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

The Aurora Project

441 Country Club Road
York, PA 17403

General Information

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Team Leaders:

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Team Mentor:

Brian Hastings
NAR Representative
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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

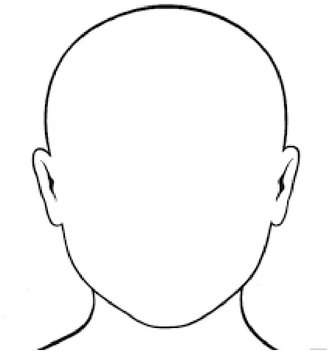
Saumil P. (Co-Captain, Recovery System)

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)

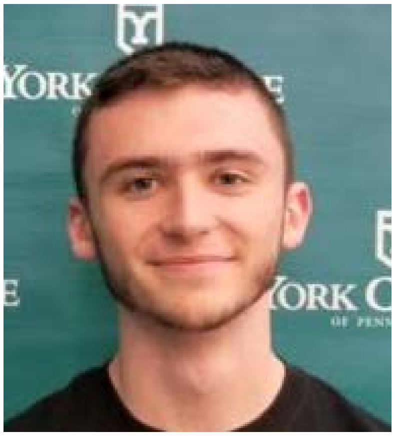


Eric is a senior electrical engineering major here at York College of Pennsylvania. He will bring his experience in electrical subsystems and Arduino programming to the project.
He will be leading the payload integration team and will assist us in building the payload that we have designed for the project.

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.

Daniel K. (Mechanical Work)



Daniel is a mechanical engineering major from Long Island, New York. Daniel chose mechanical engineering because he enjoys designing and making parts and pieces to cars, and machines. He loves making things and seeing how they work and how they could also be potentially improved. He became interested in this club because he always thought that rockets and the idea of space travel was cool and fascinating. He knows that we come nowhere near to space, but the idea of making a rocket and putting it together and then having it launch sounded awesome and something that he wanted to be a part of!

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.

Section 1: Summary of PDR 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: 10.99 feet
Mass: 27.36 pounds
Motor Choice: CTI 3419 L645 Green
Recovery Subsystem:

1. Dual Deployment Via Electronics Bay with added redundancy
2. 24-inch drogue parachute made by Fruity Chutes deployed at apogee
3. 96 inch or 120-inch parachute to be deployed at 600 feet based on Cd of manufactured parachute that is selected

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 22-inch payload tube that will be attached to the nosecone via a locking mechanism such as a small internal electromagnetic lock. This payload bay (bodytube) will be attached to the nosecone, so it will be ejected with the nosecone when the main parachute is deployed, and will be attached to the main body of the rocket via shock cord and a U-bolt on its back edge. When instructed after landing, the lock on the nosecone will be disconnected which will allow the nose cone and payload bay to become un-attached to one another. Another series of solenoids on the back edge of the payload (on the back bulkhead) will then be used. These solenoids will push the rover out the top of the payload bay, 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 2A: Changes Made from Proposal

2.1 - Changes Made to Vehicle:

