made in house using 1" tubular nylon which is able to withstand tension forces of over 1,500 pounds. The shock cord will be connected to stainless steel quick links and then the quick links will be connected to U-bolts on numerous bulkheads. This will provide a strong connection between the shock cords and the parachutes as their will there will be a large force upward on the parachute. This large force is due to the coefficient of friction that the parachutes are produced with. The U-Bolts that connect the shock cord to the rocket body or bulkhead will be ordered from Lowe's for easy accessibility and also be rated for at least a load of 1,000 pounds. Quick links also bought from Lowe's will provide the connection point between the shock cord and U-bolt/Airframe.

Through testing we were able to make sure that the shock-cord will be able to withstand the forces placed upon it during flight. See **Section 4C** for more information on how we tested our shock cord to ensure its component strength.

Parachutes

The main parachute that we plan on using is an ALS-Series Parachute by Paramedichutes, and our planned drogue parachute is a CFD parachute made by Fruity Chutes. Our main parachute will be 120 inches in diameter based on the parachute having a coefficient of drag around 1.6. Our drogue parachute will be a 24-inch parachute made to slow the rocket down to a safe terminal velocity before main parachute ejection. There parachutes were selected for being strong, durable, and made to withstand high pressures and forces.

Launch Lugs

For rocket stability, we will use 1515 launch lugs mounted to the airframe with screws to ensure that the rocket is able to exit the launch rail safely by reaching a high enough rail exit velocity (84 ft/s).

4A.4 – Integrity of Vehicle Design

Fin Material and Construction

As stated above, the fins shall be constructed from Ultem plastic. See **Section 4A.2** for detailed drawings and material justification. The fins were made to the exact size needed to maintain a static stability margin of around 2.8 (2.77). The fin shape, style, and size is suitable for the mission because it provides the rocket with a high restoring lift force for its size and also reduces the turning momentum of the rocket (instability). The fins provide enough force for the rocket to maintain stability and produce a great flight based on both simulation models and hand calculations.

Motor Mounting and Retention

The motor mount will be made using 3 ¼" thick fiberglass centering rings that are evenly spaced along the length of the motor tube. These centering rings will be placed exactly perpendicular to the motor tube by using squares to ensure that the motor mount can easily slide in the rocket airframe. Once the motor tube and centering rings have been epoxied together, they create the motor mount. The motor mount will be epoxied to the bottom tube of the rocket's airframe using Rocketpoxy to ensure a reliable and strong bond.

After drying, an AP 75 mm - P Metal Motor Retainer will be used to hold the motor in place within the motor mount during flight. These types of motor retainers slide onto the end of the phenolic motor tube. This means that at least ¾" of motor tubing must be behind the back-centering ring, which means it will overhang behind the tail of the rocket by ¾". The motor retainer will be JB Welded to the phenolic motor tube. This will ensure a strong connection between the motor tube and the motor retainer.

When it comes to overall rocket construction, the rocket shall be constructed only under the supervision of an adult advisor, and when needed a Range Safety Officer (ROC) or the Team Mentor. Rocket parts shall be handled accordingly to their Materials Safety Data Sheets. The rocket components shall either be secured or placed within the rocket so that minimal to no shifting occurs during the flight. The shock cords will be fastened within the rocket so that each component of the rocket is connected in series.

Component Masses for Full Scale Rocket

Component	Weight (lb)
Nose Cone with CO2 Ejection System	2.50
Upper Body Tube	1.76
Payload	3.50
U-Bolts in Upper Body	0.18
Middle Body Tube	2.58
Coupler	0.65
Electronics Bay	1.50
Main parachute	1.02
U-Bolts in Middle Body	0.18
Shock Cord in Middle Body	0.30
Lower Body Tube	3.25
Motor Tube	0.60
Drogue Parachute	0.194
Shock Cord in Lower Body	0.30
U-Bolts in Lower Body	0.18
Motor	8.099
Fins	1.22
Gear System	0.50
Total Weight	**28.513**
Simulation Mass	**28.499**

Fig.4.12: Component Mass Chart

4A.5 – Motor Selection

The Aerotech L-1150R rocket motor should deliver 3517 Newton-seconds of impulse over a burn time of 3.10 seconds. This motor delivers an average thrust of 1150 Newton's giving us a thrust to weight ratio of just over **9:1**. With this motor, our calculated point of apogee is planned to be 5,400 feet. With our weight, this motor will become our final motor choice. Based on our **design we have planned for an increase in weight of the rocket by 2%, due to added supports and epoxy weight.** Given this weight increase, our projected 5,400 feet height drops to 5,292 feet which is just over the target. This system works if you assume that the physics has a small effect, and take altitude and weight to be proportional, which is just under the target. The motor thrust curve is seen here in figure 4.12.

If this motor does not end up working, we can use an L-645 Green motor made by Cesaroni Technology Incorporated. This motor produces 3,419 Newton-seconds of impulse which means that we can compensate and make this motor work if the change proves necessary based on the design parameters or if a high height is achieved during testing.

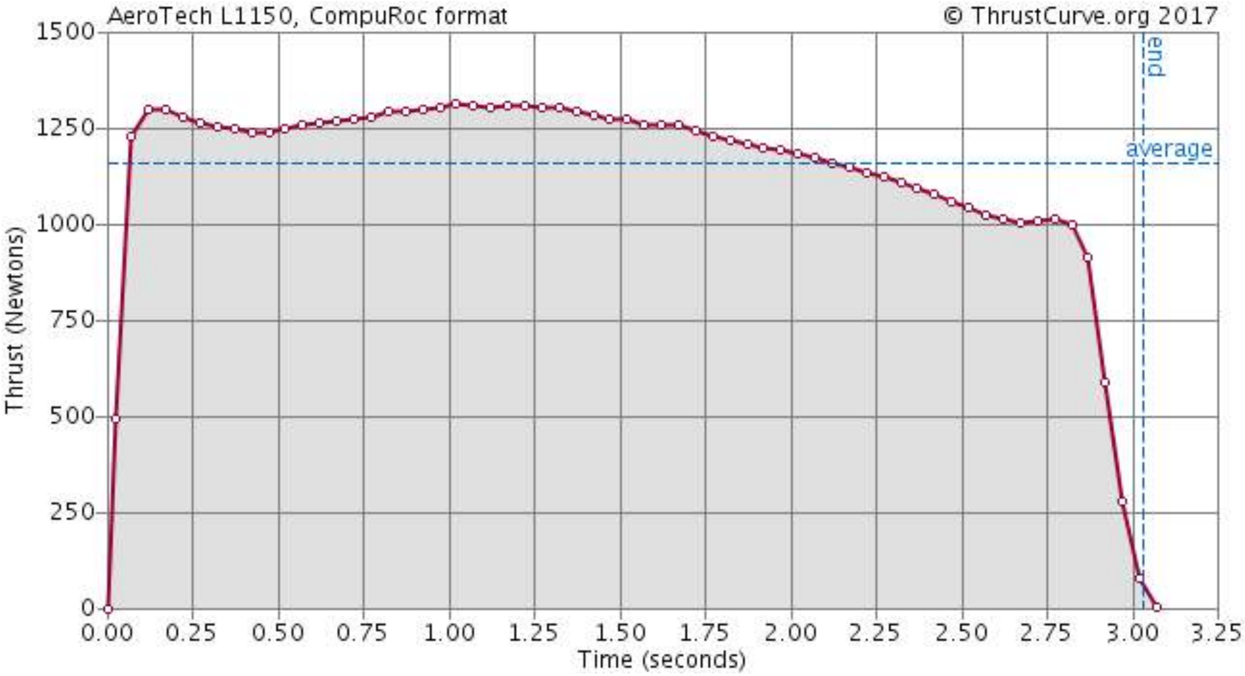


Fig.4.13: Aerotech L-1150R Thrust Curve

Subsection 4B: Subscale Flight Results

Figure 4.14: Electronics Bay Construction

Figure 4.15: Motor Mount Construction

Figure 4.16: Parachute Check to Ensure Shroud Lines Were Untangle

Subscale Rocket Mass Breakdown

Item	Number	Material	Size (in.)	Mass Per Component (oz.)
Nose – Cone (Simulated CO2 Ejection Mass)	1	Fiberglass	N/A	40.0
Payload Tube (With Simulated Payload Mass)	1	Fiberglass-Wrapped Phenolic	16”	55.0
U-Bolt	3	Steel	5/16” Thickness	3.4
Large Quick-Link	4	Steel	1/4”	3.3
Small Quick-Link	2	Steel	1/8”	1.2
Drogue Parachute	1	Nylon	18” Diameter	1.1
Fireproofing Sheet	2	Nomex	N/A	2.5
Parachute Swivels	2	Steel	1/8”	1.3
Shock Cord	2	Tubular Nylon	192” 168”	8.7 6.7
Front Body Tube	1	Fiberglass-Wrapped Phenolic	36”	22.6
Main Parachute	1	Nylon	72” Diameter	12.0
Back Body Tube (Include Motor Mount Tubing)	1	Fiberglass Wrapped Phenolic	28”	42.5
Fin Can	1	ABS Plastic	See Dimensions	8.0
Electronics Bay	1	Varying	N/A	33.9

Figure 4.17: Mass Breakdown of Subscale Rocket Flown on 12/16/17

Subscale Flight Results

The subscale rocket was launched on Saturday, December 16th, 2017 in Henderson, Maryland.

Subscale Launch Conditions

- Temperature = 36 degrees Fahrenheit
- Pressure = 30.15 inches
- Humidity = 63%
- Wind Speeds = Sustained @ 8 mph / Gusts @ 15 mph
- UV Index = 1/10

The subscale rocket was constructed as a 2/3 model of the full-scale rocket. The subscale rocket had a diameter of 4.0 inches, and each of the body-tubes were 2/3 of the length of the full-scale body-tubes. On the pad, the rocket weighed 21.8 pounds and was launched on a CTI K650 Smoky Sam motor.

According to the onboard altimeters, the rocket reached an apogee altitude of 3,494 feet on the first launch and 3,650 feet on the second launch.

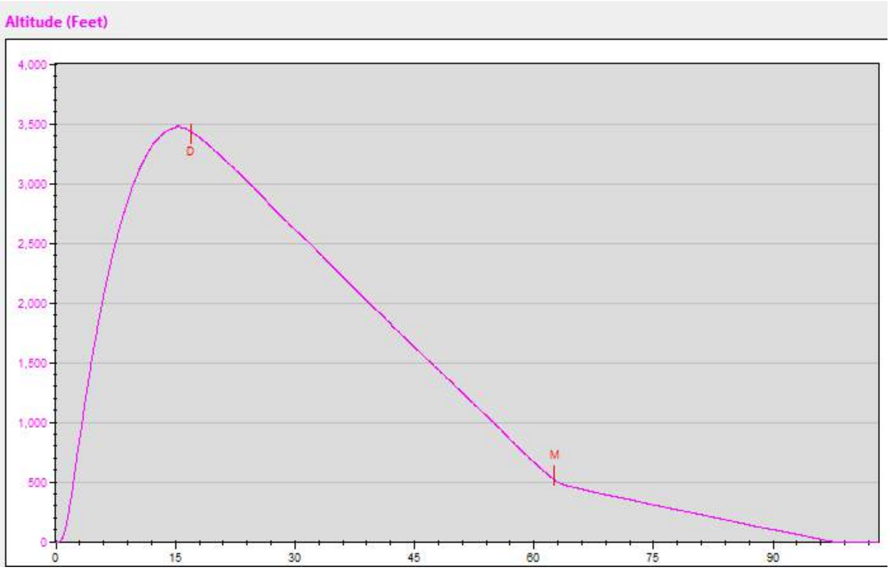
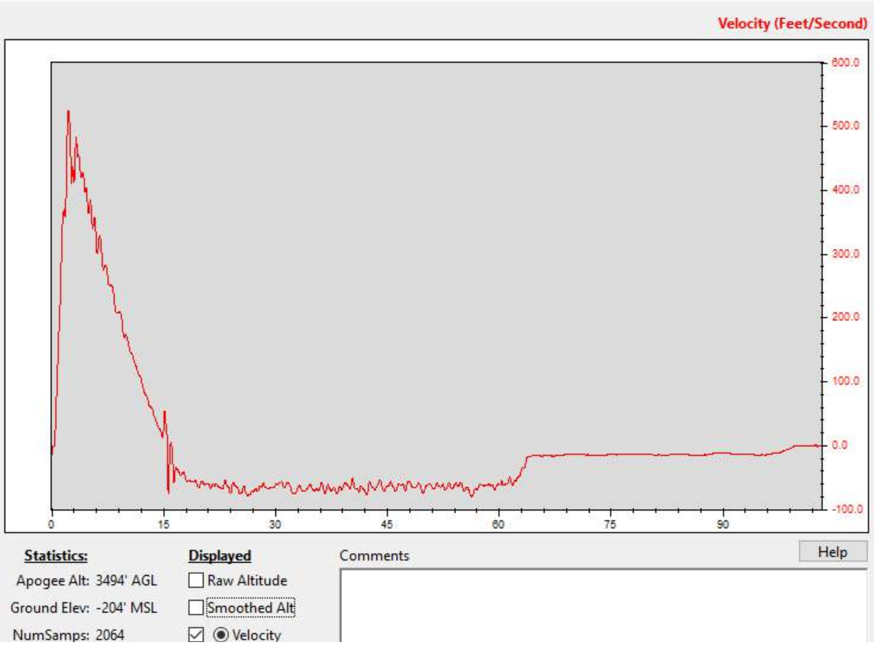


Figure 4.18: Subscale Flight #1 Altitude vs. Time Graph

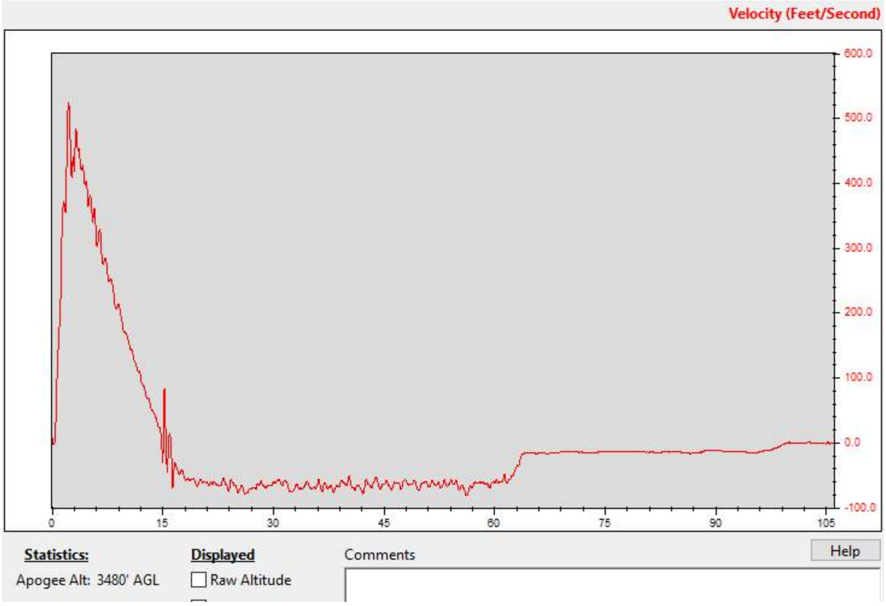


Statistics:
Apogee Alt: 3494' AGL
Ground Elev: -204' MSL
NumSamps: 2064

Displayed
☐ Raw Altitude
☐ Smoothed Alt
☑ ● Velocity

Comments

Figure 4.19: Subscale Flight #1 Velocity vs. Time Graph



Statistics:
Apogee Alt: 3480' AGL

Displayed
☐ Raw Altitude

Comments

Figure 4.20: Subscale Flight #2 Velocity vs. Time Graph

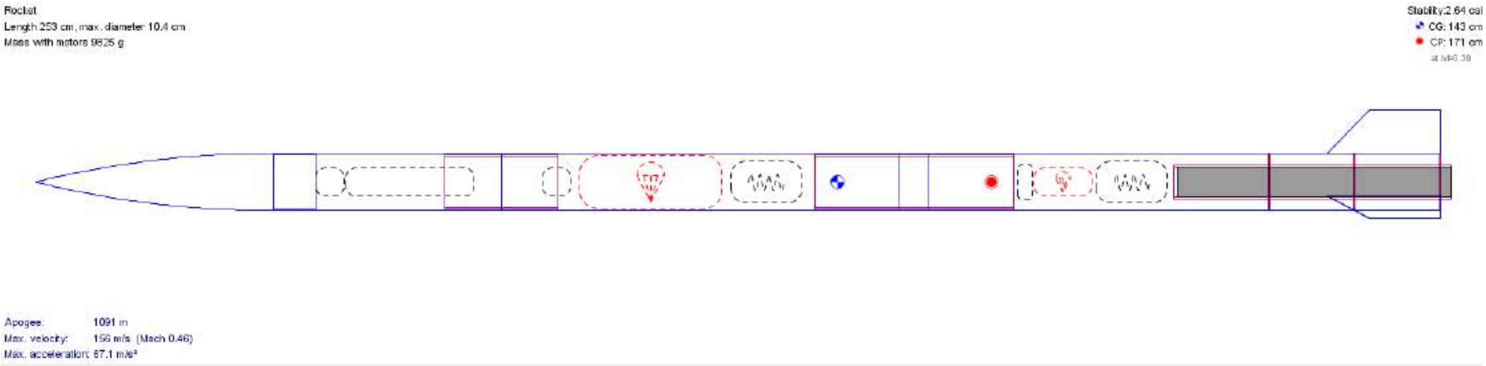
Scaling Factors

When it came to designing the subscale rocket it was important to realize that there were things that needed to be kept constant.

- To check flight stability, the subscales stability margin, center of gravity, and center of pressure needed to be very close to that of the full-scale rocket. This is to ensure that the subscale would be able to accurately test if the full-scale rocket would be able to maintain stability during flight. For example, the calculated stability margin of the full-scale rocket is 2.77 cal, and the calculated stability margin of the subscale rocket was very close to that, at 2.64 cal.
- To be able to accurately find a drag coefficient of the subscale rocket and then use that in full-scale rocket simulations, it was important to use the same nose-cone shape and airframe material as the full-scale rocket. Fiberglass wrapped phenolic tubing (same as full-scale rocket) was used for the airframe material so that the drag of the sub-scale and full-scale rockets would be pretty close to equal.
- To be able to test the strength and durability of our 3-D printed fin-can it was important to be able to use a scaled down model of our full-scale fin can design also using Ultem plastic material
- Similar recovery materials were used on the sub-scale rocket that will be used on the full-scale rocket. This was to test that our calculations were accurate and that the shock cord, quick-links, and U-bolts could withstand the dynamic loads during flight.
- We also tried to keep a similar thrust to weight ratio between the subscale (8:1) and full-scale (9:1) rocket so that we could analyze launch results and make sure that the rocket maintained stability off of the launch pad

What didn't matter when it came to the sub-scale rocket was the length of the rocket or the inner materials used such as U-bolts, quick-links, exc.

Simulation Results



Rocket
Length 253 cm, max. diameter 10.4 cm
Mass with motors 9825 g

Stability:2.64 cal
CG: 143 cm
CP: 171 cm
at M=0.30

Apogee: 1091 m
Max. velocity: 156 m/s (Mach 0.46)
Max. acceleration: 67.1 m/s²

Fig 4.21: Simulation Results of Sub-Scale Rocket Using OpenRocket

The simulation calculated that the rocket would reach an apogee of 1,091 meters. The average actual apogee between the two flights was 1,088 meters, which is a -0.275% error. That means the simulation software did an excellent job at calculating the apogee of the rocket. When looking at the actual flight model and the simulated flight model, there were not a lot of differences. The acceleration values may have varied by up to 1%, but the rest of the data matches pretty perfectly including the profile of the graph. The drift calculations were also fairly accurate. The sub-scale rocket drifted an average of 1,780 feet from the launch pad during testing and the calculated drift in 10 mph winds was 1,625 feet in the simulation.

As we were told by our NAR Mentor, the simulation is only as smart as the data that you place into it. This subscale test proved that if you can place accurate information into your simulation (exact materials, lengths, masses, exc.), the results will also be very accurate.

Based on the simulation software the estimated starting drag coefficient of the full-scale rocket is **0.71**

The subscale flight data has just solidified our full-scale rocket design and has helped us move into the next phase of the project. It has proven that we have taken a concept and made an actual design that is stable, can house our payload, and also reach an apogee height close to where we have predicted and simulated it to reach.

Subsection 4C: Recovery Subsystem

4C.1 – Final Component Analysis and Testing Results

Quick link: ¼" Quick links

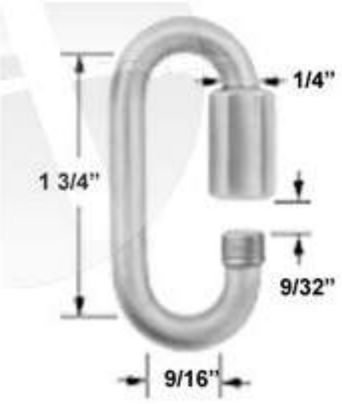


Fig 4.22: ¼" Quick Link

We proposed two quick links of different sizes in the PDR. The first quick link proposed in the PDR was the 1/8" quick link made of zinc and the second quick link proposed was the ¼" quick link also made of zinc. We have decided to use the latter, the ¼" quick link because of the high factor of safety of around 2.25.

Based on our static test data, the ¼ inch quick link was able to withstand a force of 2030 pounds as seen in the graph below. The quick link should be able to withstand more force than 2030 pounds considering that the breakage was in the threads and the quick link never broke apart. The ¼ inch quick link is rated by the manufacturer to withstand a force of 880 pounds.

$$FS = \frac{\sigma_{yield}}{\sigma_{actual}} = \frac{2030\ lb}{880\ lb} = 2.31$$

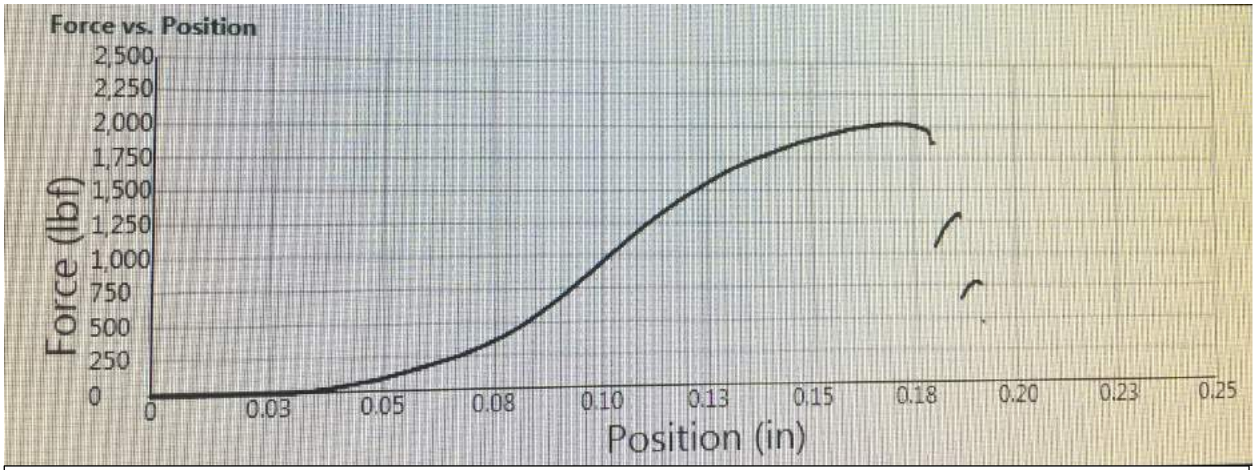
This means that the manufacturer disclosed the yield of 880 pounds with a factor of safety of 2.31.

$$FS = \frac{\sigma_{yield}}{\sigma_{actual}} = \frac{2030\ lb}{405\ lb} = 5.01$$

$$FS = \frac{\sigma_{yield}}{\sigma_{actual}} = \frac{2030\ lb}{945\ lb} = 2.15$$

While our rocket will be experiencing a dynamic load from 405 to 945 pounds, a factor of safety range of 2.15 to 5.01 can be established if using the yield to be 2030 pounds which we tested in our lab. This should prove to be sufficient due to the high factor of safety even though the load applied in the lab was quasi-static while the rocket will be experiencing a dynamic load.

Fig 4.23: Strength Test of a 1/4" Quick-Link



Force vs. Position Graph of ¼" Quick-Link Strength Test

For the quick-link, a Solidworks' analysis was also performed to find the area with the maximum stress and strain, and also test various stresses on the quick-link. Our tested quick-link is made of steel and is a ¼" thick. Based on the test results that are shown below, we are confident that our quick-links are strong enough to withstand the dynamic loads during flight.