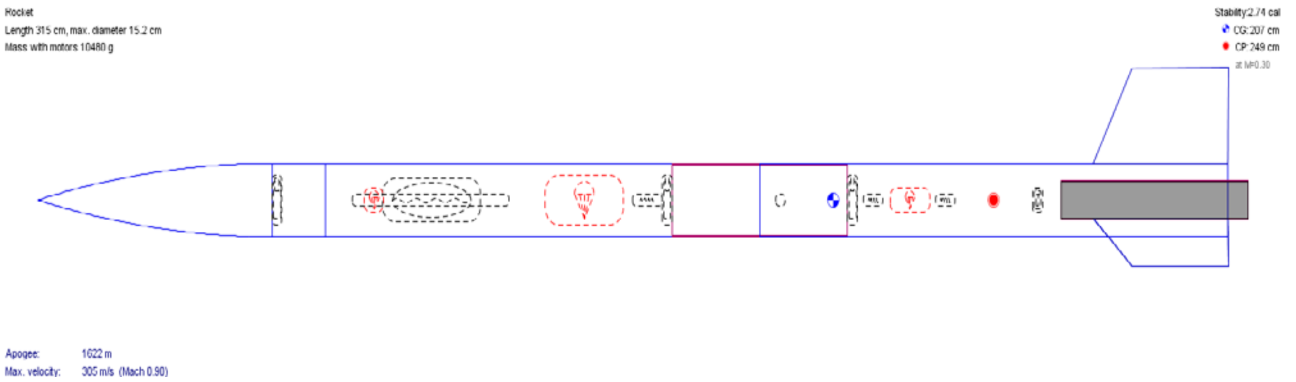


Fig 2.1: Initial Rocket Design as Proposed in Proposal Design

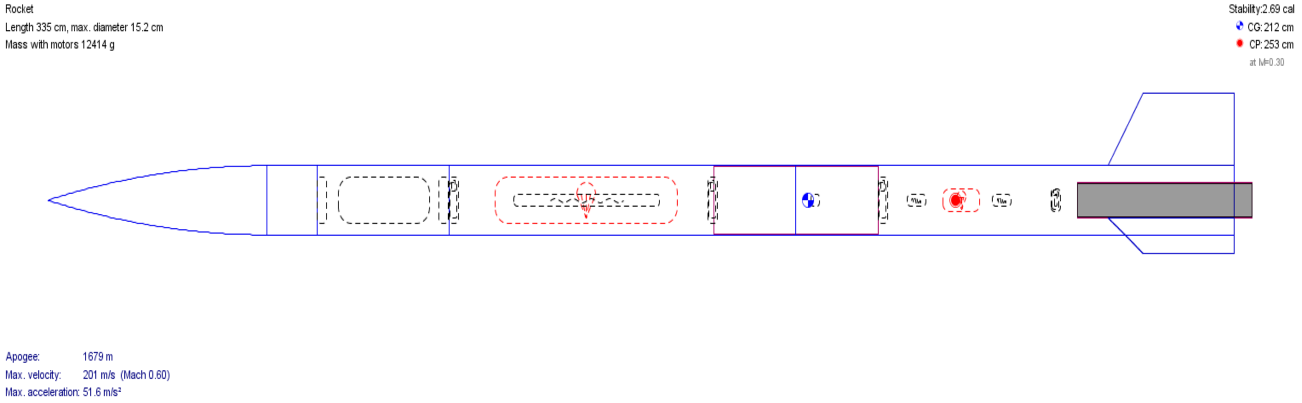


Fig 2.2: Proposed Rocket Design for PDR Report

Our initial rocket design (See Figure 1), was composed of a 6-inch carbon fiber airframe with a length of 315 cm or 10.33 feet. Our initial design was based on a payload that would be ejected from the rocket during main parachute ejection, so there was a subsystem of 2 body-tubes that made up the main airframe. This subsystem only consisted of 2 body tubes as the payload was placed inside a body-tube that also contained the main parachute. Our new rocket design (See Figure 2), is made up of 3 separate body tubes with lengths of 48, 38, and 22 inches respectively. The airframe will be made up of 6-inch fiberglass wrapped phenolic tubing that will make up the airframe sub-system of the rocket. The change in body tube material is due to the relative cost saving of the fiberglass wrapped phenolic tubing compared to that of carbon fiber tubing. The move to 3 body tubes is to create a 3rd body tube that will house the payload during flight. This third tube will be attached to the nose cone during flight and will separate with the nose cone during main parachute ejection. With this new design, the payload will stay contained within the main airframe until the range safety officer clears the range for payload extradition. The new length of the rocket will be 335 cm or 10.99 feet. The increase in size is due to the addition of the third body tube that will house the payload. The increase in length and movement of the payload mass further forward on the rocket design by 4 inches allows the fins to be lowered in height by 2 centimeters. This is due to the movement forward of the center of gravity which allows the center of pressure to be moved as well to maintain a stability margin between 2.5 and 3.0.

2.2 - Changes Made to Payload:

Our initial payload called for a lander based device to be ejected from the rocket during main parachute ejection at 600 feet. The lander would then have had a parachute attached to its top edge to correct the orientation of the rover on landing. After a clarification of the rules, the payload was redesigned to ensure that it would be within the rules that NASA deemed necessary to maintain project outlines and safety. Our new payload will feature a four-wheeled rover that will be extracted from the rocket after launch. The rocket design has been analyzed and documented to include a 20-inch payload tube that will be attached to the nosecone via a locking mechanism such as a small internal electromagnetic lock. This payload bay will be attached to the nosecone, so it will be ejected with the nosecone when the main parachute is deployed, and will be attached to the main body of the rocket via shock cord and a U-bolt on its back edge. When instructed after landing, the lock on the nosecone will be disconnected which will allow the nose cone and payload bay to become un-attached to one another. Another series of solenoids on the back edge of the payload (on the back bulkhead) will then be used. These solenoids will push the rover out the top of the payload bay, 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. This new design allows the rover to exit the launch vehicle once instructed, instead of during vehicle descent.

2.3 - Changes Made to Project Plan:

No major changes have occurred to our project plan since the proposal was submitted. The timeline and budget have since been updated to reflect the latest materials and component costs. Our funding plan was also updated to include a new grant that we have since received from The Walmart Community Foundation. We are continuing to work to create a better Gantt Chart for scheduling and launch dates, as well as working with local companies to find support for our amazing program.

Section 2B: Facilities and Equipment

2B.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.

2B.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.

2B.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 3: Vehicle Criteria

Subsection 3A: Selection, Design, and Rationale of Launch Vehicle

3A.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.

3A.2 - System Level Design

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 we used a factor chart as well as a decision matrix 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 discussed below, we as a team used several factors in determining what materials would work best for our design and what we felt the best route would be during construction. The team first considered a variety of materials to use for the vehicle. These materials included Kevlar, Fiberglass, Wood, Carbon Fiber, Aluminum, and Cardboard "phenolic" (Used in Phenolic Tubing). These materials were researched and each was found to have its own set of material properties.

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 3A.1: Material Properties

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.

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 3A.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 3A.3: Decision Matrix

As you can see from the above decision matrix carbon fiber is the best available material to use for our rocket airframe. But because of the exceedingly high cost of carbon fiber, we have decided instead to use fiberglass wrapped phenolic tubing for our main airframe. This decision matrix was used later in the project for our design projects as well. In the following sections, we will go into more detail for each specific part of the rocket design.