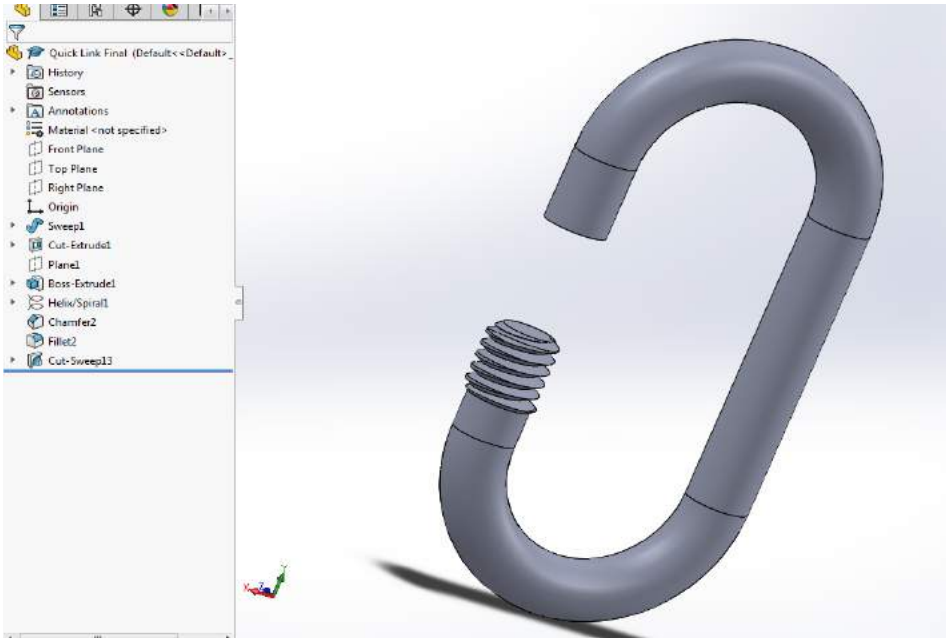


Fig 4.24: Initial Quick-Link Design on Solidworks'

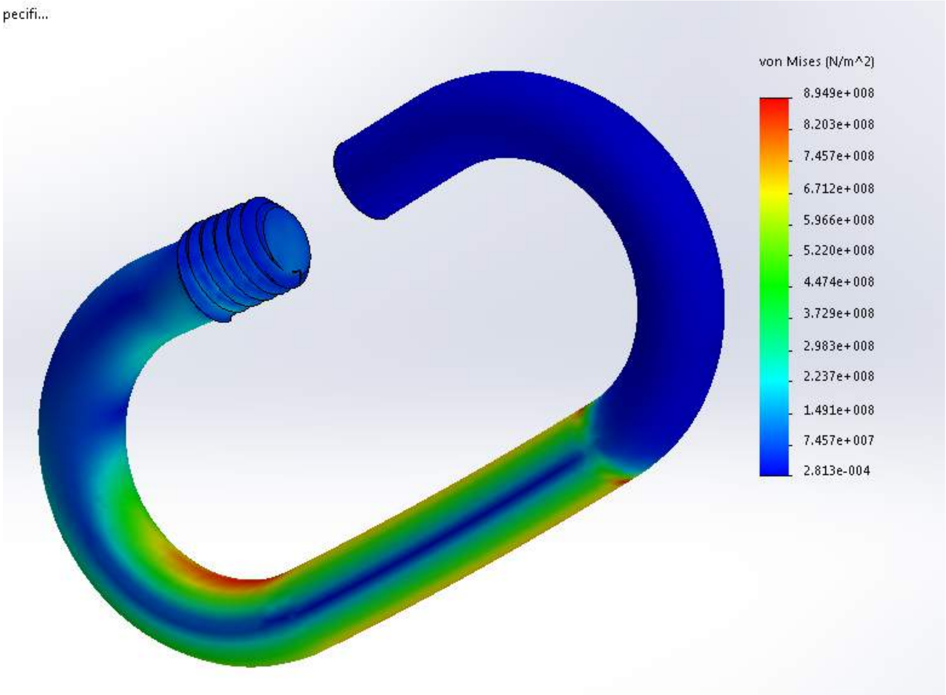


Fig 4.25: Von Mises Plot on the Quick-Link with an Applied 700 pound Axial Load

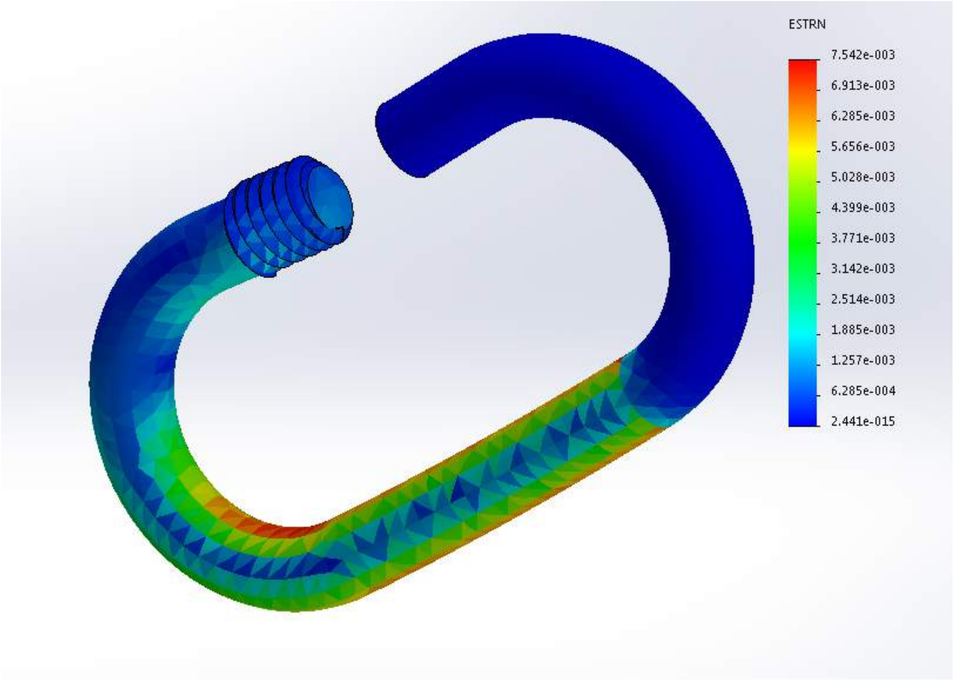


Fig 4.26: Stress in the Quick-Link with a 700 pound Axial Load

Shock Cord: 1” Tubular Nylon

We proposed two shock cords of different material and sizes in the PDR. The first proposed shock cord was the 1” Tubular Nylon and the second one was the ½” Tubular Kevlar. We have decided to use the 1” Tubular Nylon due to the high factor of safety.

There were other viable alternatives such the Tubular Kevlar ½ inch. But while the Tubular Kevlar has a higher yield than the Tubular Nylon and is also stronger and more fire resistant compared to it, the Tubular Nylon has a lot more stretch than the Kevlar thus resulting in a reduced shock loading at parachute deployment. Tubular Nylon is also less abrasive than Kevlar which reduces the chances of zippering.

The 1” Tubular Nylon is rated by the manufacturer (Giant Leap Rocketry) to have a yield of 4000 pounds which is more than satisfactory for our rocket design. To prove this yield, we conducted our own strength tests in our lab. The results were unsatisfactory because the Tubular Nylon was only able to withstand forces up to 1680 pounds before it snapped. Even though the shock cord could withstand a force that is much greater than what the dynamic force on the rocket will be, we have decided to perform additional tests before February to ensure component strength. Below are the results of the tests performed in the lab.

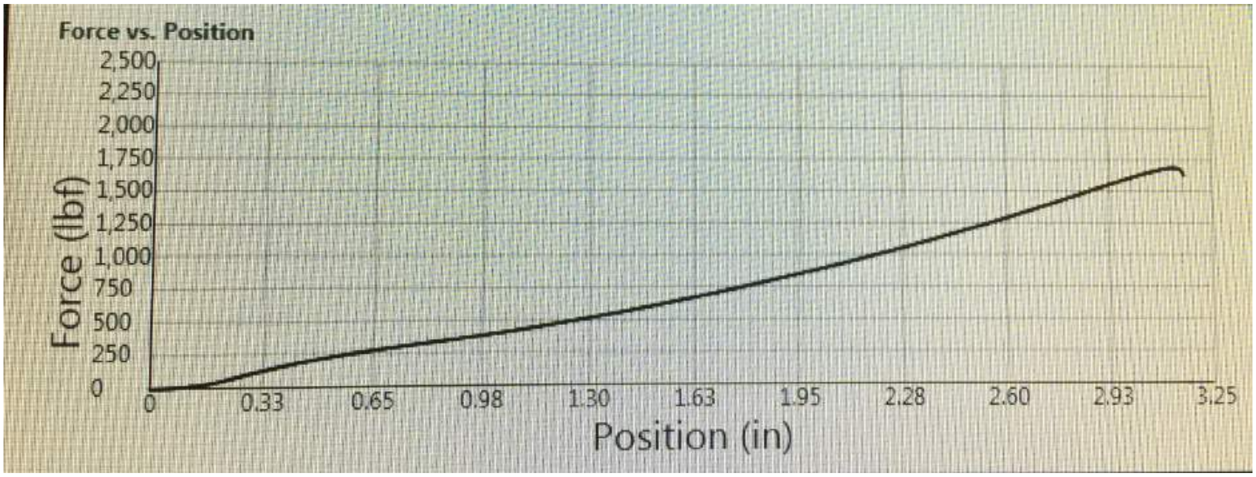


Fig 4.27: Force vs. Position Graph of the 1” Tubular Nylon Shock Cord

Fig 4.28: Strength Test Performed on the 1” Tubular Nylon Shock Cord

U-Bolt: 1/4" Steel

For the rocket, we will use 1/4" thick steel U-bolts throughout. This was determined by finding the stress/force put on the U-bolt by the quick link and shock-cord during flight. By finding this, we compared that number to the maximum shear stress allowable for the quick link with a factor of safety of 2.0. The steel U-bolt was the lightest option that also maintained the maximum shear strength needed to completely maintain its strength during flight.

Recovery Design

Figure 4.29 shows below shows the rocket's various deployment stages and also shows where the drogue and main parachute will deploy from on the full-scale rocket. At apogee, there will be an ejection charge for the drogue chute from the first altimeter. After a delay of about 2-3 seconds, the redundant altimeter will put off a similar charge, just in case the first one did not fully separate the rocket. As the rocket slows on its descent, at about 600 feet above ground level, the main ejection charge will go off, releasing the main parachute from the front half. This will separate the rocket into three parts, the front half, the middle half with both parachutes deployed, and the top body tube containing the payload and nose-cone.

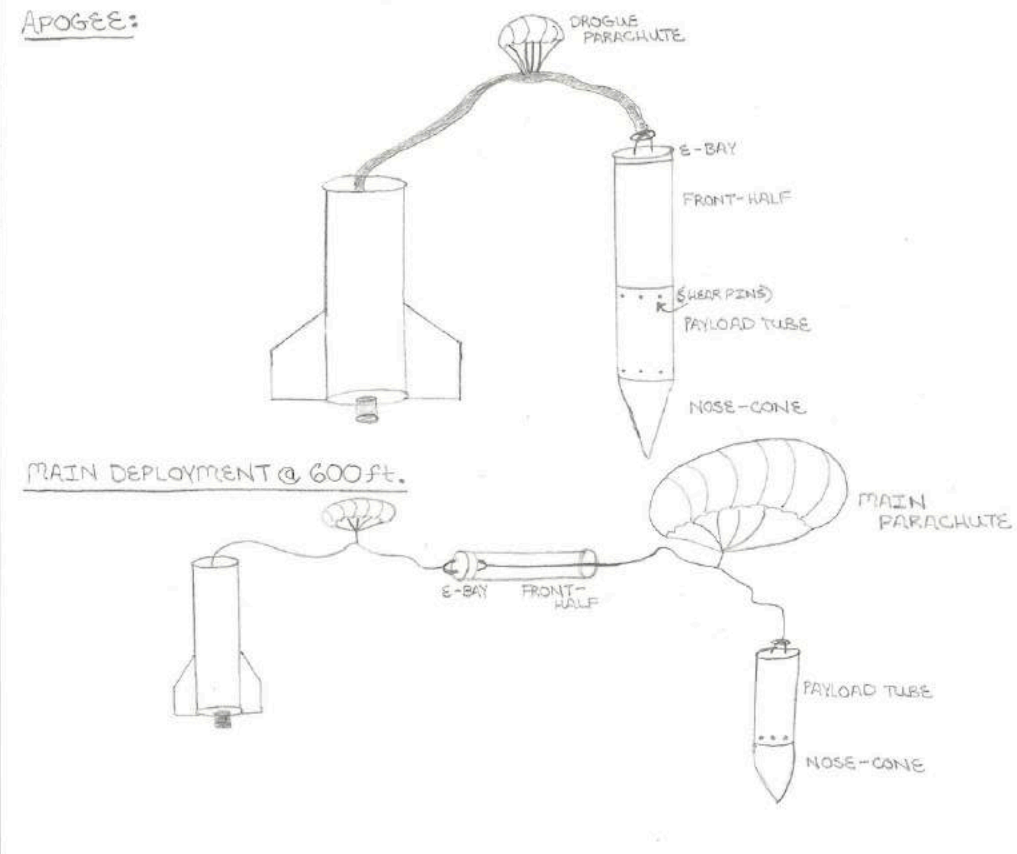


Fig 4.29: Rocket Deployment Diagram

4C.2 – Electrical Components and Redundancy

Redundancy:

The deployment of the parachutes will be deployed with the help of a PerfectFlite altimeter. We plan on using PerfectFlite Stratologger CF altimeters. This altimeter measures acceleration and barometric pressure. These altimeters can handle up to two pyrotechnic outputs as well as measure acceleration, and they have been reliable in past experience. Inside of the electronics' bay there will be two of these altimeters' on which one will be our main altimeter and the other on will be our redundant altimeter. If the first charges fail to go off for some reason, the second altimeter will be delayed up to 2 seconds after the first so that we make sure the parts are blown apart. This is part of our redundant system. At apogee there will be an ejection charge for the drogue chute from the first altimeter. After a delay of about 2-3 seconds, the redundant altimeter will put off a similar charge, just in case the first one did not fully separate the rocket. As the rocket slows on its descent, at about 600 feet above ground level, the main ejection charge will go off, releasing the main parachute from the front half. This will separate the rocket into three parts, the front half, the middle half with both parachutes deployed, and the top body tube containing the payload and nose-cone.

There will also be an arming switch within the rocket for the pyrotechnic charges. The arming system will be accessible from the outside of the rocket airframe. For the arming system we will use 2 key-switches located on opposite sides of the rocket. In order to eliminate interference with these key switches, two precautions must be taken. First, the key switches must not be placed 90 degrees from each other. Instead, pairs of key switches will be placed next to each other, with the center of both pairs at 180 degrees to each other. This will allow for the protruding part of the key switches to not interfere with the sled or altimeters which must come down into the E-Bay by sliding it down the two all thread rods. The key switches being used will be SPDT Switches 11-3360 from The Surplus Center.

The altimeter and other recovery system components run electrically, and will be able to function properly for three hours after arming the device by using power from a 9-volt battery. It won’t receive interference from any other rocket component, including the payload. The electronics bay must also be assembled in a specific way, in order to limit any interference with other components of it.

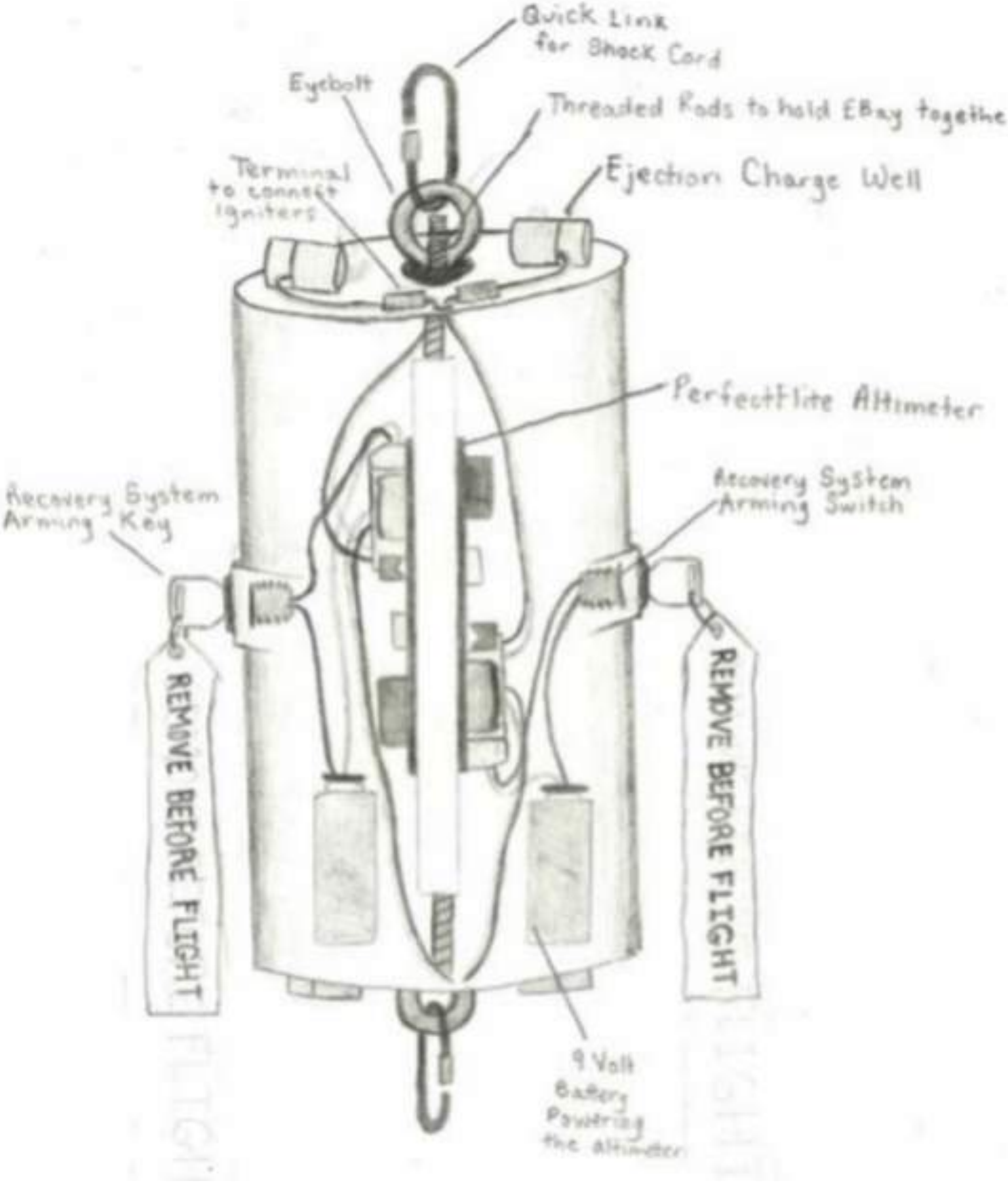


Fig 4.30: Electronics Bay Diagram

|

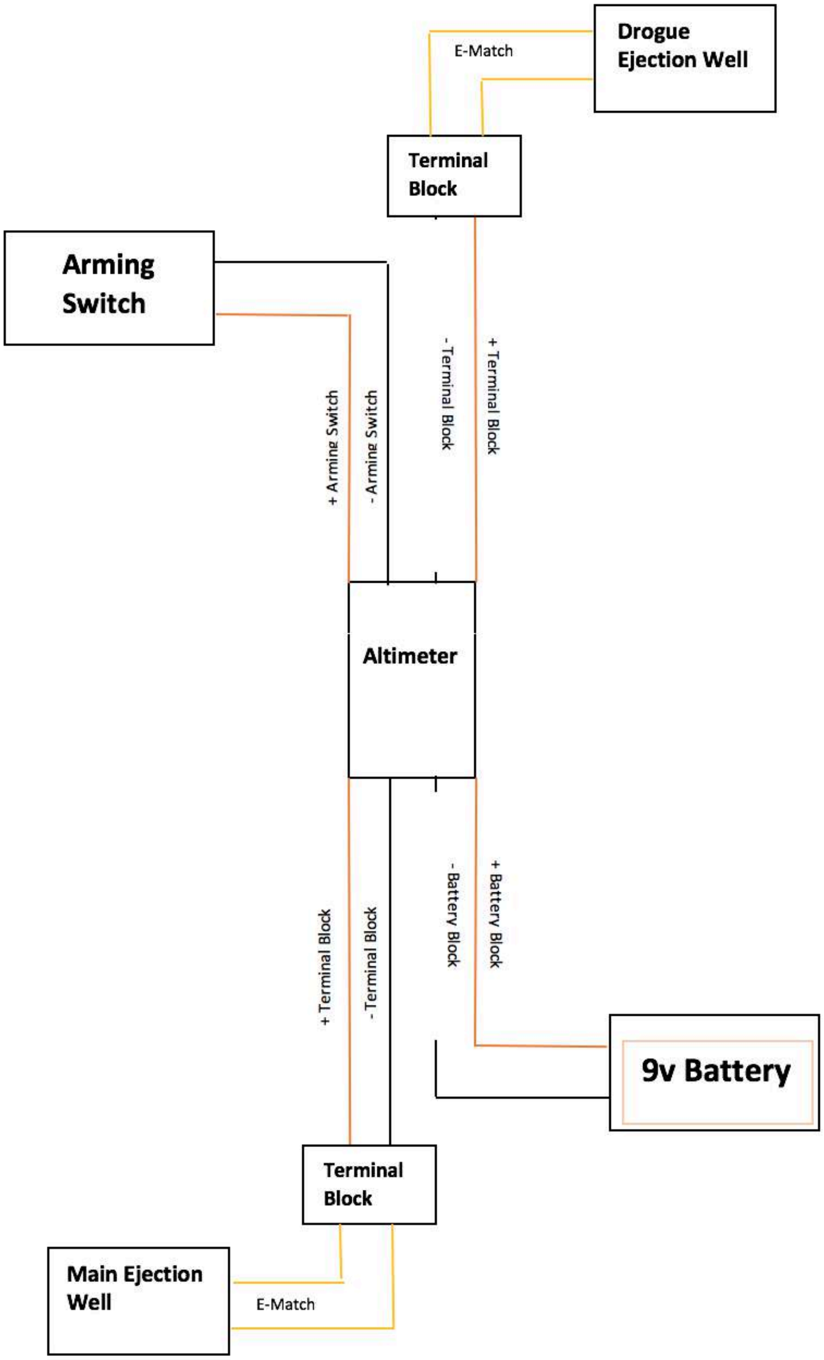


Fig 4.31: Electronics Bay Wiring Schematic

4C.3 – Trackers and Recovery Devices

The tracking transmitter that we will be using is a relatively small and light weight tracker that has a range of 10 miles and a one-week battery life. This transmitter is sold by AMWPro-x. This transmitter is also shockproof and waterproof, so this will prevent it from getting damaged during and after flight. The receiver that we will be using is 100CH Tracker Receiver. This advanced receiver covers two bands with 50 channels in each band and can be used with various transmitters. With a very long range, this makes for the ideal receiver in our case.

The transmitter (tracker) uses channel 83 in the 100CH Rx Range which means that it uses a frequency of 223.170 MHz.

We also tested the receiver and the transmitter during the sub-scale launch that took place in Maryland. We were successfully able to locate the rocket after it landed on the ground using the transmitter and receiver piece described above.

4C.4 - Parachute Calculations

Parachutes: Main- 120" diameter by Medichutes, Drogue- 24" diameter by Medichutes

Our parachutes we plan to use are elliptical parachutes by Medichutes, a local company that gives us a discount on parachutes that the maker hand sews and develops. These parachutes were selected for being strong, durable, and made to withstand high pressures and forces. They were also selected because the maker is helping to support a local university team by offering us a discount. To calculate the size of the parachute we used the equation drag force = force of gravity.

So according to our calculations we would need a parachute of 121.24 inches in diameter.
The recovery will consist of two events where the first will occur at apogee and the second will occur at 600 ft. At apogee, the first event will occur at the back half of the E-bay. During the first event, a 24" elliptical drogue chute connected to both sections of the rocket will be ejected. This first ejection charge will need 3.5 grams of black powder to separate both sections successfully. The mass calculations for the black powder are shown below for reference. This attachment consists of the shock cords each connected to a quick-link hooked on to a U-bolt. The U-bolt is secured to the wooden bulkhead of the rocket section.

At 600 ft. during descent, altimeters will fire the second event's black powder charges in the E-bay, which will separate the payload tube and nose-cone from the front body tube. The main parachute will also be ejected out from this opening. The ejection charges will also need 3.5 grams of black powder to pull out the main parachute. The main parachute will be 120" in diameter. This attachment will also consist of the shock cords each connected to a quick link hooked on to a U-bolt. The U-bolt is then secured to a wooden bulkhead of the E-bay.

$$\frac{1}{2}\rho v^2 c_d A = mg$$

$\rho = .075 \frac{lbs}{ft^3}$

$v = 12.3658 \frac{ft}{s}$

$c_d = 1.6$

$m = 22.844\ lbs$

$g = 32.2\ \frac{ft}{s^2}$

$$A = \frac{2mg}{\rho v^2 c_d}$$

$$A = \frac{2(22.844\ lb)(32.2 \frac{ft}{s^2})}{.075 \frac{lbs}{ft^3}\left(12.3658 \frac{ft}{s}\right)^2 (1.6)} = 80.17\ ft^2$$

$$A = \pi r^2$$

$$r = \sqrt{\frac{A}{\pi}}$$

$$r = \sqrt{\frac{80.75\ ft^2}{\pi}} = 5.05\ ft$$

$$d = r * 2 = 10.1\ ft = 121.24\ inches$$

Subsection 4D: Mission Performance Calculations

Flight Profile Simulations

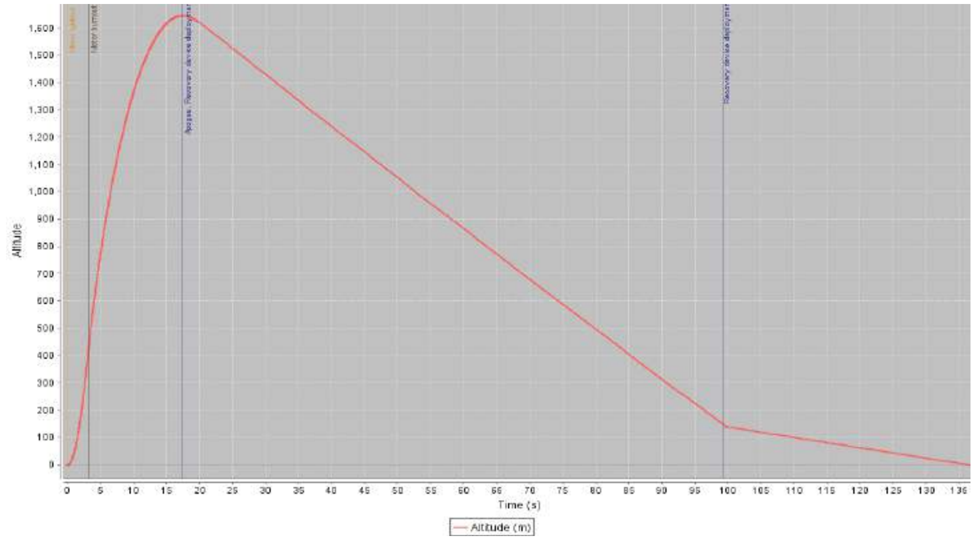


Fig 4.32: Altitude vs. Time Graph of Full-Scale Flight

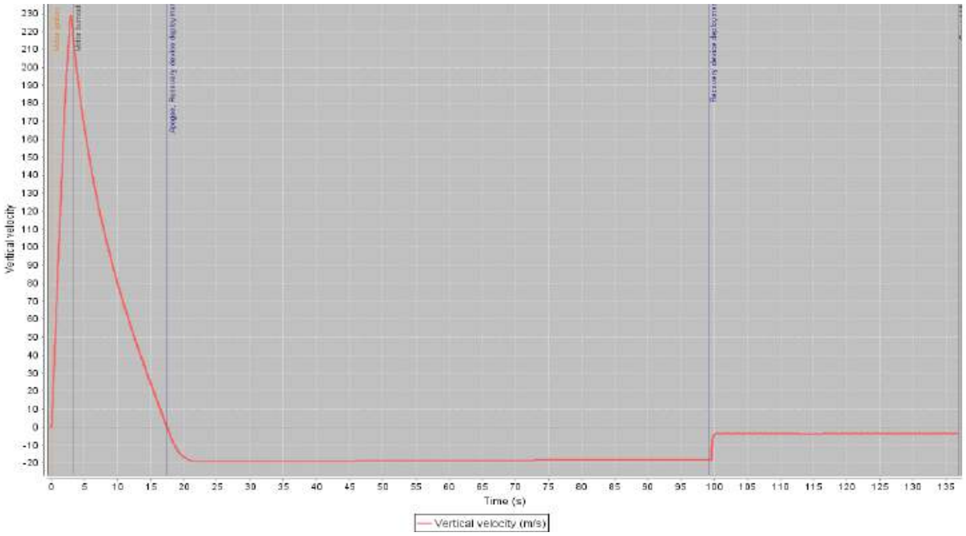
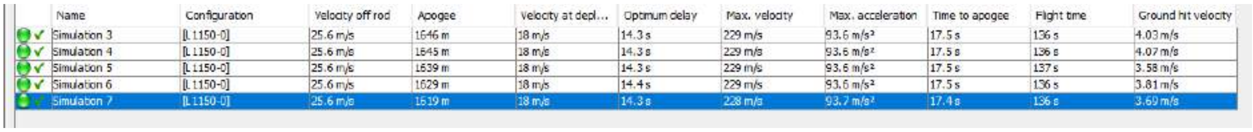


Fig 4.33: Velocity vs. Time Graph of Full-Scale Flight



Name	Configuration	Velocity off rod	Apogee	Velocity at depl...	Optimum delay	Max. velocity	Max. acceleration	Time to apogee	Flight time	Ground hit velocity
Simulation 3	[L1150-0]	25.6 m/s	1646 m	18 m/s	14.3 s	229 m/s	93.6 m/s²	17.5 s	136 s	4.03 m/s
Simulation 4	[L1150-0]	25.6 m/s	1645 m	18 m/s	14.3 s	229 m/s	93.6 m/s²	17.5 s	136 s	4.07 m/s
Simulation 5	[L1150-0]	25.6 m/s	1639 m	18 m/s	14.3 s	229 m/s	93.6 m/s²	17.5 s	137 s	3.58 m/s
Simulation 6	[L1150-0]	25.6 m/s	1629 m	18 m/s	14.4 s	229 m/s	93.6 m/s²	17.5 s	136 s	3.81 m/s
Simulation 7	[L1150-0]	25.6 m/s	1619 m	18 m/s	14.3 s	228 m/s	93.7 m/s²	17.4 s	136 s	3.69 m/s

Fig 4.34: Altitude vs. Wind Speed (From 0 mph (Sim.3) to 20 mph (Sim. 7))

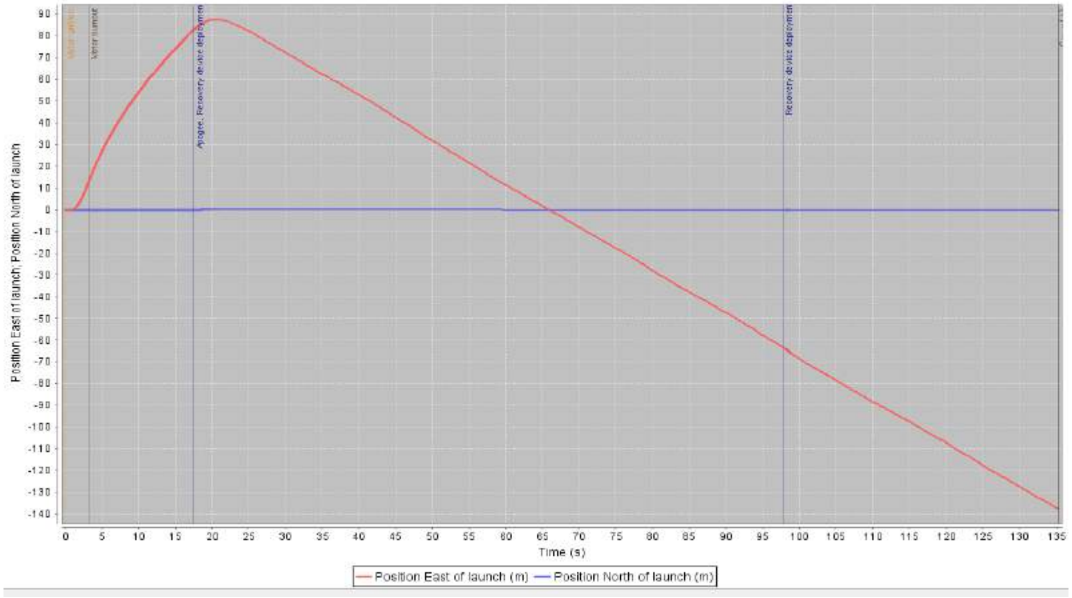


Fig 4.35: Full-Scale Rocket Drift in 5 mph winds

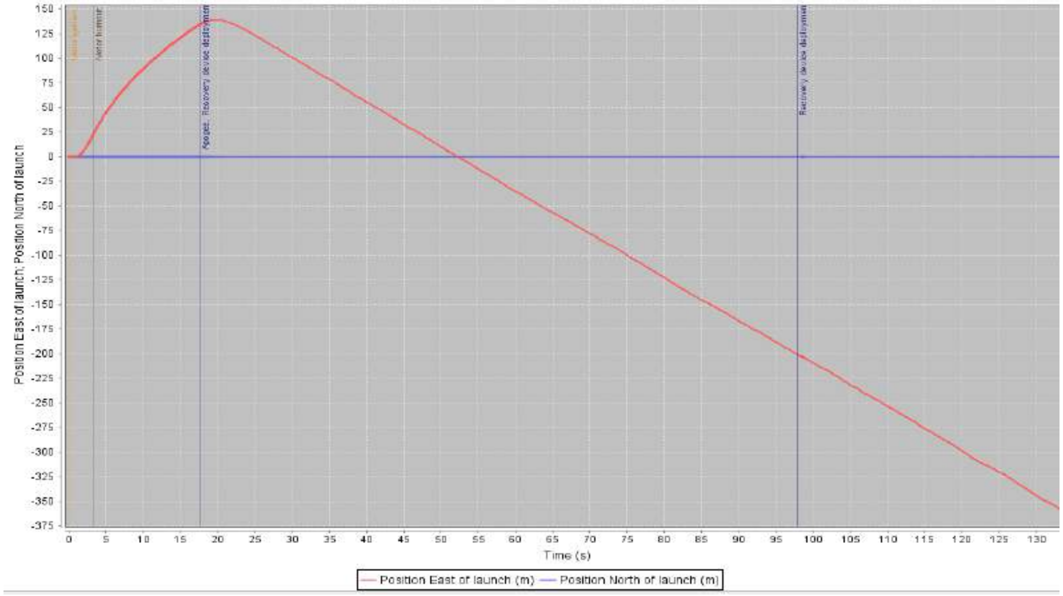


Fig 4.36: Full-Scale Rocket Drift in 10 mph winds

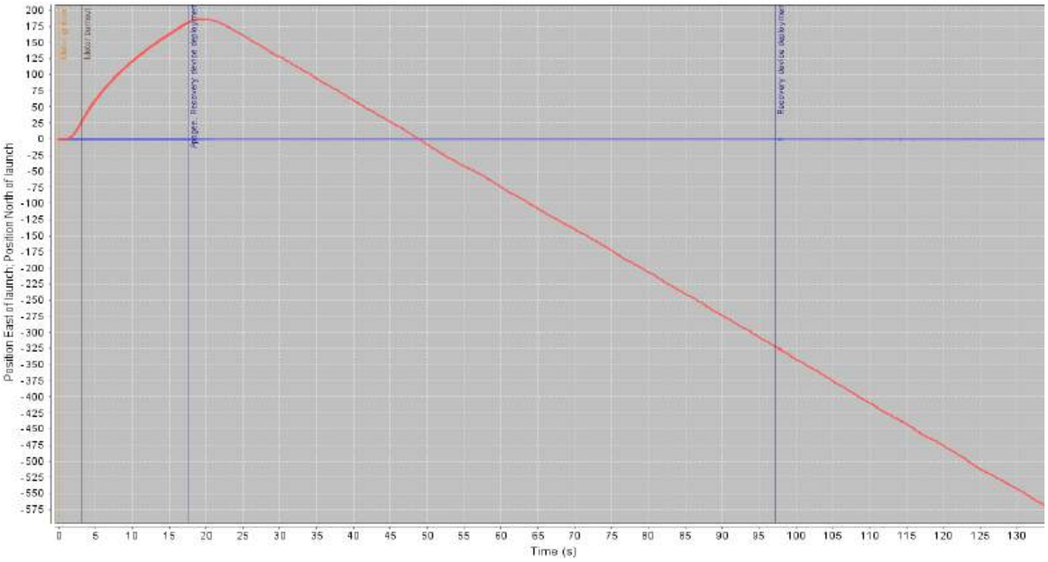


Fig 4.37: Full-Scale Rocket Drift in 15 mph winds

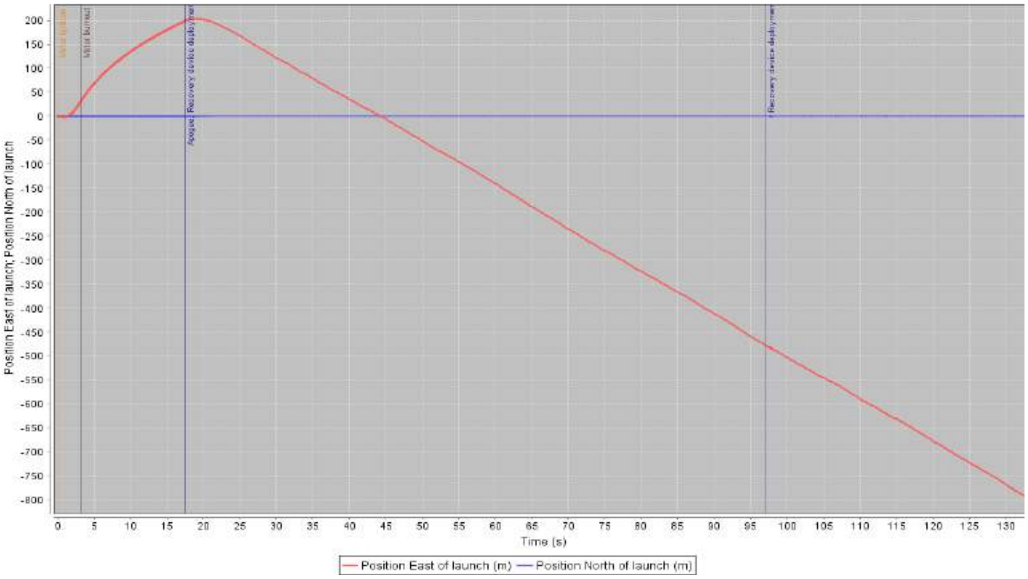
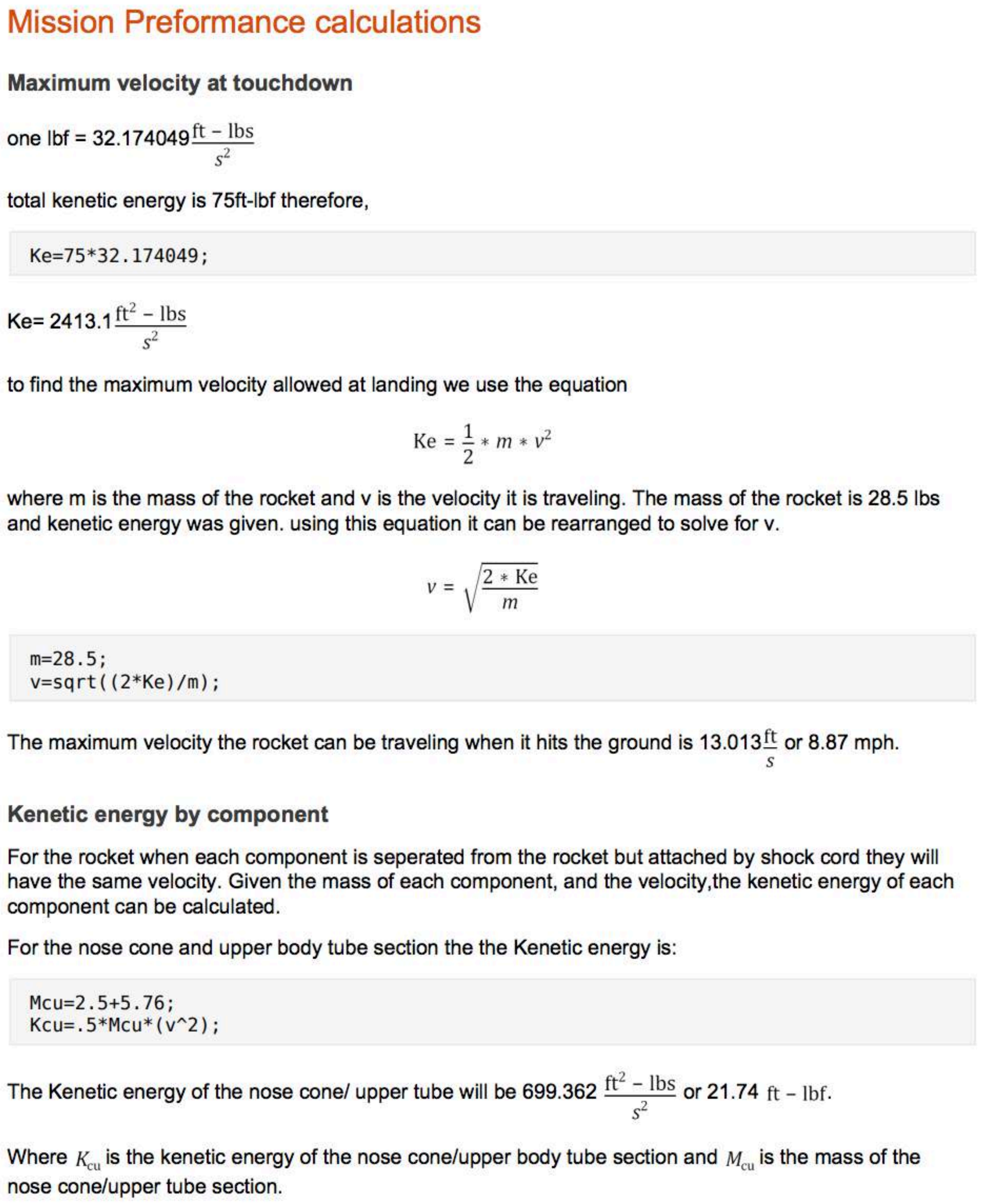


Fig 4.38: Full-Scale Rocket Drift in 20 mph winds

Hand Calculations



Mission Preformance calculations

Maximum velocity at touchdown

one lbf = 32.174049$\frac{\text{ft}-\text{lbs}}{s^2}$

total kenetic energy is 75ft-lbf therefore,

```
Ke=75*32.174049;
```

Ke= 2413.1$\frac{\text{ft}^2-\text{lbs}}{s^2}$

to find the maximum velocity allowed at landing we use the equation

$$\text{Ke} = \frac{1}{2} * m * v^2$$

where m is the mass of the rocket and v is the velocity it is traveling. The mass of the rocket is 28.5 lbs and kenetic energy was given. using this equation it can be rearranged to solve for v.

$$v = \sqrt{\frac{2 * \text{Ke}}{m}}$$

```
m=28.5;
v=sqrt((2*Ke)/m);
```

The maximum velocity the rocket can be traveling when it hits the ground is 13.013$\frac{\text{ft}}{s}$ or 8.87 mph.

Kenetic energy by component

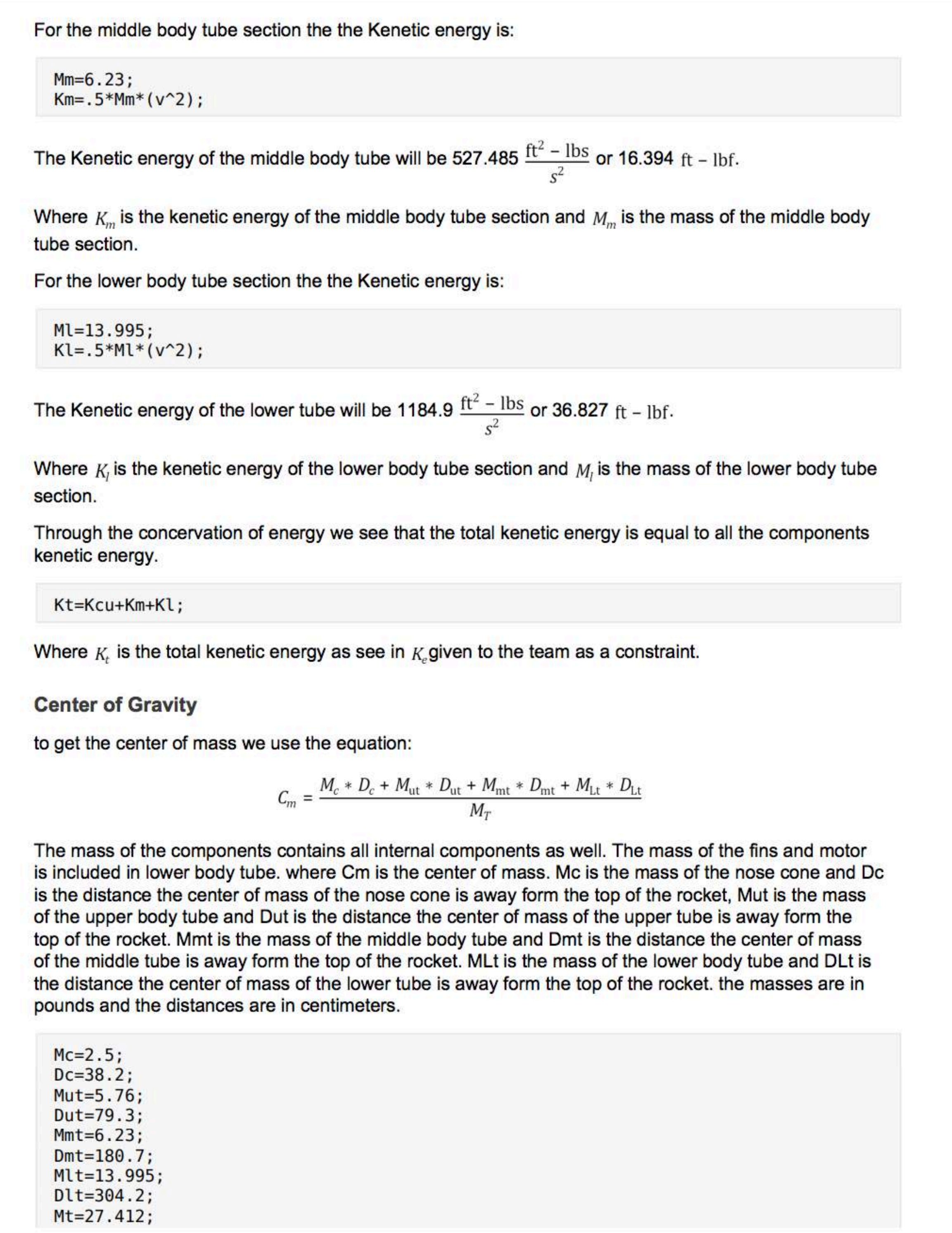
For the rocket when each component is seperated from the rocket but attached by shock cord they will have the same velocity. Given the mass of each component, and the velocity,the kenetic energy of each component can be calculated.

For the nose cone and upper body tube section the the Kenetic energy is:

```
Mcu=2.5+5.76;
Kcu=.5*Mcu*(v^2);
```

The Kenetic energy of the nose cone/ upper tube will be 699.362 $\frac{\text{ft}^2-\text{lbs}}{s^2}$ or 21.74 $\text{ft}-\text{lbf}$.

Where K_{cu} is the kenetic energy of the nose cone/upper body tube section and M_{cu} is the mass of the nose cone/upper tube section.



For the middle body tube section the the Kenetic energy is:

```
Mm=6.23;
Km=.5*Mm*(v^2);
```

The Kenetic energy of the middle body tube will be 527.485 $\frac{\text{ft}^2 - \text{lbs}}{s^2}$ or 16.394 $\text{ft} - \text{lbf}$.

Where K_m is the kenetic energy of the middle body tube section and M_m is the mass of the middle body tube section.

For the lower body tube section the the Kenetic energy is:

```
Ml=13.995;
Kl=.5*Ml*(v^2);
```

The Kenetic energy of the lower tube will be 1184.9 $\frac{\text{ft}^2 - \text{lbs}}{s^2}$ or 36.827 $\text{ft} - \text{lbf}$.

Where K_l is the kenetic energy of the lower body tube section and M_l is the mass of the lower body tube section.

Through the concervation of energy we see that the total kenetic energy is equal to all the components kenetic energy.

```
Kt=Kcu+Km+Kl;
```

Where K_t is the total kenetic energy as see in $K_e$given to the team as a constraint.