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. According to the decision matrix above, the body tubes should be constructed from carbon fiber. But due to budget constraints, we have decided to go with fiberglass wrapped phenolic tubing. This is because of their relative strength, which is high enough to withstand the high forces put on the airframe during launch, and for their relatively lower cost compared to carbon fiber tubing (1/2 the cost).

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 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 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.

Coupler

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 to ensure structural stability and to ensure that the rocket does not tilt upon launch. These couplers must be able to withstand forces experienced during rocket ascent to keep the structure of the body attached. This includes shear stresses from the body tubes during flight as well as axial stress in the electronics bay coupler that holds the electrical components inside.

For coupler construction we considered two methods:

Method 1: 3-D print all couplers from Ultem plastic

By printing our own couplers we could control both the exact diameter as well as exact length of the couplers being printed. This could help in rocket construction progress and also help to ensure that the couplers are exactly how we would want them. The downfalls of the 3-D printed couplers would be that the Ultem couplers would have very thin walls relative to their size, and this can cause the Ultem plastic to be prone to cracking when placed under stress. This could become critical especially when designing the electronics bay coupler. We can control the thickness of the couplers, but we also want to be conscious of weight, which could be impacted when 3-D printing couplers.

Method 2: Phenolic Couplers

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. So no additional testing would need to be completed on these couplers to ensure flight worthiness. The downfall of these couplers would be the increased cost compared to 3-D printing our own couplers. For these reasons, the team has decided to use phenolic tubing couplers in our final rocket design.

Bulkheads

Bulkheads are typically flat plates used create airtight spaces in a rocket. This may 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. Also aluminum is a smooth metal. For bulkheads to be attached to the airframe, they often require an epoxy to be applied which bond the bulkhead to the airframe at a specified point. Due to the smoothness of the material, it would be hard to bond to the airframe without a significant 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.

We as a team have decided to use wooden bulkheads due to their reliability and for cost saving measures. For CDR, calculations will be done to ensure that the wooden bulkheads are strong enough to prevent stress failures during flight.

Centering Rings

The purpose of the centering rings are 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. These centering rings will be made either with wood using a laser cutter or with carbon fiber depending on the availability of material to us. The general dimensions of the centering rings will be a mass of 4 oz., an outer diameter of 6 inches with an inner diameter of 75 mm. The thickness of each ring will be approximately 0.25 inch.

U-Bolts

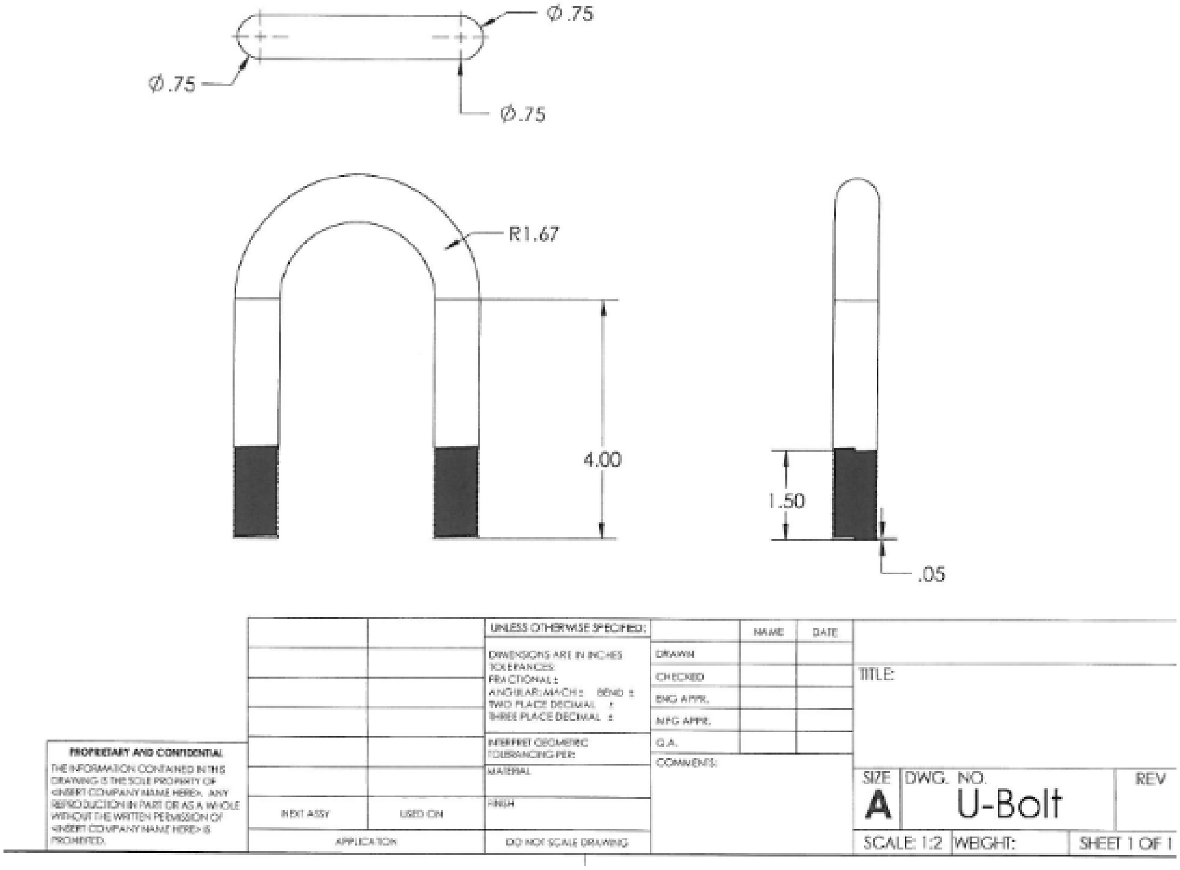


Fig 3A.4: U-Bolt Assembly

For the rocket we will use ¾” thick aluminum 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 aluminum quick link with a factor of safety of 2.0. The aluminum U-bolt was the lightest option that also maintained the maximum shear strength needed to completely maintain its strength during flight.

Fin Design

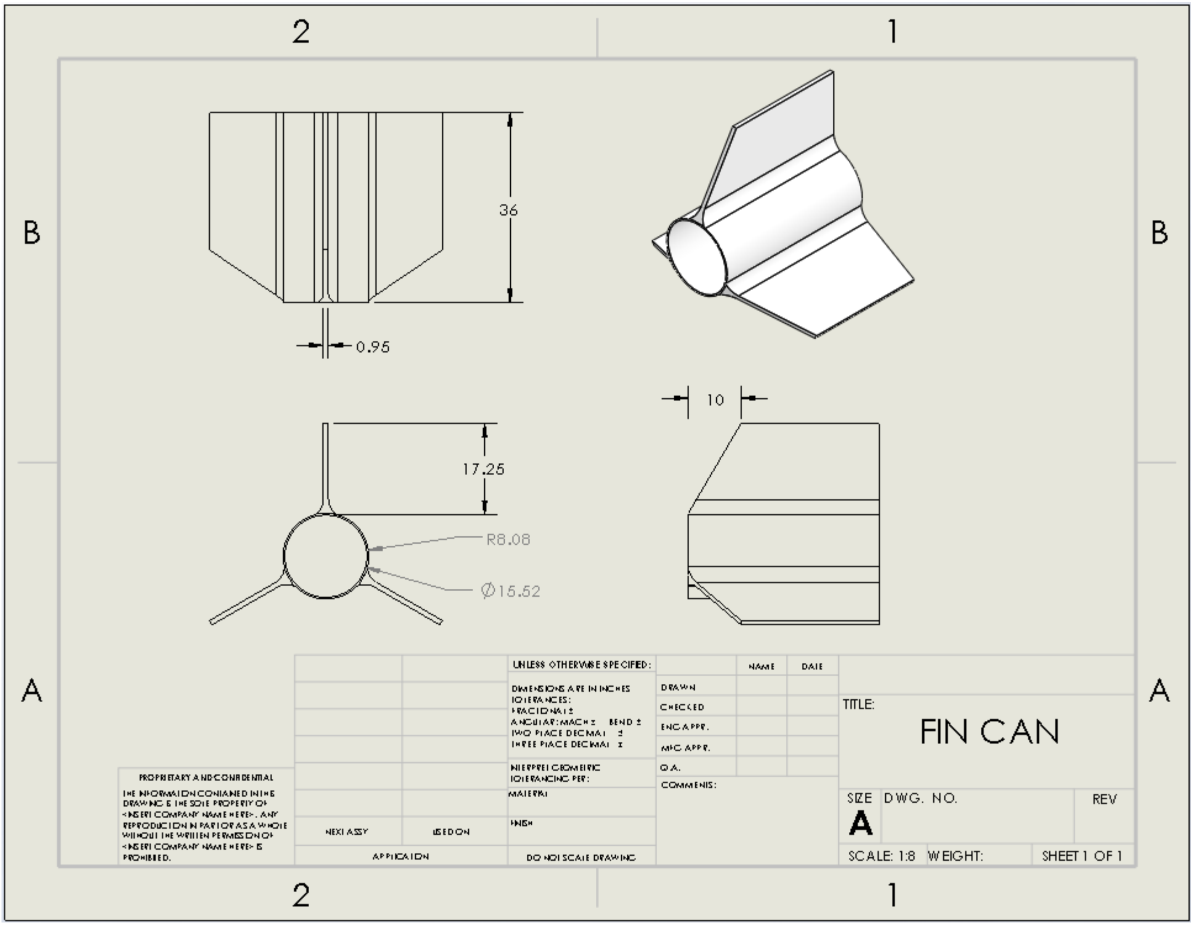


Fig 3A.5: Fin Can Design

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 17 centimeters tall with a diagonal creating a surface area of 96 square inches. The fin system on this rocket will utilize an Ultem plastic 3-D printed fin-can system. Kyle, our team lead, implemented this type of system while with Spring Grove Area High School and wants to continue to use it while at York College. The fin can system will be designed as one solid piece on Solidworks. The component is currently being 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. Ultem is valued and used because of its cost efficiency and relative strength and ability to hold up to physical stresses; tensile strength.

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. The fin can will also be secured to the airframe by a series of screws running down the center of the 3-D printed fin can system. 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 3A.5, which is an accurate drawing to represent the exact dimensions of the fin can system that will be 3-D printed.