Center of Gravity

to get the center of mass we use the equation:

$$C_m = \frac{M_c * D_c + M_{\text{ut}} * D_{\text{ut}} + M_{\text{mt}} * D_{\text{mt}} + M_{\text{Lt}} * D_{\text{Lt}}}{M_T}$$

The mass of the components contains all internal components as well. The mass of the fins and motor is included in lower body tube. where Cm is the center of mass. Mc is the mass of the nose cone and Dc is the distance the center of mass of the nose cone is away form the top of the rocket, Mut is the mass of the upper body tube and Dut is the distance the center of mass of the upper tube is away form the top of the rocket. Mmt is the mass of the middle body tube and Dmt is the distance the center of mass of the middle tube is away form the top of the rocket. MLt is the mass of the lower body tube and DLt is the distance the center of mass of the lower tube is away form the top of the rocket. the masses are in pounds and the distances are in centimeters.

```
Mc=2.5;
Dc=38.2;
Mut=5.76;
Dut=79.3;
Mmt=6.23;
Dmt=180.7;
Mlt=13.995;
Dlt=304.2;
Mt=27.412;
```

```
Cm=((Mc*Dc)+(Mut*Dut)+(Mmt*Dmt)+(Mlt*Dlt))/(Mt);
```

The center of mass for the is 216.5 cm or 85.236 in from the top of the rocket.

Center of pressure

The center of pressure is dependent on 3 components the nose cone the fins and if the rocket has one the transition. Our rocket has a nose cone and fins but no transition. to calculate the center of pressure there are multiple equations. the equations for the nose cone are:

$$(C_n)_n = 2$$

$$X_n = 0.466L_n$$

Where Ln is the lenght of the nose cone.

The second set of equations has to do with the fins:

$$(C_n)_F = \left[1 + \left(\frac{R}{R+S}\right)\right]\left[\frac{4N\left(\left(\frac{S}{D}\right)^2\right)}{1+\sqrt{1+\left(\frac{2L_f}{C_R+C_T}\right)^2}}\right]$$

$$X_F = X_B + \frac{X_B(C_R+2C_T)}{3(C_R+C_T)} + \frac{1}{6}\left[(C_R+C_T) - \frac{(C_RC_T)}{(C_R+C_T)}\right]$$

Where R is the radius of the body at aft end, S is the fin semispan, D is the diameter of the nose cone base, Cr is the fin root chord, Ct is the fin tip chord, Lf is the lenght of the fin mid chord line, N is the number of fins, Xb is the distance form the nose tip to the fin roots chord's leading edge. for our design we do not have a transition there for the transition part of equations is not needed

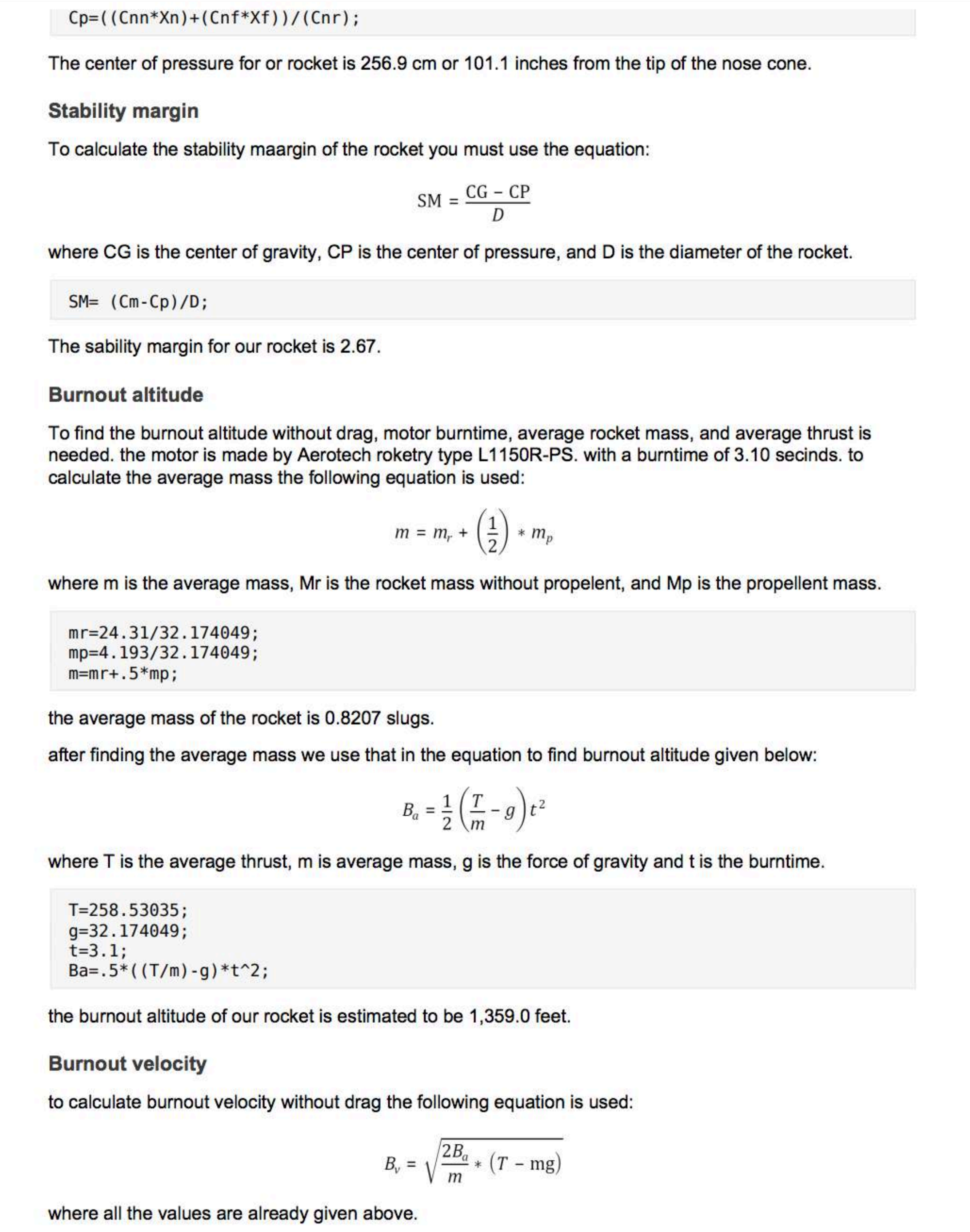
The last 2 equations that are use to find center of pressure combine the 4 equatons above to make:

$$(C_n)_R = (C_n)_n + (C_n)_F$$

$$X = \frac{(C_n)_R X_n + (C_n)_F X_F}{(C_n)_R}$$

Where X is the distance the center of pressure is away form the tip of the nose cone

```
Ln=61;
D=15.2;
Cr=35.2;
Ct=25.28;
S=16;
Lf=16.75;
R=7.6;
Xr=9.92;
Xb=300.3;
N=3;
Cnn=2;
Xn=0.466*Ln;
Cnf=(1+(R/(S+R)))*((4*N*(S/D)^2)/(1+(sqrt(1+(2*Lf/(Cr+Ct))^2))));
Xf=Xb+((Xr*(Cr+2*Ct))/(3*(Cr+Ct)))+((1/6)*((Cr+Ct)-((Cr*Ct)/(Cr+Ct))));
Cnr=Cnn+Cnf;
```



```
Cp=((Cnn*Xn)+(Cnf*Xf))/(Cnr);
```

The center of pressure for or rocket is 256.9 cm or 101.1 inches from the tip of the nose cone.

Stability margin

To calculate the stability maargin of the rocket you must use the equation:

$$\mathrm{SM} = \frac{\mathrm{CG} - \mathrm{CP}}{D}$$

where CG is the center of gravity, CP is the center of pressure, and D is the diameter of the rocket.

```
SM= (Cm-Cp)/D;
```

The sability margin for our rocket is 2.67.

Burnout altitude

To find the burnout altitude without drag, motor burntime, average rocket mass, and average thrust is needed. the motor is made by Aerotech roketry type L1150R-PS. with a burntime of 3.10 secinds. to calculate the average mass the following equation is used:

$$m = m_r + \left(\frac{1}{2}\right) * m_p$$

where m is the average mass, Mr is the rocket mass without propelent, and Mp is the propellent mass.

```
mr=24.31/32.174049;
mp=4.193/32.174049;
m=mr+.5*mp;
```

the average mass of the rocket is 0.8207 slugs.

after finding the average mass we use that in the equation to find burnout altitude given below:

$$B_a = \frac{1}{2}\left(\frac{T}{m} - g\right)t^2$$

where T is the average thrust, m is average mass, g is the force of gravity and t is the burntime.

```
T=258.53035;
g=32.174049;
t=3.1;
Ba=.5*((T/m)-g)*t^2;
```

the burnout altitude of our rocket is estimated to be 1,359.0 feet.

Burnout velocity

to calculate burnout velocity without drag the following equation is used:

$$B_v = \sqrt{\frac{2B_a}{m} * (T - \mathrm{mg})}$$

where all the values are already given above.

```
Bv=sqrt((2*Ba/m)*(T-m*g));
```

the burnout velocity is estimated to be 876.7511 ft/second.

Peak altitude

to calculate the max altitude the following equation is used:

$$P_a = \frac{T * B_a}{m * g}$$

where all the values have been defiined above.

```
Pa=(T*Ba)/(m*g);
```

peak altitude is 13,305 feet.

Time of apogee

to calculate the time of apogee wihtout drag the following equation is used:

$$t_a = t + \sqrt{\frac{2}{g}\left(P_a - B_a\right)}$$

Where t was defiined above as the motor burntime.

```
ta=t+sqrt((2/g)*(Pa-Ba));
```

the time of apogee is 30.35 seconds.

Drag influence number

this number is used to find the coefficients that we multiply all the calculated values by there respective coefficient in order to find the value with drag. The equation to find the drag influence number is given as:

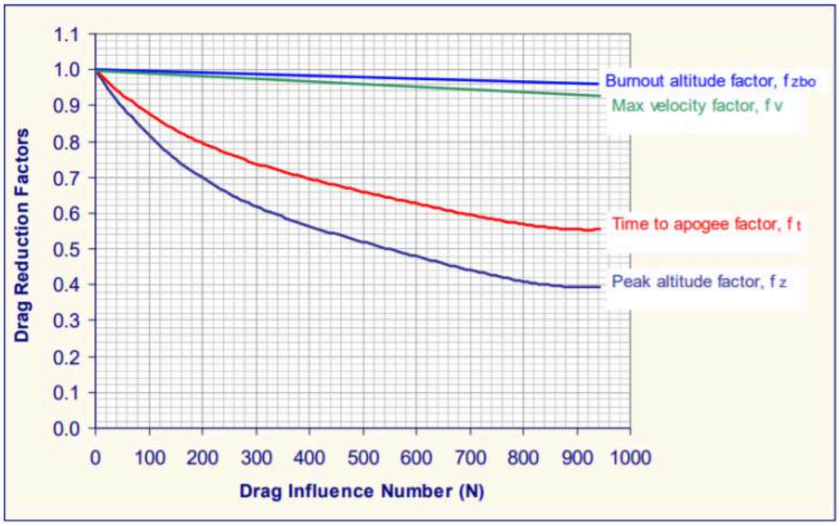
$$N = \frac{C_d * D^2 * B_v{}^2}{24353 * m_r}$$

Where Cd is the drag coefficent of the rocket, D is the diameter of the rocket, and the other values have been defined above.

```
Cd=.7;
Dr=6;'diameter in inches';
N=((Cd*Dr^2*Bv^2)/(24353*mr));
```

the drag influence number is 980.

the drag infllunce number is used to look up the reduction factors for the burnout alititude, peak altitude, max velocity, and time to apogee oo this chart:



peak altitude factor,Fpa,0.4

time of apogee factor,Fta,0.56

burnout velocity factor,Fbv,0.91

burnout altitude factor,Fba,0.95

Time of apogee, Burnout altitude and velocity, and Peak altitude with drag acounted for.

to find out how the drag affects the values listed above they have to be multiplied by their respective reuction factors.

Time of apogee with drag

```
Fta=0.56;
Tad=ta*Fta;
```

Where Tad is the estimated time of apogee with drag and is calculated to be 16.996 seconds.

Burnout velocity and altitude with drag

```
Fbv=0.91;
Fba=0.95;
Bvd=Bv*Fbv;
Bad=Ba*Fba;
```

Where Bvd is the burnout velocity with drag and Bad is the burnout altitude with drag. The burnout velocity and burnout altitude with drag are 797.84 ft/second or mach 0.71 and 1291 ft respectively.

Peak altitude with drag

```
Fpa=0.4;
Pad=Pa*Fpa;
```

where Pad is the peak altitude with drag which is calculated to be 5,321.9 feet.

Maximum acceleration of the rocket

to calculate the maximum acceleration the folllowing equation is used:

$$a = \frac{T_{\max}}{m_d}$$

Where a is the maximum acceleration Tmax is the max thrust, md is the rockets dead weight, and g is gravitational acceleration.

```
Tmax=302.6;
a=Tmax/(mr);
```

The maximum acceleration for our rocket is 400.5 ft/s^2

Terminal velocity of the Drouge parachute

The drouge parachute has a diameter of 24 inches and a coefficent of drag of 1.2. The equation for terminal velocity is:

$$V_t = \sqrt{\frac{2 * m * g}{\rho * A * C_d}}$$

Where m is the mass of the rocket, rho is the density of air, A is the area if the parachute, and Cd is the coefficent of drag.

```
p=0.0765;
Cd=1.2;
Ad=3.1415;
mp=24.31;
Vtd=sqrt((2*mp*g)/(p*Ad*Cd));
```

Vtd is the terminal velocity of drouge which is estimated to be 73.6496 ft/s

Terminal velocity of the Main parachute

For the main chute we are assuming a 120 inch chute with a coefficent of drag of 1.6 using the same equation as above with a different area and coefficent of drag. There is also an option for a parachute with a 96 in diameter and a coefficent drag of 2.2 which has the same affect as the larger parachute with smaller coefficent of drag.

```
Cdm=1.6;
Am=78.539;
Vtm=sqrt((2*mp*g)/(p*Am*Cdm));
```

Vtm is the terminal velocity of the main parachute is 12.7564 ft/s or 8.698 mph.

Time of drouge

The equation for time at a constant velocity is:

$$t = \frac{D}{V}$$

where D is distance travel and V is the velocity of travel.

```
Di=5044-600;
td=Di/Vtd;
```

time of decent for the drouge parachute is 60.3398 seconds.

Time of main

The equation is the same as above.

```
Di=600;
tm=Di/Vtm;
```

time of decent for the drouge parachute is 47.0353 seconds.

Total Filght time

To find the total flight time you add the time to apogee to the time it takes the rocket to return to the ground. in this case the time to apogee is 17.23 seconds. however the time down hasnt been calculated yet. to do that we use the terminal velocity of the drough and the distance it is open for to find that time. Then using the terminal velocity for the main chute and the distance it is open for we find that time. In order to find the total time of decent you as the two together.

```
time=td+tm+Tad;
```

The total flight time of the rocket is 124.37 seconds.

Drift calculations

First to find the wind force on the rocket we use the equation:

$$F_w = P * A * C_{\mathrm{dr}}$$

where P is the wind pressure, A is the cross sectional area, and Cdr is the coefficent of drag of the body tube.

```
Vw=[0 5 10 15 20];
P=0.00256*Vw;
A=12*6;
Cdr=1.2;
Fw=P.*A*Cdr;
```

The calcuation was done with a vector to calculate the wind force of 0, 1.106, 2.212, 3.318, 4.424 lbf at 0, 5, 10, 15, and 20 mph respectively. Using the wind force we then get the acceleration due to the wind. the eqution to do that is:

$$a_w = \frac{F_w}{M_w}$$

where aw is the acceleration, and Mw is the loaded mass of the rocket.

```
mw=28.5;
aw=Fw./mw;
```

After solving for the acceration of 0, 0.0388, 0.0776, 0.116, 0.155 ft/s^2 it is plugged into the following equation to find the drift distance.

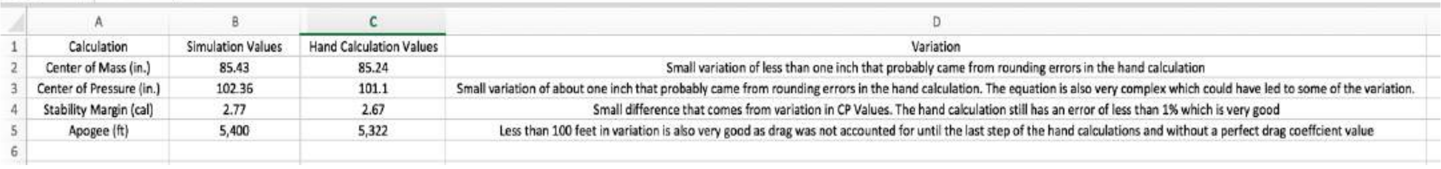
$$x = \frac{1}{2}\left(a_w\right) * t^2$$

where t is the total flight time.

```
t=124.37;
X=0.5*aw.*t^2
```

The drift distances for 0, 5, 10, 15, 20 mph are 0, 300.1,600.2, 900.3, and 1200.4 ft respectively.

Variation in Calculations



Calculation	Simulation Values	Hand Calculation Values	Variation
Center of Mass (in.)	85.43	85.24	Small variation of less than one inch that probably came from rounding errors in the hand calculation
Center of Pressure (in.)	102.36	101.1	Small variation of about one inch that probably came from rounding errors in the hand calculation. The equation is also very complex which could have led to some of the variation.
Stability Margin (cal)	2.77	2.67	Small difference that comes from variation in CP Values. The hand calculation still has an error of less than 1% which is very good
Apogee (ft)	5,400	5,322	Less than 100 feet in variation is also very good as drag was not accounted for until the last step of the hand calculations and without a perfect drag coeffcient value

Section 5: Safety

5A – Launch Concerns and Operation Procedures

Recovery Preparation (To be signed by Recovery Lead Before Flight)

- ○ Make sure Electronics Bay connections are secure and well attached
- ○ Insert new 9V batteries and hook up all leads
- ○ Program altimeters for launch (Check program if not reprogramming)
- ○ Close Electronics Bay and seal by tightening nuts on outside
- ○ Measure correct amount of gun powder for rocket separation
- ○ Place E-match into ejection well and hook up to terminal block
- ○ Place gun powder in ejection well and add wadding
- ○ Secure gun powder and tape with wadding
- ○ Repeat previous 4 steps for all 4 ejection wells **(If not done, an ejection will not occur) (Possible Ballistic Rocket if these steps are missed)**
- ○ Fold parachute Properly
- ○ Place parachute into correct body-tube
- ○ Double check to see if heat shield is up and protecting the parachute **(If not done, the parachute could catch on fire)**
- ○ Make sure all quick links are tight and connected to the proper U-Bolts
- ○ Secure Ebay in rocket

Motor Preparation (To be signed by NAR Mentor and Team Captain before launch)

- ○ When building the motor, make sure there are no flammable objects around, other team members are aware that you are building the motor, and your work space is clean
- ○ Inspect motor for any deformations/problems
- ○ Inspect motor containment on rocket for any irregularities
- ○ Make sure to follow all directions on building the motor
- ○ Insert motor in rocket carefully
- ○ Double check to make sure motor is in correctly

○ Secure motor to ensure motor doesn't move **(If motor is not secured, the motor could eject out from the rocket and cause harm to spectators)**

Setup on Launch Pad

○ 2-3 carry the rocket out to the pad

○ Watch where you step to make sure rocket doesn't hit the ground or that anyone gets hurt walking on the path

○ Carefully slide rocket onto guild rails with all team members helping to guide the rocket safely onto the rail

○ Make sure rocket moves freely on rails

○ Carefully stand up rocket and engage pin to make sure rail does not fall down

○ Turn keys to turn on altimeters in electronics bay

○ Turn on altimeter in the nose-cone

○ Make sure wireless device is talking to the rocket (gear system specifically)

Igniter Installation

○ Make sure that the electronics bay is armed before the igniter is installed in case the motor ignites for some unknown reason

○ Carefully slide the igniter into the motor after all team members have cleared the area surrounding the rocket

Troubleshooting (To be done only by Team Captain or NAR Mentor)

○ If an issue arises, the igniter will be taken back out, the altimeters will be turned off and then we will make sure that the pad is safe

○ The rocket will then be removed from the launch rail and carefully carried back to base to fix the issue

Post Flight Inspection

○ Wait until the safety officer clears the range to go and recover the rocket

○ Upon arrival, inspect the rocket to ensure that all of the gun powder went off

○ If gun powder didn't go off clear the area and carefully remove gun powder (Team Captain only)

○ Once gun powder is checked, place keys into the altimeters to ensure that they are not lost

○ Check the rocket for any damage

○ Once we are sure that the rocket is safe, we can engage the gear system to drive the rover out from the body-tube

○ Watch rover move 5 feet and deploy its solar panel

○ Then fold up any parachutes

○ Carefully carry the rocket back to station

Safety Plan

We have appointed a safety officer who is Jacob Van Brunt. He will oversee all construction with holding to the NAR High Power Rocketry Safety codes. The safety officer has also been appointed as our range safety officer. He will also certify that the launch facility, rocket engine components, and environmental conditions are within safety regulation requirements. Our motor expert will be Kyle Abrahims; he will be responsible for the safety and handling of the rocket motors. He is also responsible for the safety of all students while he is handling a motor. In addition, Jacob Van Brunt will oversee the construction of the project and will ensure that the Safety Plan is being followed throughout the entire project. Kyle Abrahims is NAR Level 3 certified. Therefore, he will also be responsible for the ordering and storage of our rocket motors.

Plan for Motor Handling and Storage

Rocket motors will be purchased through our NAR level III certified representative, Kyle Abrahims. All motors will be stored within a Type 4 magazine and access will be granted solely to our NAR representative. Mr. Abrahims will be responsible for the safe transportation and construction of the rocket motor reloads. Any use of the motor will be under his supervision at all times.

Knowledge and Understanding of Safety from All Team Members

Inspection for every rocket will be made before any attempt of a launch must go through a safety inspection. If a team member doesn’t comply they will be removed from the area so that the inspection will be done properly. If the range safety officer sees any problems with the rocket or the rocket doesn’t meet the inspection list. They have the right to deny any launch of that rocket. The failed rocket must go back through inspection and pass before that rocket can be launched. If a team member doesn’t have correct equipment or clothing when working on the rocket will not be allowed to participate in the launch of the rocket. Until they have meet the safety requirements

5B – Personnel Hazard Analysis

Risks	Causes	Likelihood of Risk *(1-10)	Severity of Risk *(1-5)	Impact on Project Progress	Mitigations
Tripping and falling hazards	Loose materials or tools being left around the shop.	5	2	Minor or severe injury, delay of rocket progress could occur.	The team will make sure the walking path is clear and keep clutter off the floor. All materials and tools will have designated zones that they will return to after use.
Injury could occur during Exacto knife usage.	Improper use of blade.	4	3	A small injury could occur, possibly delaying the rocket-building progress.	The team will carry the knife in cautious matter, cut away from oneself, and be aware fingers when using this tool. Anyone who is unfamiliar with the tool will ask a team member who is familiar for assistance.
Accidental adhesion to materials or self	Improper use of adhesives. Failure to pay attention to surroundings.	6	2	Minor injury or destruction to parts due to the strength of the adhesive used.	The team will exercise proper caution when handling adhesive material and will not use

					too much of the material. If any infraction were to occur, the member would act with haste to lessen the effects of the adhesion.
Burning caused by soldering iron usage	Improper use of soldering iron.	4	2	Minor injury and delay of progress.	The team will use soldering iron in a proper manner and use the necessary safety gear.
Abrasions and bruises caused by belt sander	Improper use of belt sander.	3	2	Minor injury or harm to part.	The team will use caution while using the sander to remove the risk of injury.
Improper usage of chemicals/chemical choice.	Failure to follow chemicals listed for certain tasks.	3	4	Possible injury to team as well as harm to specific rocket component.	The team will use only the right chemicals for adhesives and other uses while working on the project.
Injury could occur while using coping saw.	Improper use of coping saw.	2	2	A leave of absence of a team member could occur due to minor or severe injury.	The team will be aware of limbs and fingers when using this tool.
Allergic reactions to chemicals involved in rocket production	Failure to alert team to medical conditions prior to working on the rocket.	2	3	Minor or severe chemical burns of team members and possible delay of rocket	The team will make all students aware of each other’s allergies and stay away

				progress could occur.	from possible allergens.
Injury during drill press usage	Improper usage of press.	2	3	Severe injury and delay of progress could occur.	The team will keep clothing, hair, and body parts away from the drill bit and use safety glasses.
Premature ignition of rocket motors	Miscommunication between team members at moment of ignition.	2	4	Possible minor or severe injury, the need to reorder rocket motors, and delay of rocket progress.	Ensure that only the proper level certified personal handle the rocket motors and installations as well as reloads.
Misuse or mishandling of hazardous materials	Failure to comply with MSDS for chemicals.	2	3	Minor or severe injury, leave of absence for team member affected, and delay of progress	The team will follow all safety code regulations, laws, and instructions.
Inhalation of dangerous fumes	Improper safety equipment used during working with chemicals.	2	3	Minor to severe injury, time lost taking student to ER, delay of progress.	The team will wear proper safety gear, exercise proper use of fume hoods, and be aware of surroundings.
Electrocution during electrical outlet usage	Unsafe working environment.	1	3	Minor or severe injury could occur.	The team will only use electrical outlets if hands are dry and static free. The team will

					keep fingers away from prongs.