A scaled fin can will be 3-D printed and used on our subscale rocket to be launched on December 16th, before the CDR report and presentation are due. Testing of this 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.

Nose-Cone

For our rocket, we are planning to use a conical 6.00" nosecone from Public Missiles Limited made from fiberglass. 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 and calculate 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.

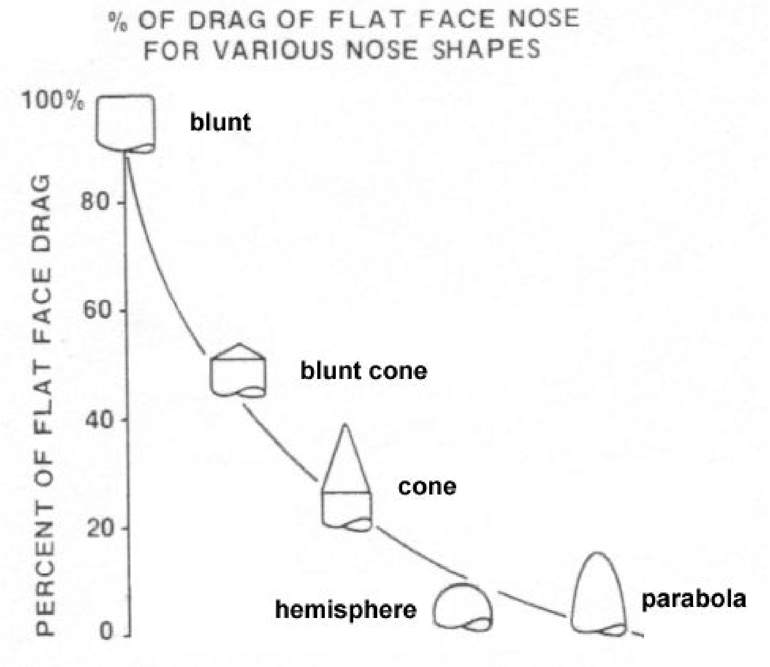


Fig 3A.6: Rocket Nose Percent Drag Calculations Based on Nose-Cone Shape (http://www.aerospaceweb.org/question/aerodynamics/q0151.shtml)

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 3A.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. More simulation and calculations will be done to see if we can make our final nose-cone from Ultem Plastic as well. This design process will continue to evolve over the 2 months between the PDR and CDR submission dates.

3A.3 - Vehicle Design

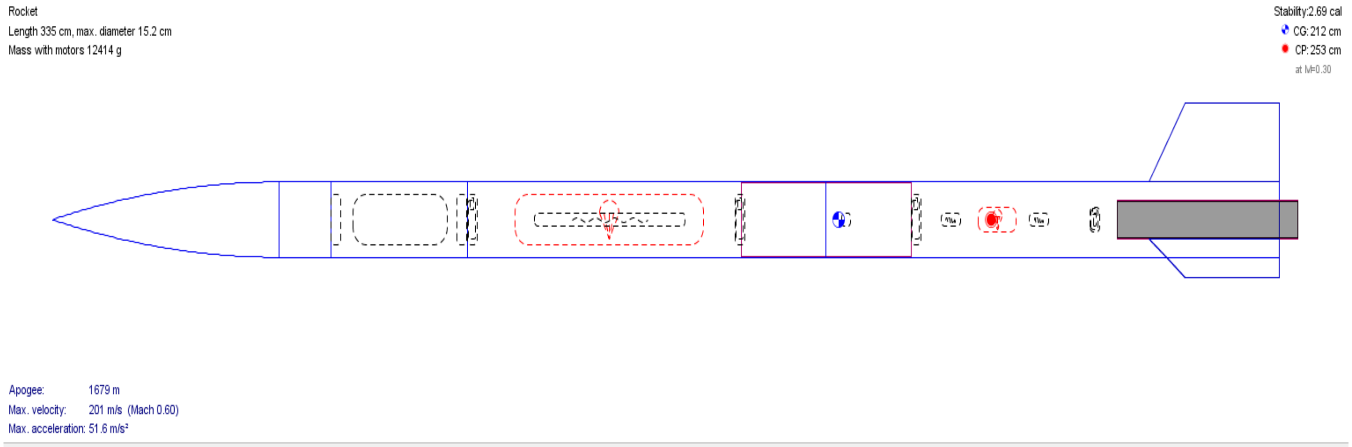


Fig. 3A.7: Proposed Rocket Design for PDR Report with Loaded Motor Mass

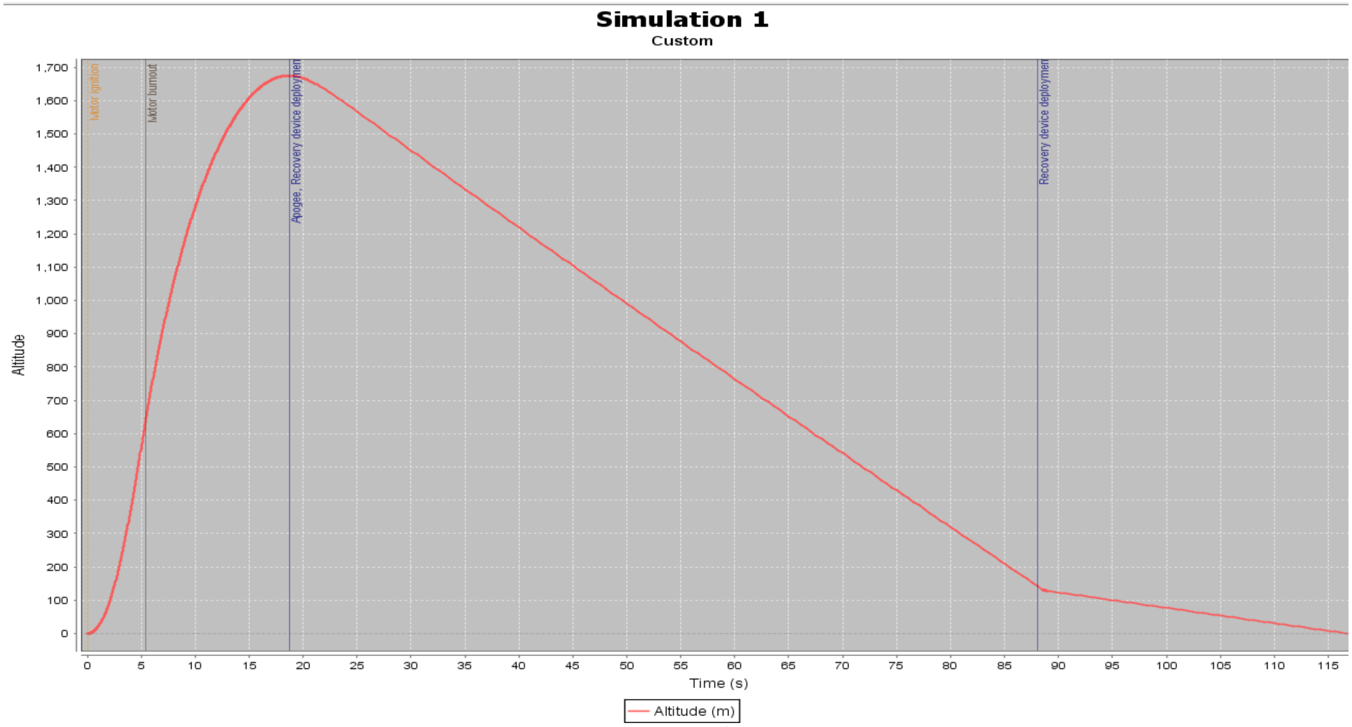


Fig 3A.8: Altitude vs. Time Graph of Simulated Rocket Flight

Component Masses for Full Scale Rocket

Component	Weight (lb)
Nose Cone	2.50
Upper Body Tube	1.49
Payload	3.00
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	8.27
Fins	1.22
Total Weight	**27.41**
Simulation Mass	**27.36**

Fig.3A.9: Component Mass Chart

Overall Vehicle Design

The proposed rocket will be 131 inches in length counting the nose cone. The planned mass of the rocket will be 12,414 grams or just over 27.3 pounds with our proposed engine, The CTI L-645 Green, loaded in it. The stability margin of the rocket is calculated to 2.85 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 3A.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 also planning to develop a drag reducer, kind of like an under-body diffuser on a car that may help to decrease our rocket's drag. The purpose for this is to counteract the effects of the "green" motor that we plan to use. With such long burn time, the effects of "green" motors are that the rocket is in the air for a longer period of time on its' initial ascent. The longer that the rocket is on its' ascent, the longer that the force of gravity and the air resistance have to work against the work that the motor is producing in the form of thrust.

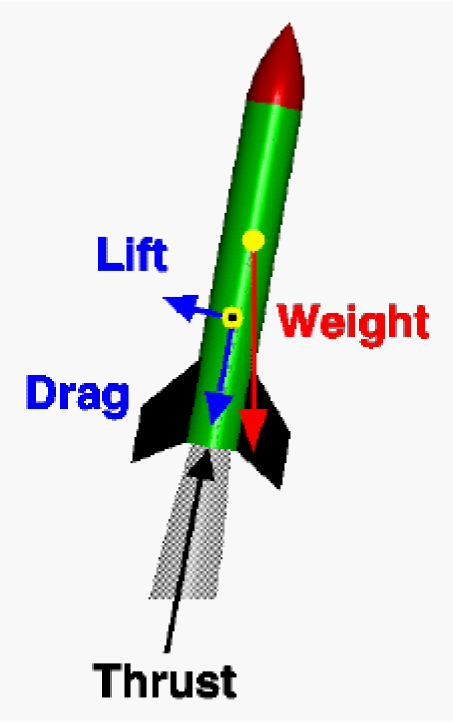


Fig 3A.10

Rocket Design

On the rocket airframe, there are a total of three PML body tubes with a diameter of 6.00 inches. The top tube is going to be 22 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 two pieces will be a small 2.0 inch ring that is part of the electronics bay which will have the key switches on it.

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 a second best option to carbon fiber tubing. 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. The **nose cone** will also be purchased from Public Missiles Limited for the same reason as mentioned above. The shock cord used will made in house using 1” tubular nylon which is able to withstand tension forces of over 1,000 pounds. See the recovery subsection for more information on how we tested our shock cord to ensure its component strength. Our parachutes we plan on using are ALS-Series Parachutes by Medichutes. Our main parachute is planned to be 120 inches in diameter based on the parachute having a coefficient of drag around 1.6. These parachutes were selected for being strong, durable, and made to withstand high pressures and forces. They were also selected because the maker is local and is helping to support a local university team. They provide about the same drag force for their size compared to common hemispherical parachutes.