Tool Hazards

Framer Band Saw

Before operating the band saw, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the blade or the band saw. Also, obtain an instructor's permission to use the machine and ensure that safety glasses are covering your eyes. When cutting, make sure adjustment knobs are tight; the upper blade guard should be around one eighth of an inch above the material being cut. Do not force any material through the blade, attempt to cut a radius smaller than the blade will allow, and do not back out of long cuts. Keep fingers on either side of the cut line, never on the line. If necessary, use a push stick or scrap block to guide the material through. Do not allow bystanders to stand to the right of the machine, because if the blade breaks, an injury may occur. Never leave the machine until the blade has come to a complete stop. If an injury should occur during the usage of the band saw, stop the machine, step on the break to stop the blade quickly, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Router

Before operating the router, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the router or router bit. Also, obtain an instructor's permission to use the machine and ensure that safety glasses are covering your eyes. Ensure that the power switch is in the off position before plugging in the router. Then, check to make sure that the bit is firmly secured in the chuck and that the piece being worked on is firmly secured. Also make sure that the intended path of the router is free of obstructions. Hold the router with both hands and apply constant pressure. Never force the router or bit into the work. When changing bits or making adjustments turn off the router and unplug it from its power source. If an injury should occur during usage of the router, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Dewalt Compound Miter Saw

Before operating the saw, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the blade. Also, obtain an instructor's permission to use the saw and ensure that safety glasses are covering your eyes. Make all changes to the saw and saw blade while the power is off and the plug is disconnected from its power supply. Hold the material firmly against the fence and the table. Allow the motor to reach its full speed before attempting to cut through the material. Make sure that all guards are functioning properly. If injury occurs during usage of the Miter Saw, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Hand Sanders

Before operating the hand sanders, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the machine. Also, obtain an instructor's permission to use the hand sanders and ensure that safety glasses are covering your eyes. Replace the sand paper while the sander is off and unplugged. Only use sand paper that is in good condition and properly installed. Place the material that you intend on sanding on a flat surface and sand slowly over a large area. Wait for the sander to stop oscillating before placing it on a secure resting surface. Never carry any corded tool by the power cord. If injury occurs during usage of the hand sanders, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Electric Drills

Before operating the drill, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the bit. Also, obtain instructor permission before using the drills and ensure that safety glasses are covering your eyes. Replace the bit while the power is off, installing the bit properly and making sure the chuck is tightened and the chuck key is taken out. Never drill without first marking the hole with an awl. Ensure the material is clamped securely and drill with even pressure. Never carry any corded tool by the power cord. If injury occurs during usage of the electric drills, turn off the drill, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Powermatic Drill Press

Before operating the drill press, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the bit or machine. Also, obtain instructor permission and ensure that safety glasses are covering your eyes. Replace the bit while the power is off, installing the bit properly and making sure the chuck is tightened and the chuck key is taken out. Firmly secure the material that you are drilling with vices or clamps. Adjust the table to avoid drilling into it and pick the correct size bit that is properly sharpened. If the drill becomes stuck turn off the machine and inform an instructor. Select the proper speed for the material. If an injury occurs during usage of the drill press, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

CNC Router

Before operating the router, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the bit or machine. Also, obtain an instructor’s permission to use the router and ensure that safety glasses are covering your eyes. Turn on the sawdust collection system. Make all adjustments while machine is off. Materials must be firmly secured before the project is run through the router. A person needs to be with the machine during the entire operation. Check to make sure that the spindle rotation, speed, and depth of cut are all correct before starting the machine. Only clean the machine while it is off and make sure that all set up tools are cleared from the table. If an injury occurs during usage, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Table Saw

Before operating the table saw, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in blade. Also, obtain an instructor’s permission to use the table saw and ensure that safety glasses are covering your eyes. Turn on the sawdust collection system. Make all adjustments to the blade or guide while machine is off. Gullets of the blade must clear the top of the material. Never use the miter gauge and the fence at the same time. The miter gauge it for cross cutting and the fence is for ripping. Use extra caution while using a dado cutting head. Always use a push stick when your hand could come close to the blade and have another person at the other end of the table to catch the material that was just cut. Do not leave the table until the blade stops. If an injury occurs during usage of the table saw, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Powermatic Belt Sander

Before operating the belt sander, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in machine. Also, obtain an instructor’s permission before using the machine and ensure that safety glasses are covering your eyes. Make all adjustments while the machine is off. Check that there is adequate tension in the belt and that it is not torn before turning on the machine. Keep the material on the table at all times. Keep fingers away from the sand paper. If an injury occurs during the usage of the sander, turn off the machine, inform an instructor of the injury. The instructor will then have any students in the room go out into the hallway. This will ensure that the students do not interfere with the injured person, instructors, or medical personnel that will be helping the student.

Powermatic Drum Sander

Before operating the drum sander, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the machine. Also, obtain an instructor's permission before using the sander and ensure that safety glasses are covering your eyes. Make all adjustments while machine is off. Use the proper drum for the radius that is being sanded. Keep the material that you are sanding on the table at all times. Keep fingers away from the sand paper. If an injury occurs during usage, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Craftsman Reciprocating Saw

Before operating the reciprocating saw, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the blade. Also, obtain an instructor's permission before using the saw and ensure that safety glasses are covering your eyes. Make all changes with the power off and the plug disconnected from its power supply. Firmly secure all material to a work bench or table. Allow the motor to reach its full speed before cutting through the material. Hold the saw with both hands while you are using it. If an injury occurs during usage, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the room sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

Craftsman Circular Saw

Before operating the circular saw, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the blade. Also, obtain an instructor's permission before using the saw and ensure that safety glasses are covering your eyes. Make all changes with the power off and the plug disconnected from its power supply. Firmly secure all material to a work bench or table. Before cutting, ensure that the cut line is not above the table. At least one person must be holding the material being cut off, as long as that piece is large enough for a person to hold it. Allow the motor to reach its full speed before cutting through the material. Hold the saw with both hands while using it. If an injury occurs during usage, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

CNC Lathe

Before operating the lathe, remove all jewelry, confine long hair, and remove or roll up long sleeves along with any article of clothing that could become caught in the bit. Also, obtain an instructor's permission before using the lathe and ensure that safety glasses are covering your eyes. Make all adjustments while machine is off. The material that you intend on cutting must be firmly secured before the project is run through the lathe. A person needs to be with the machine during the entire operation. Check to make sure that the spindle rotation, speed, and depth of cut are all correct before starting the machine. Only clean the machine while it is off .If an injury occurs during the usage of the lathe, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside in the hallway to avoid being in the way of instructors and medical personnel helping the student.

5C – Failure Modes and Effects Analysis

The likelihood of risk, scales increasing from one being low likelihood and ten being high likelihood.

The severity of risk, scales increase from one being minimal severity and five being maximum severity…

Fin can failure during launch.	Improper adhesion of fin can to the rocket tube. Also, possible weakness in the 3-D printing of the fin can.	5	5	Possible launch failure/ rocket veering off course.	The team will design the fin can for rigidity as well as ensure proper adhesion. The fin can will be tested for solidity prior to assembling on rocket.
Payload fails to exit nosecone.	Nose cone motor fails to unscrew the cone from the body. The payload gets stuck within the nosecone due to friction between wheels and the walls of the rocket.	4	5	Payload would fail its task due to not moving the 5ft. specified.	The payload will be designed to fit securely while also having the ability to slide out of the nose cone. The payload removal system would be tested prior to ensure the system's success in removing the payload.
Complications during transportation of participants and	Possible traffic on route to the launch site or team meeting up later than scheduled.	5	4	Possible cancelation of launch practice on specified dates due to being unable to	The team will make sure that the launch date is known in advanced and that all

materials to SL or practice launch site	Rocket fails to be completed prior to launch dates.			make the times allotted.	specifications are planned out well in advanced. The team will pack the rocket well and make sure it is secure during transportation.
Remote control and payload do not communicate.	Distance between payload and controller. Payload or payload release system failing to power on.	5	3	Payload will fail to disengage from the rocket. The door might not open or the payload might not become mobile.	The team will check extensively to ensure a proper connection to the payload and system before launching.
The rocket parachute does not deploy, and rocket returns unsafely to the ground.	Gunpowder charge is Insufficient/ is unable to be signaled to ignite.	3	4	Loss of rocket or high damage due to high impact on ground.	The team will carefully insert the parachute and have a redundancy for the charge to cause the least chance of failing to ignite the charge. All connections will be checked in accordance to the checklist.
Accidental combustion of rocket materials	A near by fire starting it or a spark nearby.	3	3	In addition, possible injury and a delay of rocket-building progress could occur.	The team will keep 25 feet away from electrical outlets, open flame, and the

					indoor magazine.
Motor ignition delay	Poor connectors, incorrect wiring.	3	2	Launch delay, loss of motor if it does not ignite, minor to severe injury if motor ignites while personnel are approaching rocket.	The team will only use commercially available and Range Safety Officer-approved igniters.
Motor ignition failure	Poor connectors, incorrect handling of motor (see checklist).	3	2	Delay of launch testing and rocket progress.	The team will ensure that commercially available igniters and motors are used and follow the NAR High Power Safety Code, which outlines what to do during motor ignition failure.
Rocket catches fire on the launch pad	****	2	5	Possible loss of rocket, minor to severe injuries if fire is not properly extinguished.	The team will bring a fire extinguisher suitable for the needs of the fire and according to the MSDS of the motors being used.

The Rover may get lodged in rocket such that it	Motor doesn't twist out nose making rover not get pushed out.	2	5	Our team will not get the points for successfully	The team shall ensure to make sure all parts of the rocket work before launching.

doesn't come out.				completing our task.	
The rocket parachute does not deploy and rocket returns unsafely to the ground.	Our gun powder doesn't ignite.	3	4	We lose a rocket.	The team will carefully insert the parachute and make sure there is enough gun powder to shear the pins.
When the rocket has hit the ground payload doors get stuck / nose-cone does not eject off from the front body-tube	Nose cone is stuck in the ground	5	3	The rover will not leave during competition making us loss out on points.	The team will test the motor in multiple positions to make sure the nose cone will come off.
Rover moves during flight.	Improper secure of the rover.	2	2	The rocket trajectory would change directions causing our team to loss time, money, and points.	The team will design a secure container to keep rover in.
Launch preparation failure causing rocket to burn the engines	Alignment of rocket on launch pad.	1	4	This would make our team loss time, money, and possibly the rocket.	The safety captain will double check and check off launch check list to make sure making sure the rocket will launch correctly.
Wires that are connected to ignition pad	Wires were not double checked	4	2	It would delay the competition , our team	Our team will have a person who will double check and check

are not connected correctly making the rocket not launch.				would loss time, and possibly make errors when relaunched.	it off their list so that the rocket will successfully launch.
Just after rocket hits apogee the ebay fails to deploy.	Batteries or wire failure.	2	5	It would make our team loss a rocket.	Make sure ebay is correctly set up and materials are working.
Rover having to travel over uneven terrain.	Terrain recently plowed for next year's crops.	7	2	Our rover will not be able to complete its task.	Our team will designed our rover to overcome uneven terrain and have sensors to maneuver around.

5D – Environmental Hazard Analysis

Risks Environment	Causes	Likelihood of Risk *(1-10)	Severity	Impact	Mitigations
Wind	Moves the rocket midair losing its trajectory.	4	3	Possible to have the wind push the rocket off angle or when the parachute is out could make it not land where we want it.	The team made calculations making sure our center of gravity and center of pressure were more than 4 inches away from each other.
Effects of gun powder on the environment	Launching multiple rockets in one area.	5	1	The heavy metals in the gunpowder are harmful for the environment.	Use small amount of gun powder so that it doesn't affect the environment.
Uneven terrain	Stops our payload from moving.	10	3	The payload wouldn't complete its task.	The team will attach sensors so that the rover will not get stuck.
Rover/Rocket affecting the environment.	Hit any tree's or bushes.	2	1	It could tear up the ground, destroy bushes, or destroy farmers crops.	The team will be aware of surroundings and wind to make sure rocket will land where we need it to.
Rocket hitting trees or bushes	The parachute doesn't open or the wind moves the rocket during descent	3	2	It could destroy our rocket or kill the tree.	Our team design a backup black powder to ensure rocket successfully deploys parachute.
Environment affecting the rover.	The terrain is very uneven.	3	1	The rover could get stuck damaging the motors or any other moving parts.	The team will integrate sensors to make sure the rover will not get stuck.

Rocket possible hitting nearby houses.	The wind pushing the rocket when parachute is deployed.	2	4	It could damage the house or possibly the rocket.	The team will keep more than 1500 feet away from any homes.
Sunny day	There are not clouds in the sky.	8	2	It can damage your eye's if you stare at the sun for too long or it can hurt your eye's if you try to keep an eye out for the rocket.	Our team member who are keeping an eye out for the rocket will have sunglasses to help shield their eye's.

5E – Risk Analysis

Risk	Cause(s)	Likelihood	Impact	Mitigation	Effect on other parts
Going over designated budget	Not paying attention to club's money.	Medium	High	Our team has an excel document that has our budget and we check it before buying anything.	Lesser quality components for building. Less time for report due to fundraising.
Running late on report	Not sure when the report is due, or proper time management.	Medium	High	We made sure that everyone knows when the date it was due and we made our group have their part of the paper due 4 days in advance.	Less time in building/designing rocket in order to pick up the slack on the report.
Payload doesn't get pushed out	The motor fails, friction is too high, and nosecone doesn't come off.	Low	High	Team will test the design multiple time to make sure that it works correctly.	Time would be taken from other aspects of the project to fully survey the designs.
Rocket motor doesn't go off.	Ignition doesn't set off.	Low	High	The electronics are double checked before rocket is put on stand.	We wouldn't be able to launch payload.
Incorrect time management in building	Poor team communication.	Low	Medium	Team meeting used to discuss how to properly manage time for the team.	Time would be taken from other aspects of the project.
Unsafe work environment	People leave tools or materials around.	Low	Medium	Further precautions would be set in place. A safety officer would be on site during building.	A team member would be taken away to ensure safety. Budget would be lessened to put into place strong safety measures.

Section 6: Payload

6A - Payload Objective

The payload objective is to exit the rocket on the ground via remotely activated door and to travel five feet in any direction. After arriving at five feet in any direction, the payload vehicle must stop and deploy external solar panels. The ideal payload would follow this process; exit the body tube of the rocket after landing and being remotely signaled to start moving, travel five or more feet from the exit location by avoiding obstacles in the rover's path, and deploy or expose solar panels contained previously inside the rover.

6B – Leading Payload Design and Justification

"The Sparta Lander"

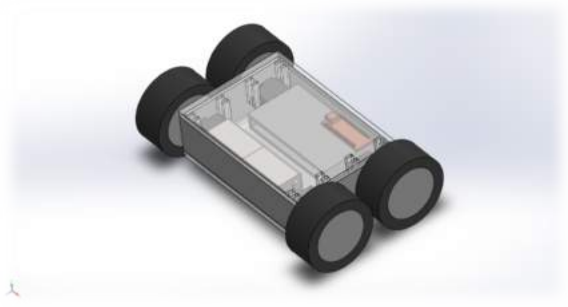


Fig 6.1: Isometric View

This view displays the clear top plate guarding the electronics from debris and moisture, but gaps provide airflow to cool the electronics while the vehicle is in motion. The dual sided solar tray is visibly contained within the middle section of the rover. The rounded back edge reduces weight and the probability of the rover hitting debris and being rendered immobile.

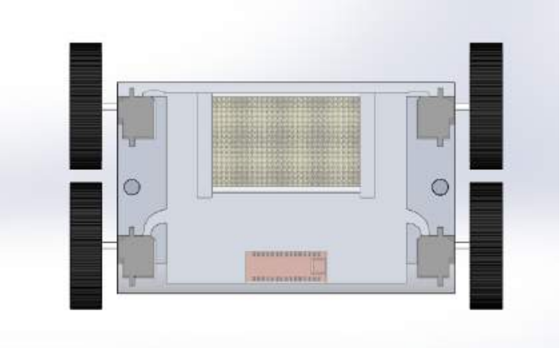


Fig 6.2: Top View

In this view, the four independent servo motors are visible. Each servo will be able to act independently, increasing maneuverability and overall traction of the rover. The computing device, an Arduino Nano, can be seen at the rear of the rover. The remaining space inside the rover will contain wiring and as many nine volt batteries as necessary to accomplish the tasks assigned.

Fig 6.3: Front View

In this view, the concealed solar panel tray is visible. Upon arrival at the final destination, the tray will eject outward until 2.12 inches of solar panel is visible. The panel tray is dual sided and houses two identical solar panels, allowing the orientation of the panel tray to be independent and deploy a panel upwards regardless if the rover is upside down or correctly oriented. The tray is connected to the rover via roller bearings and is pushed out to its deployed position by an electric solenoid (not displayed in any views shown above).

Our payload design consists of three main body pieces; a center box containing the solar panel tray, a "bottom" cap that holds the batteries in place, and a "top" piece that holds the motors in place. The payload vehicle can operate upside down because of this symmetric design and will drive in whichever direction needed according to its orientation. The main center box will be 3D printed and is designed to provide rigidity and sufficient protection to the internal mechanisms. Our design constraints include a maximum width of 5.998 inches and a length of 10.000 inches. Once these constraints are met, the payload vehicle will slide lengthwise into the payload body tube and remain secured there until deployment on the ground (Shown below).

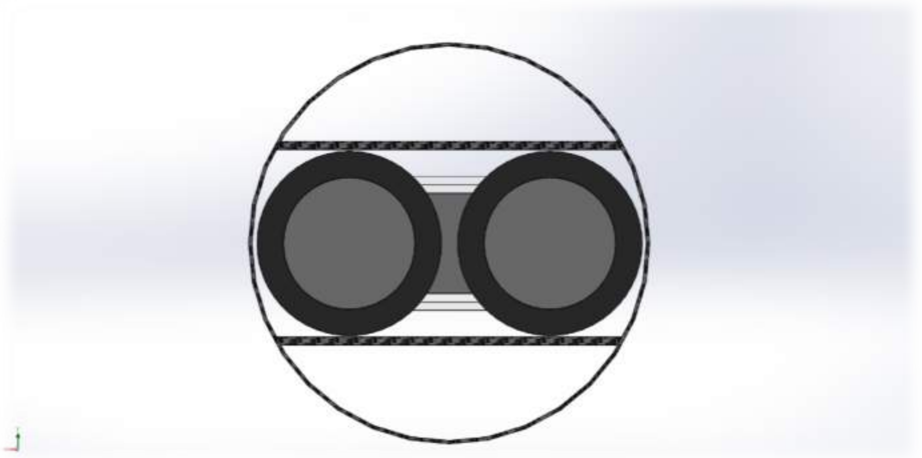
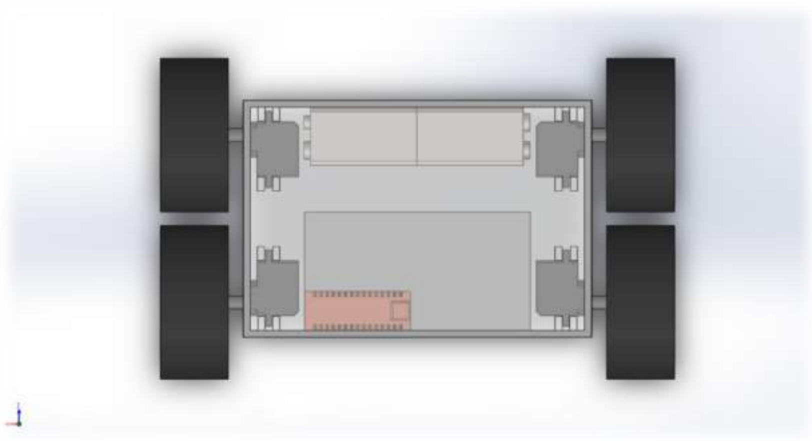


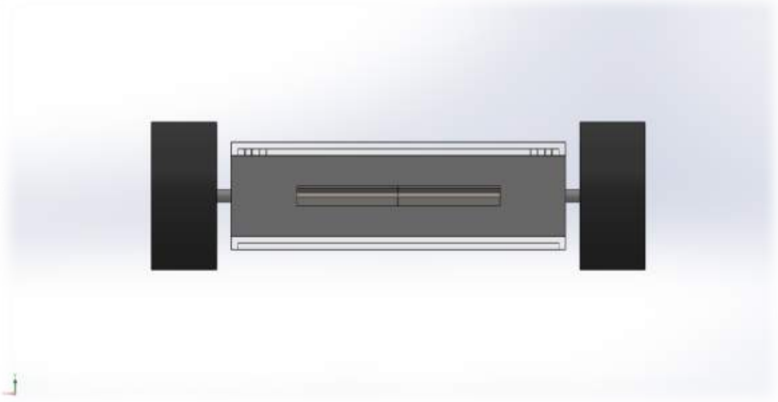
Fig 6.4: Payload Shown in Flight Configuration

Fig 6.5: Another Top View of the Rover



From this top view, the specific orientation of the internals can be more clearly seen. The motors are oriented flat to conserve the thin profile which benefits the ground clearance of the vehicle. The wiring cannot be drawn in SolidWorks, however the spacing between the mechanisms is accurate to allow space for the wires and connectors. The total outer length is just under 9.250 inches and the width is just under the inner diameter of the tube, which is 5.998 inches. The estimated weight without wires and connectors is 3.61 pounds.

Fig 6.6: Another Front View of the Rover



This view shows the clearance of the vehicle above the ground and the overall spacing of the tires. The slot in the front face is where the solar tray will be placed, a horizontally symmetrical tray that will be facing up and down, which ensures that the solar panels will be oriented upwards regardless of the orientation of the vehicle. The tires are centered vertically so provide equal clearance for top and bottom caps. The tires themselves will also be 3D printed by the team due to the strange size; no manufacturer makes them in the exact size the design requires.

6C – Payload System Analysis

Internal parts: All internal parts were selected based on the availability of the item as well as based on the previous experience of all team-members. Many parts were used by team members on different projects in their past and have been known to be accurate and reliable. Based on this accuracy and reliability we have selected the following parts to be used on our "Sparta Lander" payload.

Motors: Adafruit Industries LLC Servo Motor (4.8 VDC)

Sensors: 1. Smraza Ultrasonic Distance Sensors (*HC-SR04)*

Parameters:

A. Use voltage: DC5V
B. Quiescent current: less than 2mA
C. Detection range: 0.78~196 in/ (2cm~500cm)
D. High accuracy: up to 0.12 in/(0.3 cm)

Connection mode: VCC, trig (control), echo (receiving end), Ground

Module working principle:

A. The module automatically sends eight 40KHz square wave to detect whether a signal is returned.
B. If it finds an object in front, **Echo pin** will be high level, and based on the different distance, it will take the different duration of high level.
C. **The distance = ((Duration of high level)*(Sonic :340m/s))/2**

2. STMicro Accelerometer (*H3LIS100DLTR)*
3. Skylab Skynav SKM53 GPS w/ MT3329 IC & Embedded Antenna

Batteries: Duracell 9V

Voltage Regulators: Microchip LDO Voltage Regulators (*MCP1702-1202E/T)*

Programming chip: Arduino Nano (5V regulated external power)

Solar panels: Sundance Solar Small Solar Panel 5.0V / 50mA

6D – Payload Electronics

Microcontroller

The microcontroller chosen for the payload is an Arduino Nano shown in *Figure 6.7*. This microcontroller is very small and cost efficient compared to other microcontrollers like the TI MSP430. Not only is this unit small and compact but it has a huge community that supports multiple sensors.

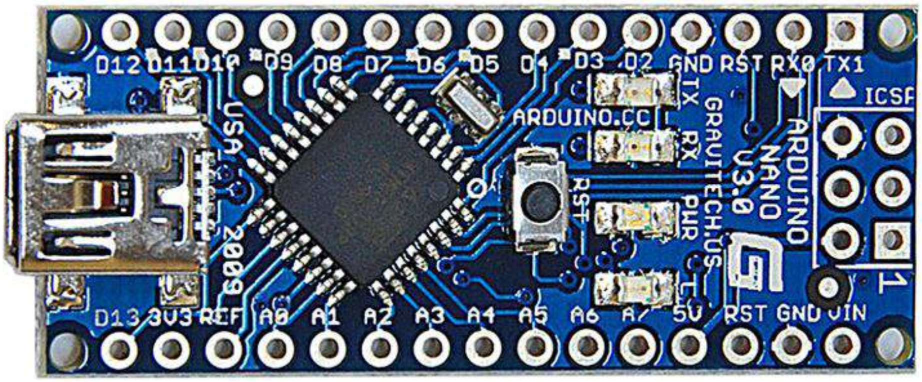


Figure 6.7: Arduino Nano

The Arduino also is very user friendly and has a very easy to work with language that many beginner programmers can understand unlike the TI MSP430 which is programmed with C++. The specs of the Arduino compared to the TI MSP430 are shown in *Table 6.1*.

Table 6.1: Comparison of Arduino Nano and the TI MSP430

	Arduino Nano	TI MSP430G2
Flash Memory	32 KB	32 KB
Clock Speed	16 MHz	16 MHz
DC Current per pin	40 mA	48 mA
Power Consumption	19 mA	270 uA
Weight	7 g	20 g
Dimensions	18 mm X 45 mm	68 mm X 51 mm
Language	Arduino	C

Based on *Table 6.1*, the MSP430 consumes less power and has the same memory and clock speed. The Arduino is chosen over the MSP430 because of the weight and the size. With the smaller unit the packaging for the payload rover can be smaller and reduce the amount of weigh the rocket will be carrying.

Sensors

For the payload, the rover will need to travel approximately five feet from the rocket then deploy solar panels. A problem arises when obstacles, like debris, are in the path of the rover. In order to combat this problem ultrasonic sensors are added to the rover in order to navigate around obstacles. The ultrasonic sensors are shown in *Figure 6.8* and use ultrasonic waves in over to detect what is in front of the rover.

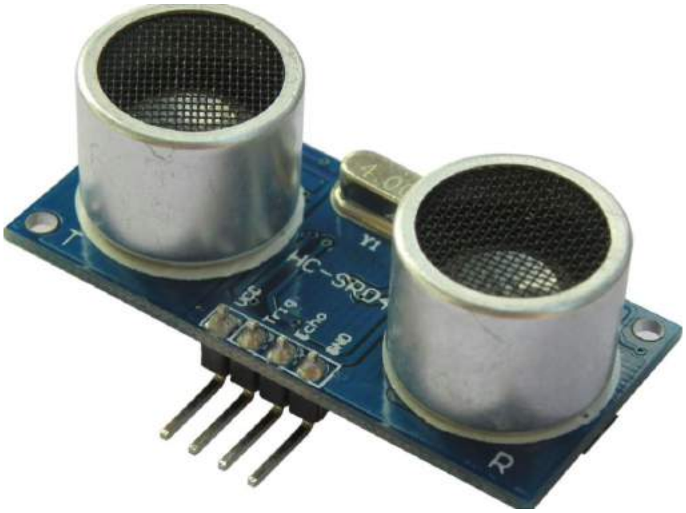


Figure 6.8: Ultrasonic sensor for Arduino:

The waves used are around 40,000 Hz which cannot be heard by humans and will have limited interferences because few electronic devices use waves at this frequency. This specific sensor (part number: HC-SR04) is made specifically for Arduino and is easy to implement.

Another problem that arises for the rover is determining when the rover has reached five feet and should deploy the solar panels. The solution to this problem is to add a GPS unit to the payload. The GPS unit chosen is the Skylab GPS Module MT3329 SKM53 shown in *Figure 6.9.* This unit has a built-in antenna which allows the payload to be very compact. The GPS module is also Arduino compatible which makes it a great choice for the Arduino Nano.

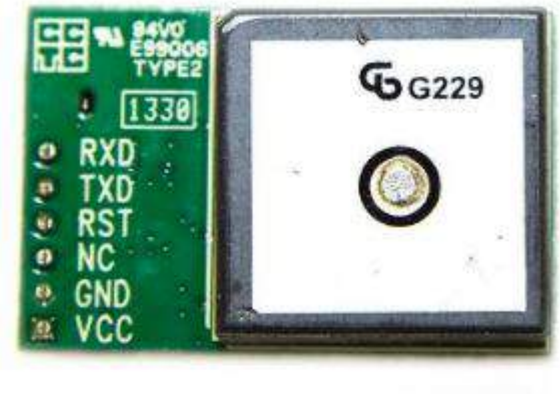


Figure 6.9: GPS unit

The GPS unit will be able to track how far the rover travels based on its starting position and will notify the Arduino when it has reach approximately five feet. With the GPS unit and the Ultrasonic sensors, the rover will know where it is and be able to guide itself around any obstacle that will present itself.

Motors

The payload will not be able to move anywhere without some sort of motor. A servo motor is chosen for the drivetrain of the vehicle. The servos used are from Adafruit Industries and have about a 200 mA power consumption. The servo pictured in *Figure 6.10*, will need an external power supply but can rotate either direction with great precision

Figure 6.10: servo used for the drivetrain

One servo will be attached to each wheel for additional torque and traction. These servos each have a torque rating of 56.49 mNm. With a servo attached to each wheel, the rover will be able to turn easier to avoid obstacles by turning opposite wheels different directions.

Power System

The payload will need an external power source in order for the rover to be mobile. *Table 6.2* shows the components and their corresponding current draw.

Table 6.2: Current draw of payload

Device	Current draw	Quantity	Total current draw
Arduino	19 mA	1	19 mA
Ultrasonic Sensor	15 mA	2	30 mA
GPS	40 mA	1	40 mA
Servo	200 mA	4	800 mA

From *Table 6.2*, the total current draw of the payload is approximately 889 mA. A single 9 V battery has approximately 500 mAh and weighs about 45 g. One 1.5 V battery has a rating of 2500 mAh and weighs around 23 g. Two power systems are designed with one using 9 V batteries and the other using 1.5 V batteries.

The first 9 V system requires 2 batteries connected in parallel that will equate to 1000 mAh and have a nominal voltage of 9 V. The second system requires 4 1.5 V batteries connected in series which will give the system a total voltage of 6 V with 2500 mAh. *Table 6.3* shows a comparison of the 2 systems.

Table 6.3: Comparison of 2 power systems

System	Voltage	Capacity	Weight
9 V batteries	9 V	1000 mAh	90 g
1.5 V batteries	6 V	2500 mAh	92 g

From *Table 6.3*, the 6 volt system has a higher capacity and only weighs 2 g more which makes this system the better option. The Arduino needs at least a 5 V power supply so the 6 V system will be sufficient. Using the 9 V system would not last as long and most likely would insufficiently power the servos due to the higher current draw. In an ideal scenario, the 9 V system would be able to power the payload for 1 hour but this is unlikely to occur in the real world.

Since the Arduino can only output 40 mA, the battery supply will need to be hookup directly to the servos in order to give them the current required. This is exhibited in *Figure 6.11*.

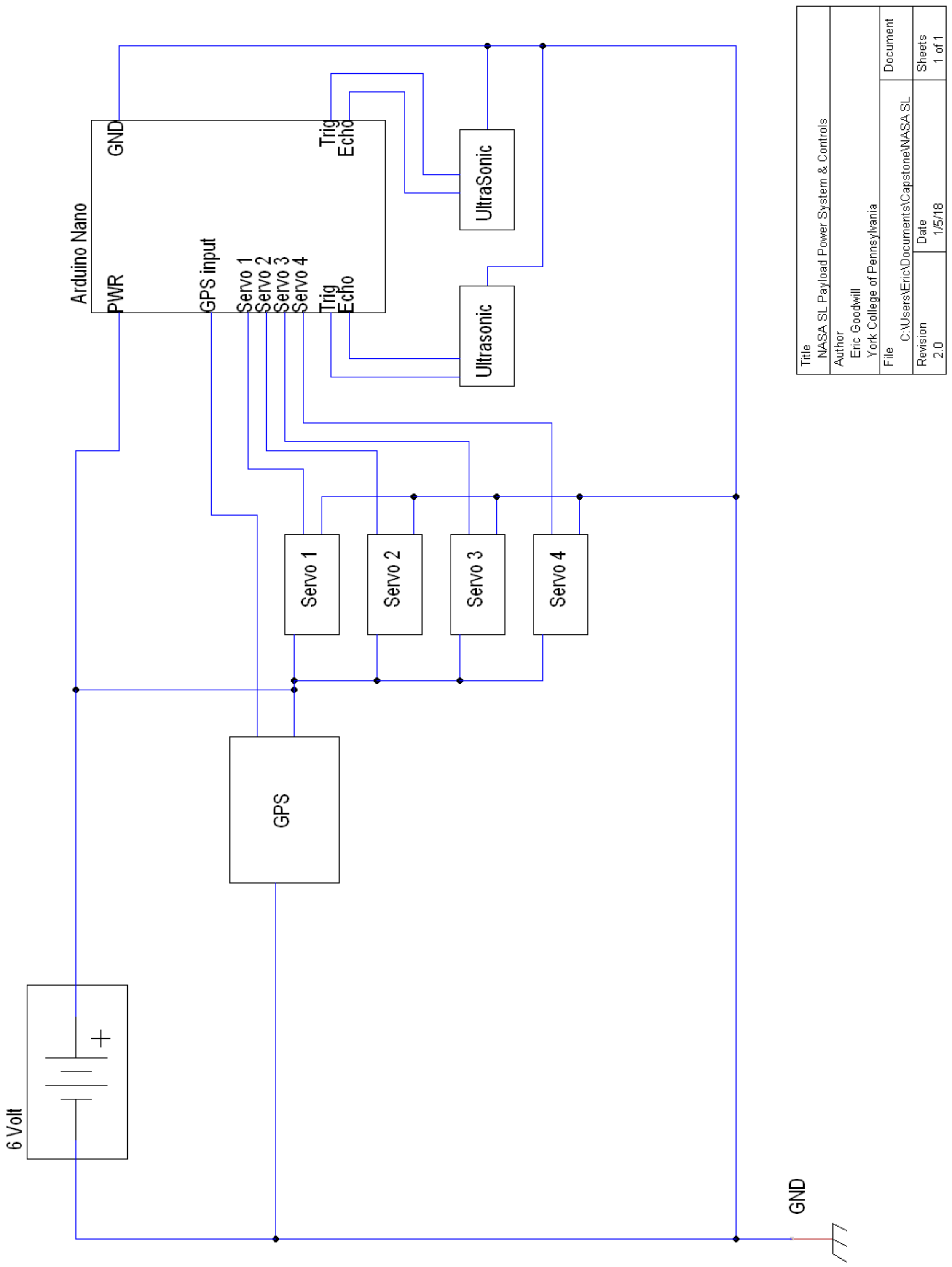
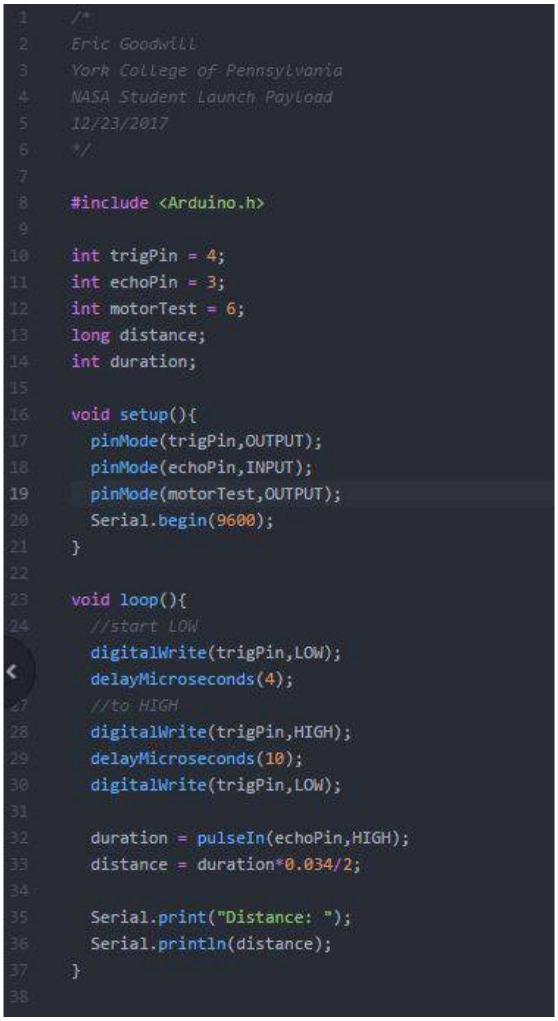


Figure 6.11: Schematic for Payload

Arduino Programming

For the Arduino to work properly it needs to be programmed. The ultrasonic sensors uses a Trigger signal which is a sonic burst. This wave travels at the speed of sound (343 m/s) and bounces off whatever object is in front of it. The wave then travels back to the sensor. The signal that is picked up is now called the Echo. The Echo is then compared to the Trigger output to determine how long the wave was traveling through the air. This (along with the speed of sound) can help the rover determine how far away an object is from it. With this information, the rover will be able to determine in it needs to move to the right or left in order to avoid the obstacle. *Figure 6.12* shows the code in order for the Arduino to read the distance of the obstacle ahead.



```
/*
Eric Goodwill
York College of Pennsylvania
NASA Student Launch Payload
12/23/2017
*/

#include <Arduino.h>

int trigPin = 4;
int echoPin = 3;
int motorTest = 6;
long distance;
int duration;

void setup(){
  pinMode(trigPin,OUTPUT);
  pinMode(echoPin,INPUT);
  pinMode(motorTest,OUTPUT);
  Serial.begin(9600);
}

void loop(){
  //start LOW
  digitalWrite(trigPin,LOW);
  delayMicroseconds(4);
  //to HIGH
  digitalWrite(trigPin,HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin,LOW);

  duration = pulseIn(echoPin,HIGH);
  distance = duration*0.034/2;

  Serial.print("Distance: ");
  Serial.println(distance);
}

```

Figure 1.12: Code for ultrasonic sensor

When the distance from the rover to an obstacle is less than or equal to 6 inches the rover will execute a turn, avoiding the obstacle.

6E - Payload Integration

Overview:

The payload will be housed within the payload tube at the front of the rocket. This tube will house the payload and also have the nose-cone attached to the front portion of it via shear-pins. The payload tube with attached nose-cone will be separated from the rest of the rocket at 600 feet during the rocket's descent. The payload tube and attached nose-cone will be attached to the rest of the rocket via shock-cord which will be attached to a bulkhead placed on the back portion of the payload tube.

For our payload to properly function and leave the payload tube housing we will have two systems in place to effectively allow the payload to dispense out of the tube and onto the surface ("the ground").

1. **Nose-Cone Ejection System**
2. **Payload Deployment System**

Nose- Cone Ejection System

Because the nose-cone and payload tube are attached during flight, the nose-cone must come off after flight in order for the payload to be pushed out through the opening in the body tube. For this to happen, we are going to use a CO2 ejection system to eject the nose-cone off and break the shear pins that were holding the payload tube and the nose-cone together during launch. This will create a separation between the nose-cone and the payload tube where the rover is housed.

As shown in Figure 6.13, we will be utilizing a Peregrine Exhaustless CO2 ejection system. For that particular system, the CO2 cartridges mount directly to the back of any bulk-head and provide their force through an opening in the bulkhead. A sled will also be built to hold the altimeter that will control the ejection of the CO2 cartridges. Because of the proximity to the nose-cone, we will not use a key-switch to arm the altimeter. We will use a *FeatherWeight Magnetic Switch* which we can wire directly to our PerfectFlite Altimeter. This magnetic switch allows any altimeter to be armed while on the launch pad by passing a Rare-Earth magnet over the altimeter. This will allow us to keep the nose-cone profile free of any holes or protrusions from key-switches. The altimeter itself will be programmed to have a delay of 65 seconds from the time that the rocket lands until the nose-cone is ejected off.

Normally the bulkhead on the nose-cone is epoxied in. In this application, we have designed a metal piece that will be epoxied into the very top of the nose-cone. Holes will be drilled into this metal piece before it will be epoxied into place. 2 all-threaded rods can then be threaded into the piece and held in place using Loctite. After drilling holes in the bulkhead, the bulkhead and sled can be secured by 2 nuts on both sides of the bulkhead. The bulkhead then can also be easily removed by removing the front nut from the all-thread. This makes changes and accessing the CO2 cartridges relatively easy.

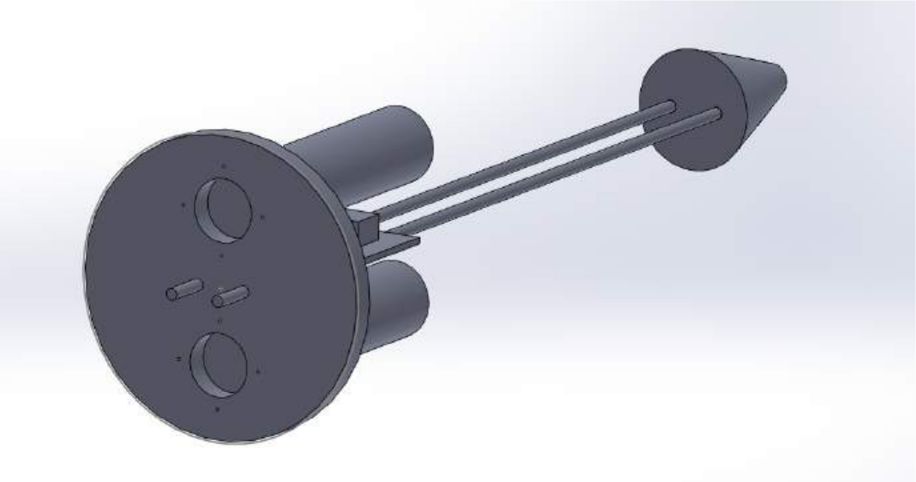


Fig 6.13: Isometric View of Nose-Cone System to Hold Bulkhead in Place

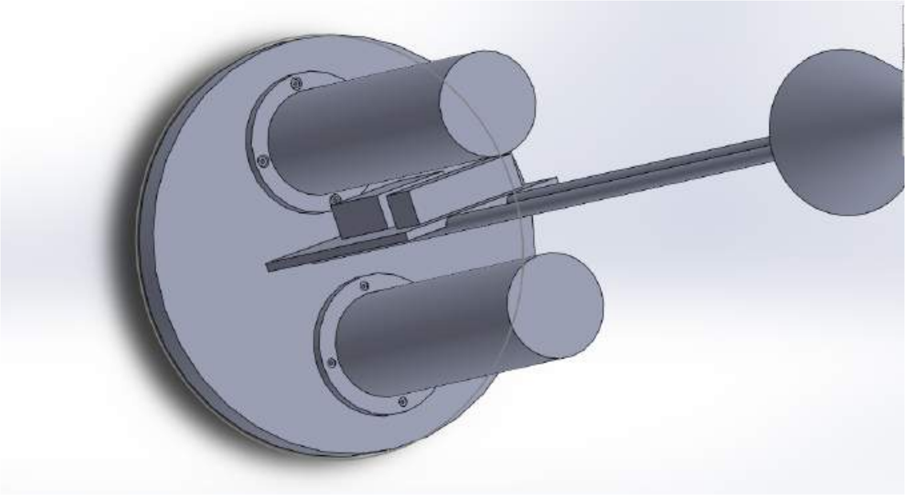


Fig 6.14: Side View of Nose-Cone System

Fig 6.15: Enclosed View of Nose-Cone

Payload Deployment System

After the nose-cone is ejected off the front of the payload tube, the front of the tube will be open to the environment. To have the rover leave the body tube it will be pushed out of the tube by a gear mechanism. The gear mechanism will be stored in coupler tubing inside the body tube. When the nose cone opens it will activate a motor with a worm gear. The worm gear will spin two gears one smaller than the other. As the large gear spins all thread rod will push the rover out of the upper body tube.

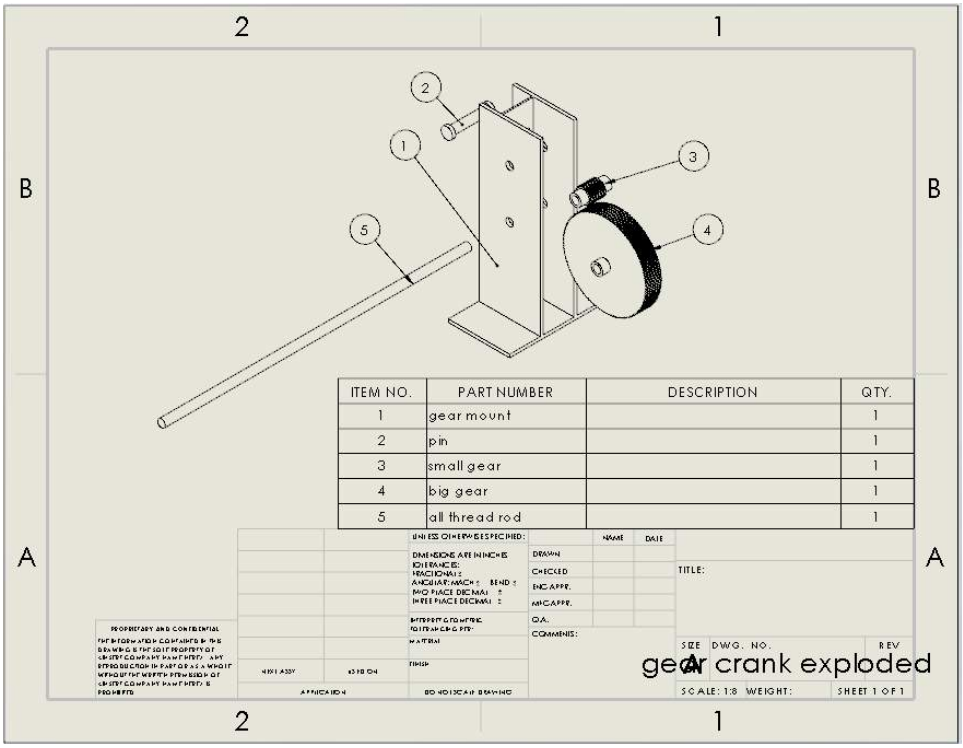
Main Parts:

- Motor
    - The motor is a Mabuchi 9V robot motor. The motor will be the main mechanism in the dispensing mechanism.
- Gear crank
    - The gear crank is the mechanism that will be mounted in the tube that hold the two gears.
    - The gears are designed so that the big gear is centered in the rocket and winds the all thread rod through the center.
    - The small gear was designed so that is allowed the motor to sit in the top left of the body tube as close to the coupler tubing as possible.
    - That all thread rod will be ¼ inch stainless steel to make sure there is no bending and was strong enough to push the rover out.