As stated above, the fins shall be constructed from Ultem plastic. Overall we will also use 1515 launch lugs mounted to the airframe with screws to ensure that the rocket is able to exit the launch rail safely.

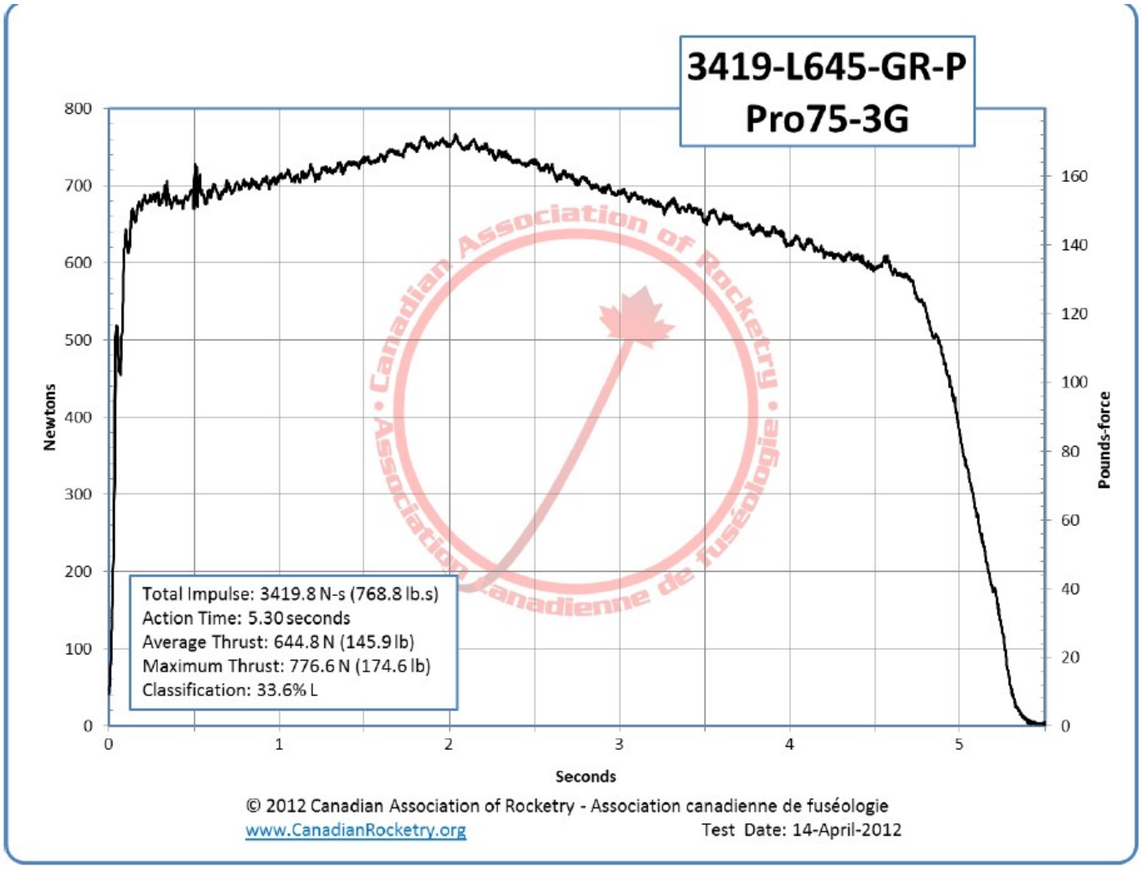
The shock cord will be connected to stainless steel quick links and then the quick links will be tied to U-bolts on numerous bulkheads. This will provide a strong connection between the shock cords and the parachutes as their will there will be a large force upward on the parachute. This large force 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. See the recovery subsection for more information on how we tested the quick-links to find their ultimate axial strength.

When it comes to 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.

3A.4 – Motor Selection and Projected Altitude

The Cesaroni L645-P rocket motor should deliver 3419 Newton-seconds of impulse over a burn time of 5.30 seconds. With this motor, our calculated point of apogee was planned to be 5,504 feet. With our weight, this should be the motor of choice for us as **we planned in the design an increase in weight of the rocket by 5%, due to added supports, epoxy weight, and clay weight.** Given this weight increase, our projected 5,504 feet height drops to 5,228 feet which is just under 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 3A.11.

If this motor does not end up working, we can use an L 1045-P motor made by Cesaroni as well. This motor produces 3,727 Newton-seconds of impulse. We can compensate and make this motor work if the change proves necessary based on the design parameters or a low height achieved during testing. This motor could only be used if we added a good amount of ballast to the front of the rocket, and according the project rules, this ballast would need to be under 10% of the total rockets mass which would be under 2.73 pounds.