- Gears and motor
    - The gear crank and motor are assembled together to make the fully functioning dispensing mechanism. The gear crank has holes in the mount that is used to hold the motor in place with two screws

Integration:

To integrate the gear housing and motor it will be riveted to the coupler tubing. Once the gear housing has been attached the coupler tubing will be epoxied to the body tube. Finally, a bulkhead will be placed in between the rover and gear housing. as the crank pushed the all tread rod through the bulkhead it will move the rove forward and out the upper body tube where the nose cone has been opened.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	gear mount		1
2	pin		1
3	small gear		1
4	big gear		1
5	all thread rod		1

Fig 6.16: Gear Crank Exploded View

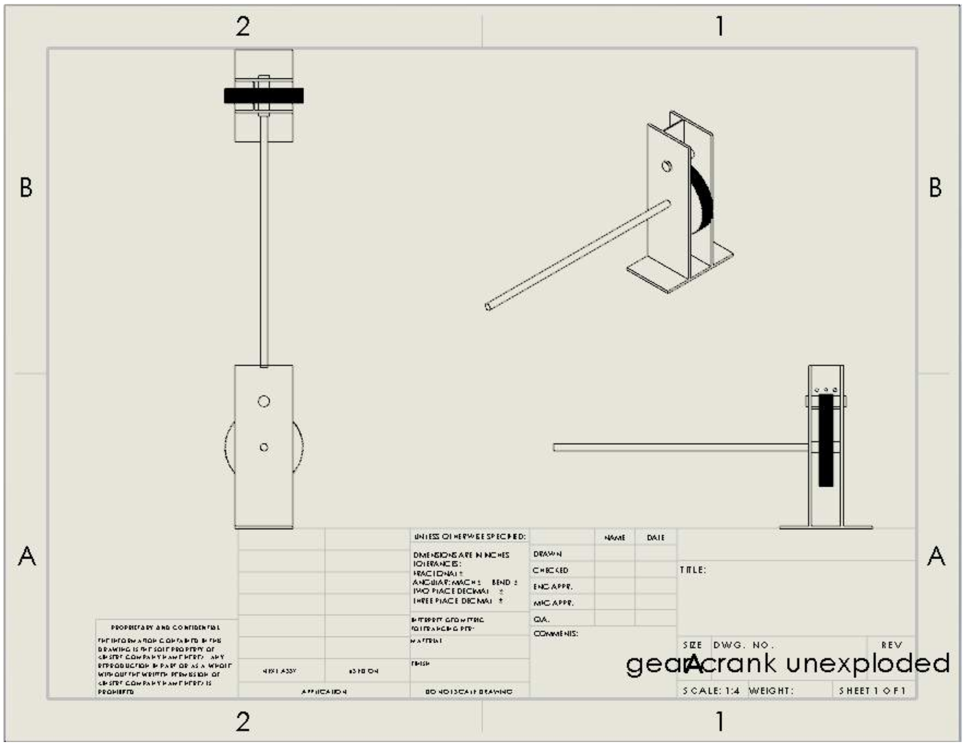


Fig 6.17: Gear Crank

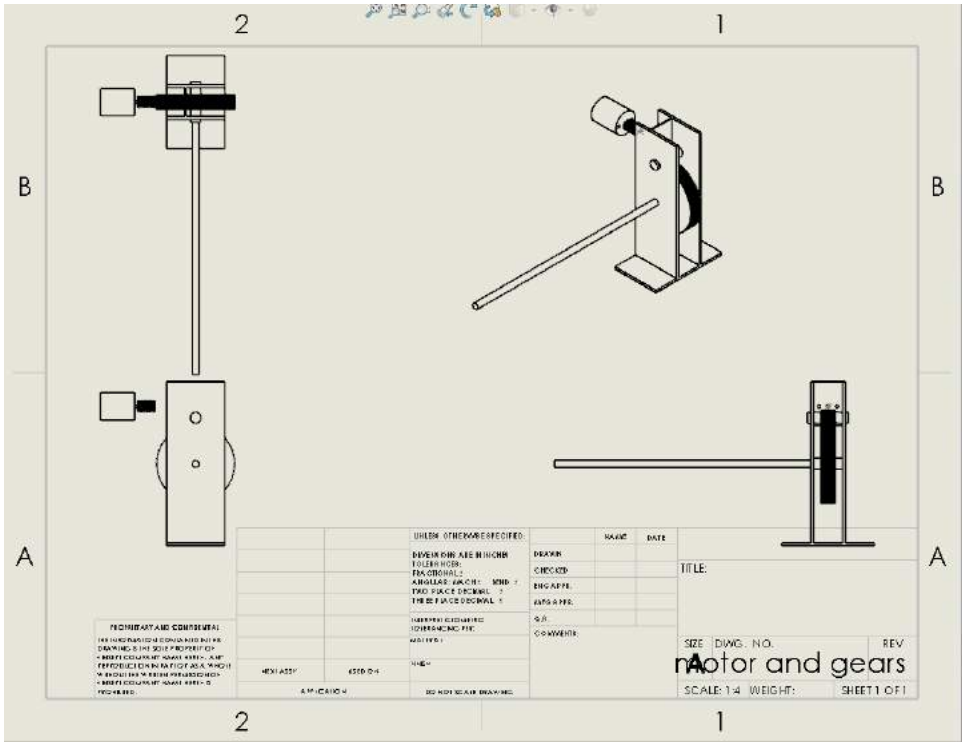


Fig 6.18: Gears and Motor Exploded View

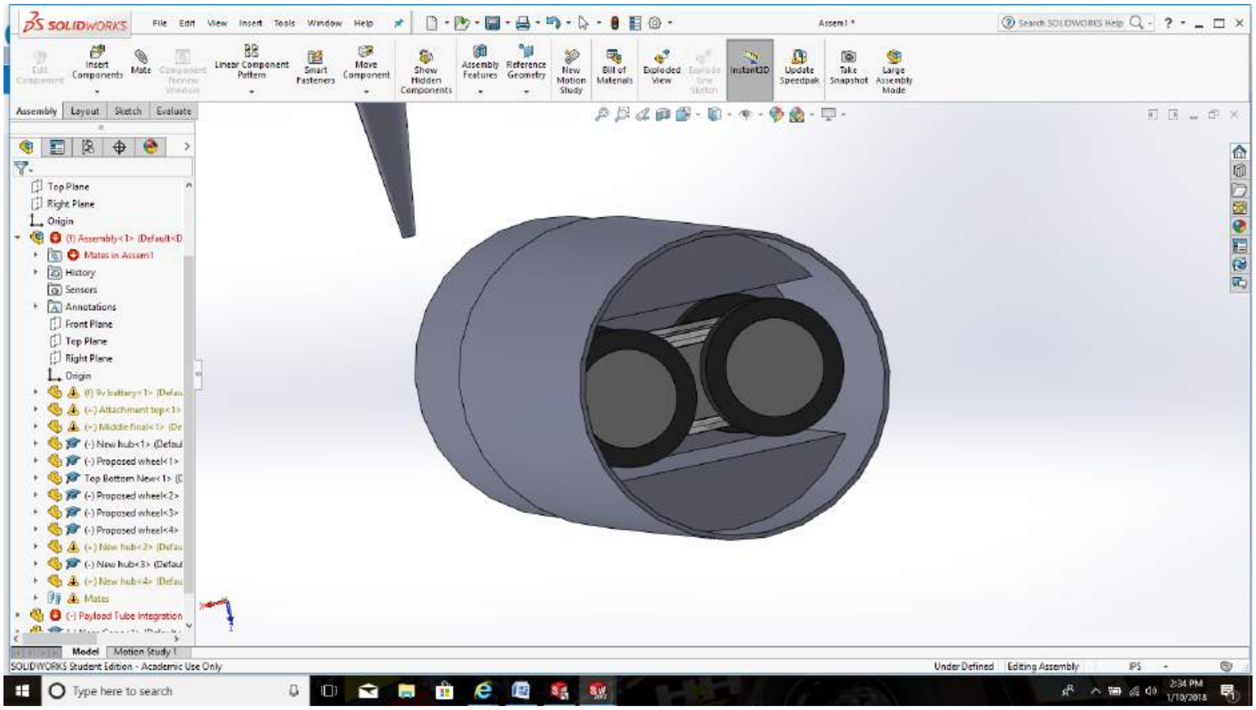


Fig 6.19: Side View of Payload Loaded Inside Rocket

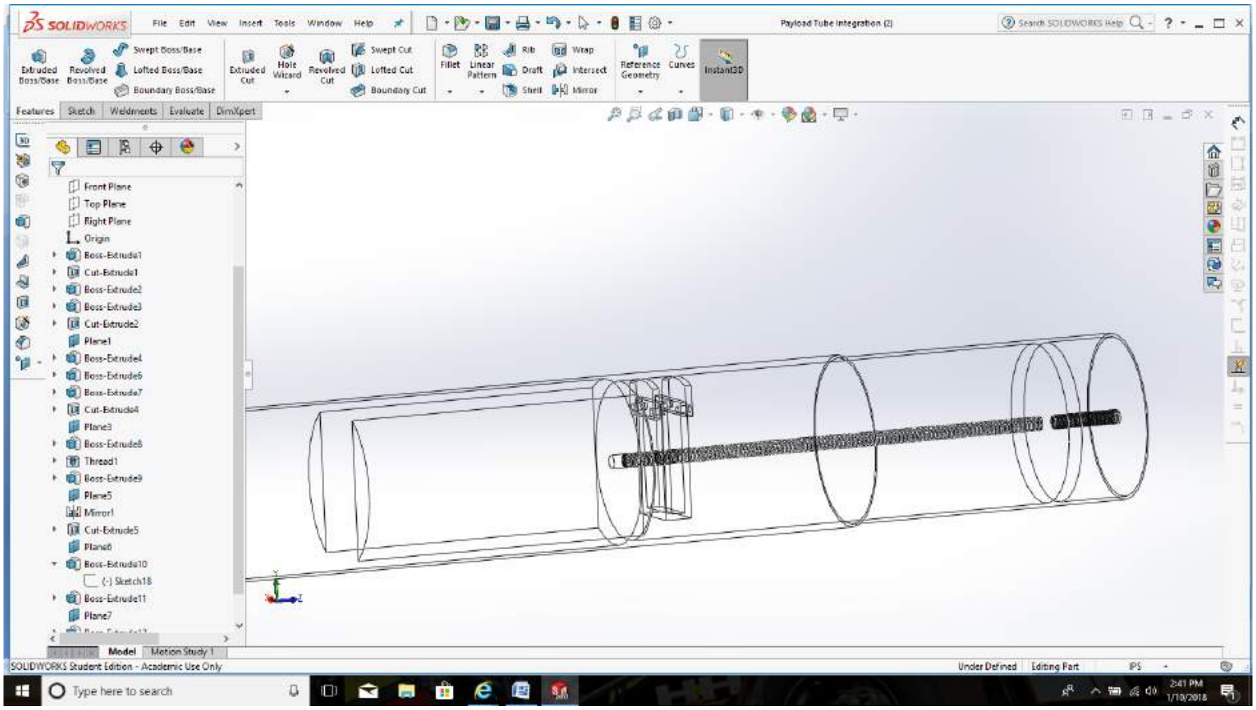


Fig 6.20: Wireframe Model Showcasing Gear System

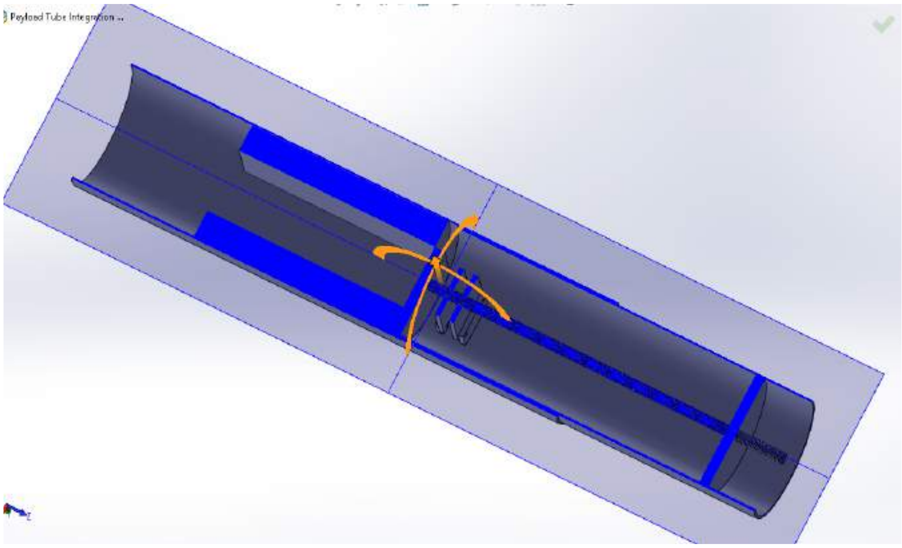
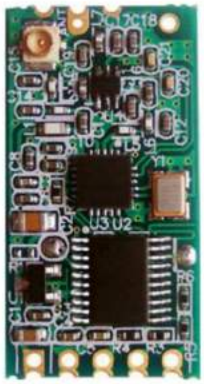


Fig 6.21: Top View of Gear System Integrated into Payload Tube

Wireless Communication
Based on the competition parameters, the rover cannot be deployed until the range safety officer gives the team the ok to deploy the rover from the rocket.

Due to this design parameter, we plan to use Serial Wireless Communication to turn on the gear motor that will spin the all-thread rod, therefore pushing the payload out. The *HC-12 wireless serial port communication module* is an embedded wireless data transmission module. Its wireless working frequency band is 433.4-473.0MHz with our setting at 441.0 MHz. The maximum transmitting power of module is 100mW (20dBm) with a communication distance of 1,000m in open space.



The transmitter module will be wired to the base-arduino and programmed via a laptop at base. The transmitter module will continuously send communication to the receiver module located inside the rocket. The receiver module will then stand-by until the signal is delivered to turn on the motor.

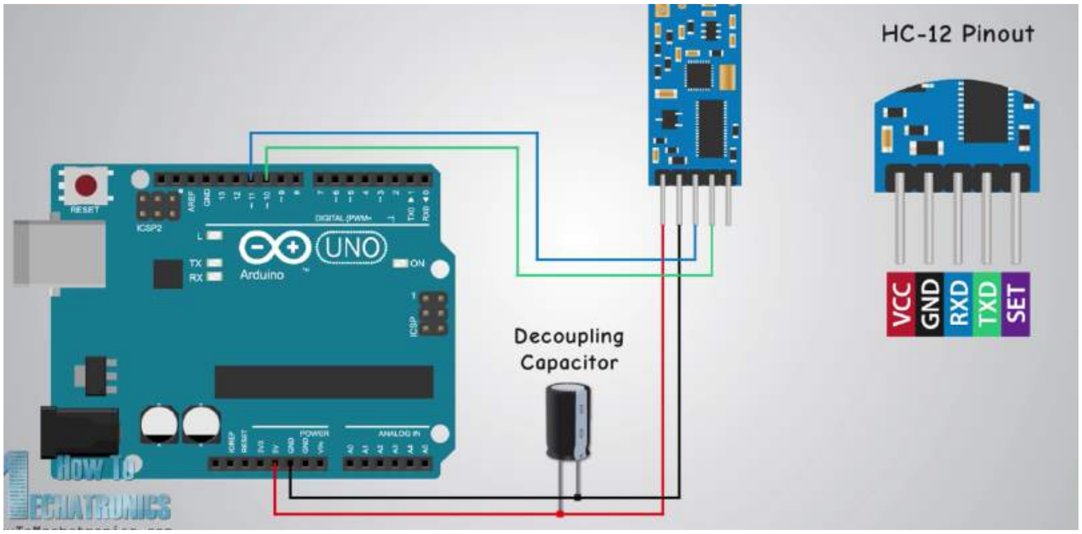
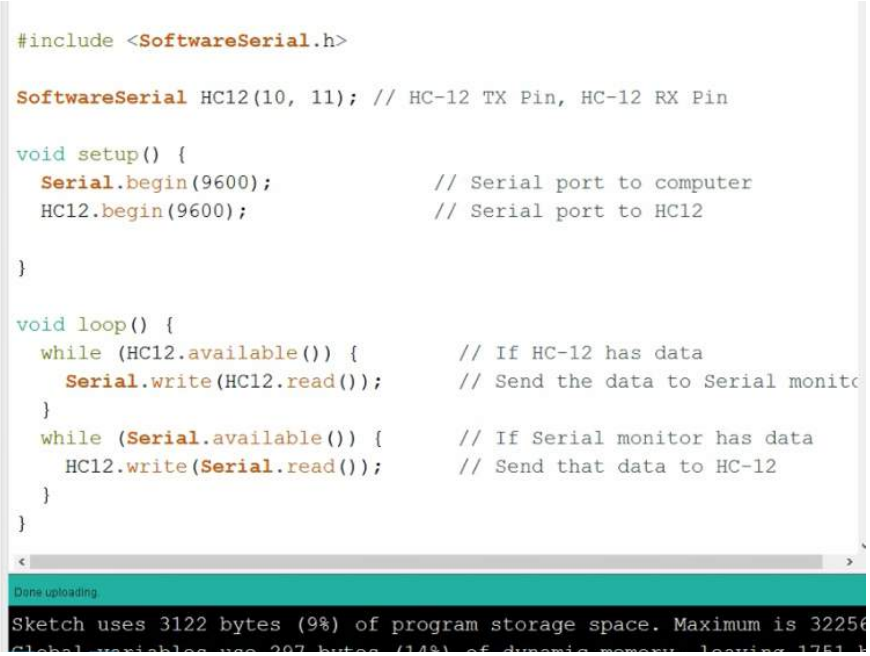


Fig 6.22: HC-12 Transmitter Schematic
(https://www.youtube.com/watch?v=vqRqtgvltOI)



```
#include <SoftwareSerial.h>

SoftwareSerial HC12(10, 11); // HC-12 TX Pin, HC-12 RX Pin

void setup() {
  Serial.begin(9600);             // Serial port to computer
  HC12.begin(9600);               // Serial port to HC12

}

void loop() {
  while (HC12.available()) {        // If HC-12 has data
    Serial.write(HC12.read());      // Send the data to Serial monitc
  }
  while (Serial.available()) {      // If Serial monitor has data
    HC12.write(Serial.read());      // Send that data to HC-12
  }
}
```

```
Sketch uses 3122 bytes (9%) of program storage space. Maximum is 32256
```

Fig 6.23: Basic Arduino Code for Transmitter Module

Section 7: Project Plan

7A - Testing

Testing

- Quick-Link Testing
- Shock Cord Testing
- U-Bolt Testing
- Ejection Testing
- Shear Pin Testing
- CO2 Ejection Testing
- Wireless Signal Testing

Quick-Link Testing

The objective of component testing is to find the strengths and weaknesses of each component. In order to test the components of the recovery system, a stress test was performed. In the testing, it showed a zinc, ¼” thick quick-link was tested to withstand a force of 2030 pounds without breaking. While our rocket will be experiencing a dynamic load from 405 to 945 pounds, a factor of safety range of 2.15 to 5.01 can be established if using the yield to be 2030 pounds which we tested in our lab. The testing was conducted in a controlled environment.

Shock Cord Testing:

For the shock cord we have decided to use the Tubular Nylon 1”. During the testing, we have found that the Tubular Nylon 1” shock cord was able to withstand up to 1680 pounds, which was less than expected due to the fact that the manufacturer rates this product to have a yield of 4000 pounds. The testing was conducted in a controlled environment, but will be repeated

U-Bolt Testing

For the rocket we will use ¼” thick aluminum U-bolts throughout. The purpose of testing the U-bolts was to find the strength/force put on the U-bolt. By finding this, we compared that number to the maximum shear stress allowable for the aluminum quick link with a factor of safety of 2.0. After testing, the steel U-bolt was the lightest option that also maintained the maximum shear strength needed to completely maintain its strength during flight.

Ejection Testing:

We completed a sub-scale rocket ejection charge test. This test confirmed that the calculations we had completed were fairly accurate and produced about the right amount of thrust to separate two sections of tubing. We will hold a black powder test with the full-scale rocket once the final rocket is assembled in early February. The rocket will be laid flat onto a table and wired directly to a current source through the key switches. We will clear a wide enough area and eject both sides of the rocket to ensure that the calculated mass is enough to separate the rocket into the need individual pieces.

Shear Pin Testing / CO2 Ejection Testing

The rocket will again need to be placed on a table, but this time we only need the payload tube and nose-cone. This test will be done to test the amount of shear pins that can be sheared off effectively using CO2 ejection canisters. This testing will also be extensively done to ensure that the nose-cone does not travel more than 10 feet from the payload tube after ground ejection. This is for safety reasons.

Wireless Signal Testing

To ensure that our wireless network will work, we need to run two tests. One test will involve continuous data being sent over the network and having two students split off and walk in different directions. The point of the test is to find the maximum range of our system. We want to make sure that we can communicate with our rocket from at least 2,560 feet away. The second test to be done is to test if the signal can penetrate through the fiberglass body-tube. We need to know that the module will be able to read signals from a long distance but also while enclosed in the body-tube.

Why Testing is Necessary:

Testing on each component is necessary to our rocket for many reasons. Testing will help us get the best results from our rocket, ensure that all the parts are capable of completing the task that they are designed to do, and most importantly, testing can help ensure that everything will be complete safely. During launch and decent, if any of the components fails, it could have negative effects on the rocket and payload.

Results:

Quick-Link Testing - Results were more than satisfactory.
Shock Cord Testing - Results were not satisfactory, but will be redone
U-Bolt Testing - Results were satisfactory.
Ejection Testing – TBD
Shear Pin / CO2 Ejection Testing – TBD
Wireless Network Testing - TBD

7B – Verification Plan

General Requirements	Verify	Plan
Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor).	Demonstration	Each component of the rocket has been divided between the team members.
The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assigned, educational engagement events, and risks and mitigations.	Demonstration	Project plan included in the CDR.
Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during these activities.	N/A	N/A
The team must identify all team members attending launch week activities by the Critical Design Review (CDR). Team members will include: 1.4.1. Students actively engaged in the project throughout the entire year. 1.4.2. One mentor (see requirement 1.14). 1.4.3. No more than two adult educators.	Demonstration	The final list was emailed to NASA representatives.
The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement Activity Report, by FRR. An educational engagement activity report will be completed and submitted within two weeks after completion of an event. A sample of the educational engagement activity report can be found on page 31 of the handbook. To satisfy this requirement, all events must occur between project acceptance and the FRR due date.	Demonstration	We have arranged to work with the York Country Day school where we will be holding demonstrations and workshops.
The team will develop and host a Web site for project documentation	Demonstration	The website has already been created. www.ycprocketry.weebly.com
Teams will post, and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline.	Demonstration	The proposal and PDR were added when it was due and the

		CDR will also be added by due date.
All deliverables must be in PDF format.	Demonstration	All files will be converted to PDF format.
In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Demonstration	Table of contents has been included.
In every report, the team will include the page number at the bottom of the page.	Demonstration	Page number has been included.
The team will provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a broadband Internet connection. Cellular phones can be used for speakerphone capability only as a last resort.	Demonstration	York College of PA I.T. department has arranged for all the necessary equipment for the teleconference.
All teams will be required to use the launch pads provided by Student Launch's launch service provider. No custom pads will be permitted on the launch field. Launch services will have 8 ft. 1010 rails, and 8 and 12 ft. 1515 rails available for use.	Demonstration	We will be using 12 ft 15 x 15 rail.
Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194) Subpart B-Technical Standards (http://www.section508.gov): 1194.21 Software applications and operating systems. 1194.22 Web-based intranet and Internet information and applications.	Demonstration	We will allow any person that is interested in joining our team the ability to join as long as he/she is a part of York College of PA.

Each team must identify a “mentor.” A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor must maintain a current certification, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attends launch week in April.	Demonstration	Our mentor is Dr. Ericson who is a mechanical engineering professor here at York College of PA.
The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL)	Test	We have verified this using OpenRocket simulation.
The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner. Teams will receive the maximum number of altitude points (5,280) if the official scoring altimeter reads a value of exactly 5280 feet AGL. The team will lose one point for every foot above or below the required altitude.	Test	We plan on testing the altimeters by performing a sub scale launch.
Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	Demonstration	The arming switches have been integrated in the E-bay design.
Each altimeter will have a dedicated power supply	Demonstration	Each altimeter has been provided with its own power source.
Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	Demonstration Inspection	We will use Key Switches that are capable of being in the “locked” position with the insertion of a key.
The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	Analysis	Most of the rocket components are reusable right away.

The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.	Demonstration	Our design for the rocket has 3 independent sections.
The launch vehicle will be limited to a single stage	Test	One motor, a “Aerotech L1150” will be used.
The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.	Analysis	We plan on practicing for assembling the launch vehicle in the allocated time slot.
The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components.	Test	The launch vehicle is operated by 9V batteries which can last up to 3 hrs. Additional test will be performed to verify the data.
The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider.	Demonstration	We are using a commercially available rocket motor that is also capable of being fired with a standard 12-Volt firing system.
The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by Range Services).	Demonstration	No external ground support will be needed for launch.
The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR). 2.13.1. Final motor choices must be made by the Critical Design Review (CDR). 2.13.2. Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.	Demonstration	We plan on using a L-class motor. Specifically we are using the “Aerotech L-1150 Motor” from Cesaroni Technology Incorporated.
Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria: 2.14.1. The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews. 2.14.2. Each pressure vessel will include a pressure relief valve that sees the full pressure of the valve that is capable of withstanding the maximum pressure and flow rate of the tank.	N/A	N/A

2.14.3. Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.		
The total impulse provided by a College and/or University launch vehicle will not exceed 5,120 Newton-seconds (L-class).	Analysis	We plan on using an L-class motor.
The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	Demonstration Testing	Our current calculations in both the simulation and by hand have our rocket with a stability margin of 2.85.
The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit	Demonstration Testing	Our current calculations in both the simulation and by hand have our rocket with a rail exit velocity of 84 ft/s.
All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets. 2.18.1. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model. 2.18.2. The subscale model will carry an altimeter capable of reporting the model's apogee altitude.	Demonstration	Our subscale rocket was successfully flown and recovered twice.
All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight: 2.19.1. The vehicle and recovery system will have functioned as designed. 2.19.2. The payload does not have to be flown during the full-scale test flight. The following requirements still apply: 2.19.2.1. If the payload is not flown, mass simulators will be used to simulate the payload mass.	Demonstration	The team plans to test launch the full-scale rocket during the MDRA February and March Launches which will occur before the FRR is due. The mass simulators will be located in the same spot as the

2.19.2.1.1. The mass simulators will be located in the same approximate location on the rocket as the missing payload mass		payload during sub-scale and full-scale launching.
If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale demonstration flight.	N/A	N/A
The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulates, as closely as possible, the predicted maximum velocity and maximum acceleration of the launch day flight	Demonstration	The full-scale motor will be flown during full scale flight testing.
The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.	Demonstration	The full-scale rocket will be flown like it will be during the National Flyoff in Huntsville, AL.
After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer (RSO).	Demonstration	The rocket will not be modified after full-scale testing.
Full scale flights must be completed by the start of FRRs (March 6th, 2018). If the Student Launch office determines that a re-flight is necessary, then an extension to March 28th, 2018 will be granted. This extension is only valid for re-flights; not first-time flights.	Demonstration	The rocket will be flown before March 6th, 2018.
Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	N/A	Agree
Vehicle Prohibitions	N/A	Agree
The launch vehicle will not utilize forward canards.	N/A	Agree
The launch vehicle will not utilize forward firing motors.	N/A	Agree
The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	N/A	Agree
The launch vehicle will not utilize hybrid motors.	N/A	Agree
The launch vehicle will not utilize a cluster of motors	N/A	Agree

The launch vehicle will not utilize friction fitting for motors	Demonstration	The team will utilize a motor retainer for motor retention purposes.
The launch vehicle will not exceed Mach 1 at any point during flight.	Demonstration Simulation	The rocket will not exceed Mach 1, and will reach a maximum speed of Mach 0.667
Vehicle ballast will not exceed 10% of the total weight of the rocket.	Demonstration	The vehicle ballast will not exceed 10% of the total weight of the rocket.
The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.	Demonstration	This system will be set up through redundancy of the altimeters within the electronics bay.
Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.	Testing	We will perform ground ejection testing here at York College to ensure that the ejection charge masses are sufficient for the launch vehicle.
At landing, each independent sections of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.	Demonstration Calculations	As seen in section 3C, the kinetic energy of each section is less than 75 ft-lb.
The recovery system electrical circuits will be completely independent of any payload electrical circuits.	Demonstration Construction	The electronics bay will be independent of all payload and other circuitry.
All recovery electronics will be powered by commercially available batteries	Demonstration	The electronics bay will be powered by a commercially available 9V battery.
The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.	Demonstration Construction	There will be 2 altimeters in the electronics bay to provide redundancy.
Motor ejection is not a permissible form of primary or secondary deployment.	Demonstration	The motor will not be ejected during flight.
Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	Demonstration	Removable shear pins will be used for both the drogue and main parachute ejections.
Recovery area will be limited to a 2500 ft. radius from the launch pads	Demonstration	As seen in section 3C, the recovery area of our rocket is less than 2500 feet, even in 15 mph winds.
An electronic tracking device will be installed in the launch vehicle and will transmit the position of the	Demonstration	A tracker will be used within our rocket.

tethered vehicle or any independent section to a ground receiver. 3.10.1. Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device. 3.10.2. The electronic tracking device will be fully functional during the official flight on launch day.		
The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing). 3.11.1. The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device. 3.11.2. The recovery system electronics will be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics. 3.11.3. The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system. 3.11.4. The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	Demonstration	No wires will connect between independent sections.
Each team will choose one design experiment option from the following list	Demonstration	We plan using option 2. We have already designed a rover for the payload.
Additional experiments (limit of 1) are allowed, and may be flown, but they will not contribute to scoring.	N/A	N/A
If the team chooses to fly additional experiments, they will provide the appropriate documentation in all design reports, so experiments may be reviewed for flight safety.	N/A	N/A
All not applicable	N/A	N/A
Teams will design a custom rover that will deploy from the internal structure of the launch vehicle.	Analysis	We already have design for the rover completed.
At landing, the team will remotely activate a trigger to deploy the rover from the rocket.	Demonstration Construction	A trigger will be activated after landing to deploy the rover from the rocket.
After deployment, the rover will autonomously move at least 5 ft. (in any direction) from the launch vehicle.	Demonstration Wiring	The rover will be programmed via and Arduino to move at least 5 feet away from the rocket while also avoiding any obstacle

		in its' way by sensor recognition to reach its target destination.
Once the rover has reached its final destination, it will deploy a set of foldable solar cell panels.	Demonstration	A set of solar panels will open up after the rover reaches its final destination.
All not applicable	N/A	N/A
Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	Demonstration	A safety and launch checklist are in the process of being constructed. They will be completed by FRR at the latest.
Each team must identify a student safety officer who will be responsible for all items in section 5.3.	Demonstration	Our assigned safety officer is Jacob Van Brunt.
The role and responsibilities of each safety officer will include, but not limited to: 5.3.1. Monitor team activities with an emphasis on Safety during: 5.3.1.1. Design of vehicle and payload 5.3.1.2. Construction of vehicle and payload 5.3.1.3. Assembly of vehicle and payload 5.3.1.4. Ground testing of vehicle and payload 5.3.1.5. Sub-scale launch test(s) 5.3.1.6. Full-scale launch test(s) 5.3.1.7. Launch day 5.3.1.8. Recovery activities 5.3.1.9. Educational Engagement Activities	Demonstration	Jacob Van Brunt has been assigned to monitor team activities
Implement procedures developed by the team for construction, assembly, launch, and recovery activities	Demonstration	We have begun to implement such procedures.
Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data	Completed	MSDS Sheets are currently posted in the team workspace.
During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch Initiative does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	Demonstration	We will listen to Bob Utley and Brian Hastings, both Level 3 certified mentors who will be at the MDRA launches when we are testing both our sub-scale and full-scale rocket.
Teams will abide by all rules set forth by the FAA.	Demonstration	Rules will be followed.

7C – Team Derived Requirements

Vehicle Requirements

Requirement	Verification	Testing Plan
7C.1 – The nose-cone will not eject more than 10 feet from the payload tube during ground ejection after a successful flight	**Demonstration** **Testing**	We plan to conduct CO2 testing to ensure the nose-cone will not move more than 10 feet from the payload tube. This will be demonstrated during full-scale testing.
7C.2 – The main and drogue parachutes will both eject successfully during launch and the total drift from the launch pad will be less than 1,500 feet.	**Demonstration** **Design**	By designing a good model and running a number of simulations we want to ensure that the drogue and main parachute ejections work perfectly and ensure that the rocket's drift will be less than 1,500 feet from the launch pad in 99% of launch conditions.
7C.3 – 3-D printed fin-can will keep its integrity during launch and also not crack upon landing	**Design** **Testing**	With a successful subscale fin-can, we found that our 3-D fin can be strong and withstand the forces put on it during launch. It is up to us to continue testing to strengthen the fin-can as much as possible.

Safety Requirements

Requirement	Verification	Testing Plan
7C.4 – Provide the team with an updated Safety Manual which includes team safety review plans, PPE requirements, emergency equipment,	**Demonstration**	The Safety Officer must keep a team Safety Manual updated with appropriate procedures prior to the subscale launch and all

MSDS, machine operation instructions, FAA laws, and NAR and TRA regulations.		safety procedures prior to the first full-scale launch.
7C.5 – Identify safety violations and take appropriate action to correct them.	**Demonstration**	If a team member is in violation of any rules, they will first be warned, and then banned for a period of time if it happens again.
7C.6– Ensure the safety of all team members while working in the team garage	**Demonstration**	The student safety officer will look out for the well-being of all students and also make sure that everyone remains safe.
7C.7 – Ensure Safe Transport of all Rocket Motors and Pyrotechnics	**Demonstration**	The student safety officer will ensure that pyrotechnics are handled carefully.

Payload Requirements

Requirement	Verification	Testing Plan
7C.8 – The rover must be held in place during the entire flight and cannot move before the rocket reaches the ground safely after flight.	**Demonstration**	The payload system is designed to not come apart until after the launch is over. Through more testing and good coding, we will ensure that the payload does not move or leave the rocket before the end of the flight.
7C.9 – The wireless HC-12 Serial Port Communication Device must be capable of receiving through the body-tube and at a distance of at least 2,600 feet from the transmitter.	**Demonstration** **Testing**	Through testing we will ensure that the receiver is able to pick up signals from a long distance and also through the fiberglass tubing.

Recovery Requirements

Requirement	Verification	Testing Plan
7C.10 – The recovery harness will be able to withstand static loads at least 20 times greater than the dynamic loads that can be put on the shock-cord, U-bolts, and quick-links during flight.	**Demonstration Testing**	Through testing we have found that the recovery system is capable of withstanding extremely high static test loads which gives me confidence that the recovery system will work well on the full-scale rocket. More testing is yet to be completed.
7C.11– Be able to locate the rocket after launch.	**Demonstration**	Place a tracking transmitter inside the rocket during launch so that we can find the rocket. Test to make sure that it works before launch.

7D - Educational Engagement

Educational engagement is an important part of this project because it allows community involvement and interaction. We feel that it is beneficial for students, and even teachers, to learn about different activities they can connect with, and passions they can pursue. We hope that in hosting activities and visiting schools, students will have the opportunity to experience STEM fields, and gain an understanding of rocketry and the design process.

We have continued pressing forward with our educational engagement activities, but have not yet gone to visit other schools. Unfortunately, we have had some minor communication problems with several places, and hope we can stay in contact with the administrators to plan around the busy school hours.

We plan to have a presentation around 25 minutes long that will explain what our project is, our design, materials, and goals for this year's competition. We will then preform a small scale launch to allow the students a hands on opportunity with the rocket, and ask any questions.

So far, these are the events we are planning:

York County School of Technology

We have plans to go to their school and do our presentation to all the high schoolers by January 23rd. It would be in two different sessions to accommodate their class schedules. The exact date is still being determined, but we are hoping to schedule for the first week York College classes resume, (01/17.)

York Country Day School

YCDS has been communicating with us for the entire duration of our project, but unfortunately getting messages back and forth is proving to be slow going. We have reinstated our contact with them, and hopefully we get some ideas of if and when we can schedule a visit to present.

Edgar Fahs Smith STEAM Academy of York City Schools

This school is very excited to be working with our team, and hope to get a date set for a visit. We are still sorting out the details, but partnering with their school sounds promising.

York College of PA K-12 Outreach Program

There is a program here at our college that has monthly outreach activities for kids to bring their own projects for feedback and ideas. We hope to partner with the professor in charge of the program to present our project to them for inspiration.

Assessment Criteria for Activities:

The event will be considered successful if:

1. Students engage in STEM team activities
2. Students learn about our club and about the exciting possibilities STEM offers
3. Students get hands on experience trying to solve a problem by going through the engineering design process
4. Students learn the basics of rocketry
5. The students have fun and enjoy the activity

We want to get students excited about the STEM fields and most importantly about building rockets. We also want them to learn critical thinking by solving problems using the engineering design process, and finally, we want the students to have FUN!

7E - Budget

COSTS

Hardware / Tools	PRODUCT A	Product B
Jb Weld Epoxy	$6.99	
3/4" PVC SCH40 Slip Cap (6)	$2.94	
Play Doh Weight	$3.00	
Dustpan w/ Brush	$3.00	
Gloss Black Paint Can (2)	$2.50	
Scott Towels (10)	$26.00	
Xacto Knife (2)	$12.98	
Bernzo Electrical Solder	$8.27	
Butane Refill for Soldering Gun	$4.98	
Bernzo Solder Tool	$27.99	
Shapie 5 pack	$4.98	
Dymo160 Label Maker	$19.98	
Wet/Dry Vac	$29.97	
6 ft Table (2)	$77.76	
10 X 10 Canopy	$89.00	
PVC Pieces to make rocket stands (48)	$60.13	
3/4" U-Bolt (6)	$5.88	
1" U-Bolt	$7.80	
Threaded Rod (36" X 5/16"X18)	$10.52	
5/16" Hex Nuts (100 count)	$8.57	
5/16" Washers (100 count)	$9.95	
14 Gauge Wire (50 ft.)	$8.87	
12 Gauge Wire (100 ft.)	$19.87	
Dremel Accessories	$36.61	
Dewalt 30 piece Maxfit Set	$12.97	
Energizer Batteries 9V 6-pk (4)	$51.94	
Dremel 12V Max Cordless Rotary Tool	$99.00	
Milwaukee M18 Drill/Driver (2)	$258.00	

Rocket Parts	PRODUCT A	Product B
1/4" Quick Links (12)	$47.28	
Nylon Shear Pins (20 pack) (5)	$15.50	
Removable Plastic Rivets (10 pack) (6)	$22.26	
1010 Rail Buttons (2)	$7.00	

1515 Rail Buttons (4)	$20.00
Aero Pack 75mm Motor Retainer-P	$47.08
G5000 Rocketpoxy - 8 oz. package	$12.00
30 in. Shock Cord Protector (5)	$64.75
18 in. Nome Black Parachute Covering (4)	$41.96
120 in. Classic Elliptical Main Parachute	$320.00
24 in. Classic Elliptical Parachute (2)	$110.00
Fiberglass Wrapped Phenolic Body Tubes	$554.97
Mouser Terminal Block (10)	$24.60
Mouser Keystone 1295 Battery Holder (10)	$1.87
9V Batteries (3 - 8 packs)	$27.00
SPDT Switch 11-3360 (5)	$20.00
Strattologger CF Altimeters (4)	$219.80
Data Transfer Kit	$24.99
Black Powder Dispenser	$35.00
Subscale Rocket	
4 in. Fiberglass Wrapped Body Tubes	$209.98
Fin Assembly (3-D printed)	$50.00
Components mentioned above…	
Payload	
Arduino Ultrasonic Sensor (3)	$2.97
Ardunio Nano pack of 3	$11.86
Servo (5)	$29.75
MCP1702 Voltage Regulator (10)	$4.80
Solar Panels (4.5V Output) (2)	$11.18
Various Other Electrical Components	$20.00

Indirect Costs	PRODUCT A	Product B
Travel to Practice Launches	$1,000.00	
Food for all Trips	$2,500.00	
Travel to Hunstville, AL	$4,000.00	
Lodging in Huntsville, AL	$3,500.00	

7F - Funding Plan

As of right now we have already obtained a few sources of funding. The Pennsylvania Space Grant Consortium has donated $7,500 towards the Student Launch project. Any funds left over after buying full-scale parts will continue to help pay for the trip to Huntsville.

We have also received a grant of $1,000 from the Walmart Foundation. In order to meet our funding goal, we will need to raise an additional $6,000. We have been applying to numerous other grants including the York College Great to Greater Fund for up to $5,000. We are waiting to hear back from this source at this time.

We also will be doing numerous fundraisers, many of which we have already begun. The main one will be a raffle auction event during one of our accepted student days.

We also plan on selling rocket space for our full-scale rocket to be launched in Huntsville. This will be sold through the Christmas season, possibly raising around $1000 - $1500 dollars for our project.

Further efforts will be made to fundraise for the complete projects. More fundraisers will be occurring until the completion of the project. We are actively searching for and applying to grants, and we have contacted dozens of local businesses with hopes of a donation, sponsorships, or any type of monetary donation. We have already received a donation of $50 from one of these local businesses: NTM Engineering. With all of these fundraisers, grants, and donations, we will be able to raise enough to pay for the completion of the 2017 - 2018 SL project.

7G – Updated Schedule / Timeline

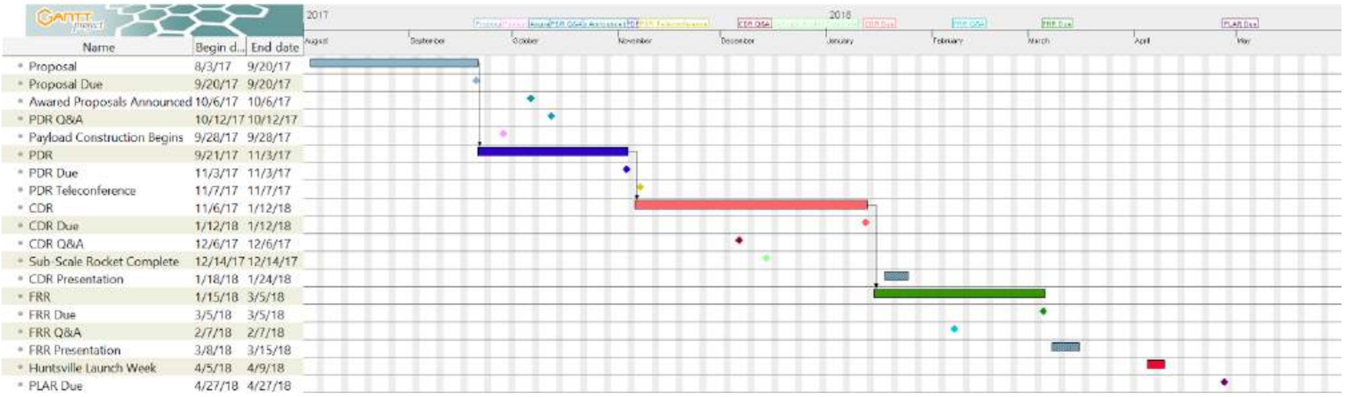
Date	Event
August 2017	
3	Year Planning and regroup
September 2017	
20	Proposal Due by 5PM
21	Rocket Final Design Plans
28	Construction Begins on Payload
October 2017	
6	Construction (Payload)
6	Awarded Proposals Announced
12	Kickoff and PDR Q + A
13	Construction (Sub-Scale Rocket)
18	Wind Tunnel Testing
20	Construction
27	Construction
November 2017	
2	Construction
3	PDR and subsequent documentation is due
7	PDR Teleconference
7	Team Meeting
9	Construction
14	Team Meeting
16	Construction

21	Team Meeting
23	Construction
28	Team Meeting
30	Construction
December 2017	
5	Team Meeting
6	CDR Q + A
7	Construction
12	Team Meeting
14	Construction
14	Sub-Scale Rocket is Complete
16	Test Launch
14-19	Educational Engagement Activities Begin
19	Team Meeting
21	Construction
26	Team Meeting
28	Construction
January 2018	
2	Team Meeting
4	Construction
9	Team Meeting
11	Construction
12	CDR and subsequent documentation is due
16	Team Meeting
18	Construction

18-24	CDR Presentation
20	Test Launch
23	Team Meeting
24	Full-Scale Rocket nearing completion
25	Construction
30	Team Meeting
February 2018	
1	Construction
6	Team Meeting
7	FRR Q + A
8	Construction
13	Team Meeting
15	Construction
15	Test Launch
20	Team Meeting
22	Construction
27	Team Meeting
March 2018	
1	Construction
5	FRR and subsequent documentation is due
6	Team Meeting
8	Construction
8-15	FRR Presentation
9	Test Launch
13	Team Meeting

15	Construction
20	Team Meeting
22	Construction
27	Team Meeting
29	Construction
April 2018	
3	Team Meeting
5-9	Huntsville Launch Week
17	Team Meeting
24	Team Meeting
27	PLAR Due

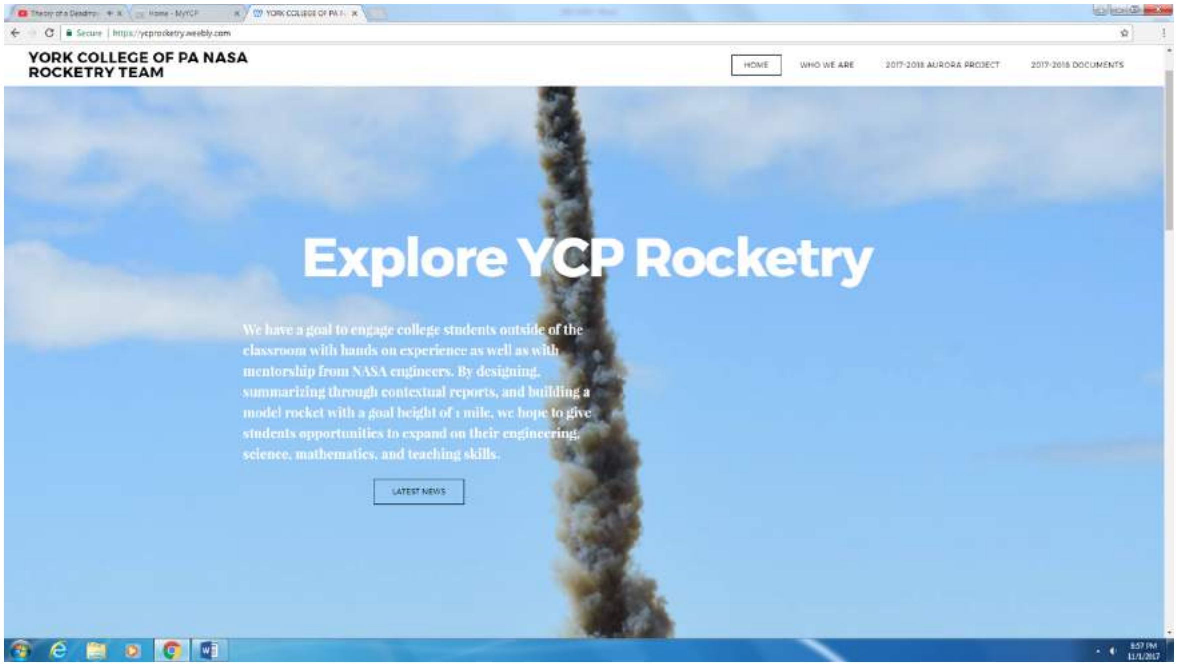
GANTT Chart of Team Activities and Team Schedule



Name	Begin d...	End date
Proposal	8/3/17	9/20/17
Proposal Due	9/20/17	9/20/17
Awared Proposals Announced	10/6/17	10/6/17
PDR Q&A	10/12/17	10/12/17
Payload Construction Begins	9/28/17	9/28/17
PDR	9/21/17	11/3/17
PDR Due	11/3/17	11/3/17
PDR Teleconference	11/7/17	11/7/17
CDR	11/6/17	1/12/18
CDR Due	1/12/18	1/12/18
CDR Q&A	12/6/17	12/6/17
Sub-Scale Rocket Complete	12/14/17	12/14/17
CDR Presentation	1/18/18	1/24/18
FRR	1/15/18	3/5/18
FRR Due	3/5/18	3/5/18
FRR Q&A	2/7/18	2/7/18
FRR Presentation	3/8/18	3/15/18
Huntsville Launch Week	4/5/18	4/9/18
PLAR Due	4/27/18	4/27/18

Website and Team Outreach

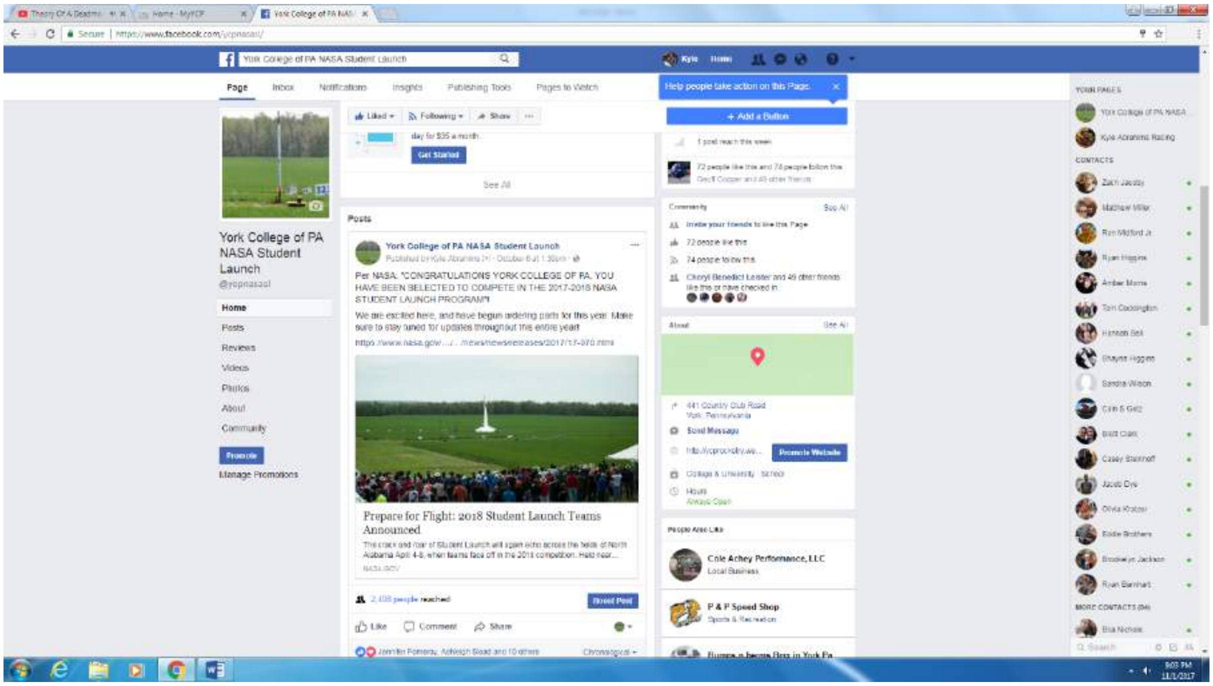
We as a team will use both our website located at www.ycprocketry.weebly.com and our Facebook page to continue to interact on social media, spread awareness about our club, and provide updates on our progress to our followers.



Explore YCP Rocketry

We have a goal to engage college students outside of the classroom with hands on experience as well as with mentorship from NASA engineers. By designing, summarizing through contextual reports, and building a model rocket with a goal height of 1 mile, we hope to give students opportunities to expand on their engineering, science, mathematics, and teaching skills.

Figure 7.1: Screenshot from Website



York College of PA NASA Student Launch

Per NASA: "CONGRATULATIONS YORK COLLEGE OF PA, YOU HAVE BEEN SELECTED TO COMPETE IN THE 2017-2018 NASA STUDENT LAUNCH PROGRAM!"

We are excited here, and have begun ordering parts for this year. Make sure to stay tuned for updates throughout this entire year!

Prepare for Flight: 2018 Student Launch Teams Announced

Figure 7.2: Screenshot from team Facebook Page