Total Impulse: 3419.8 N-s (768.8 lb.s)
Action Time: 5.30 seconds
Average Thrust: 644.8 N (145.9 lb)
Maximum Thrust: 776.6 N (174.6 lb)
Classification: 33.6% L

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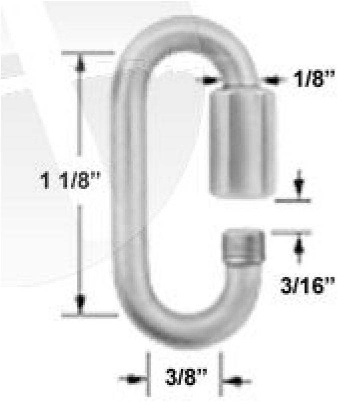
www.CanadianRocketry.org Test Date: 14-April-2012

Fig.3A.11: CTI L-645 Thrust Curve

Subsection 3B: Recovery Subsystem

<u>3B.1 – Component Analysis</u>

Quick links: Option 1 – 1/8" Quick links



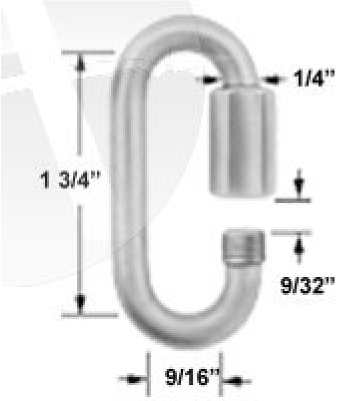
Pros

- Save on rocket mass because it is significantly lighter than the ¼ inch quick link, it also helps with flexible room on U-bolt so there is more room to attach additional items if needed

Cons

- The yield for this quick link is significantly smaller. It is rated to withstand a force of 220 pounds which is much less than the dynamic force 405 pounds to 945 pounds which will be exerted upon the rocket.

Quick links: Option 2 – ¼" Quick links



Pros

- It has good factor of safety of around 2.25. This quick link has been rated by the manufacturer to have a yield of 880 pounds but it was able to handle quasi static forces of up to 2030 pounds which means it has an ideal yield.

Cons

- It is much larger than the alternative and thus weighs more which adds more mass to the rockets.
- This should be chosen because it is able to withstand the 405 pounds to 945 pounds dynamic load which is exerted upon the rocket. It also has an ideal yield. This quick link also provides a factor of safety of around 2.25

Shock Cords: Option 1 – Tubular Nylon 1”

Fig 3B.1: 1” Tubular Nylon

Pros

- It has a high yield of 4000 pounds. It is less abrasive than Kevlar shock cords. Using this shock cord gives us a factor of safety of over 4.

Cons

- It is less fire resistant compared to the Kevlar.

Shock Cords: Option 2 – Tubular Kevlar ½ inch

Fig 3B.2: ½” Tubular Nylon

Pros

- It has a greater yield than the tubular nylon. It has a yield of 6000 pounds which gives us a factor of safety of over 6. It is also more fire resistant and stronger than most other shock cords.

Cons

- It is more abrasive than tubular nylon and can increase chances of tethering.

3B.2 - Component Testing

In order to test some of the components of the recovery system, a stress test was performed on both the shock cord and quick-links to find the ultimate and shear strength of the materials. The results of the stress testing will be covered over the next few pages of information. For the quick-link, an initial Solidworks' Analysis was performed to find the area with the maximum stress and strain in the quick-link. Our tested quick-link is made of zinc and is a ¼" thick.

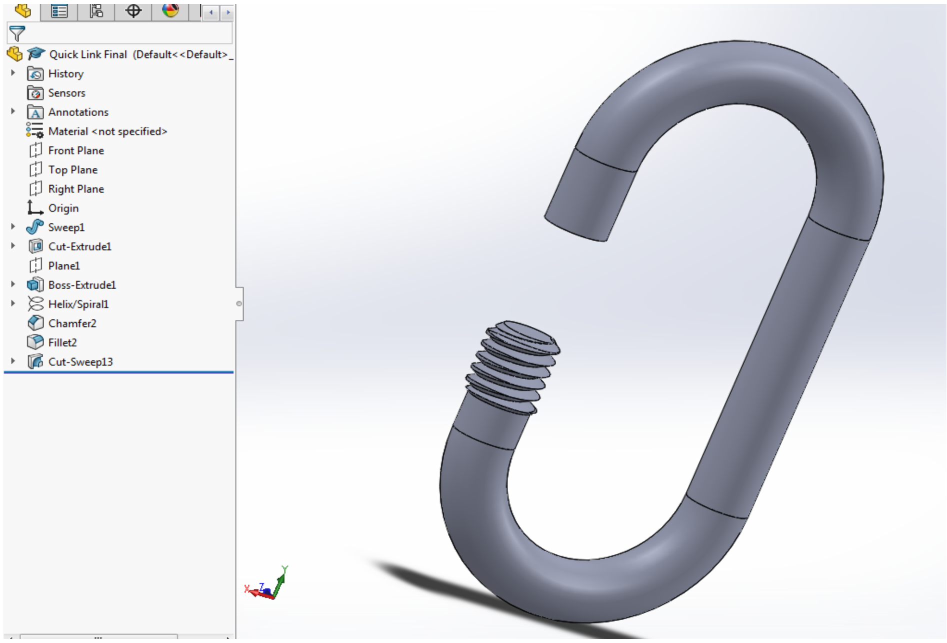


Fig 3B.3: Initial Quick-Link Design on Solidworks'

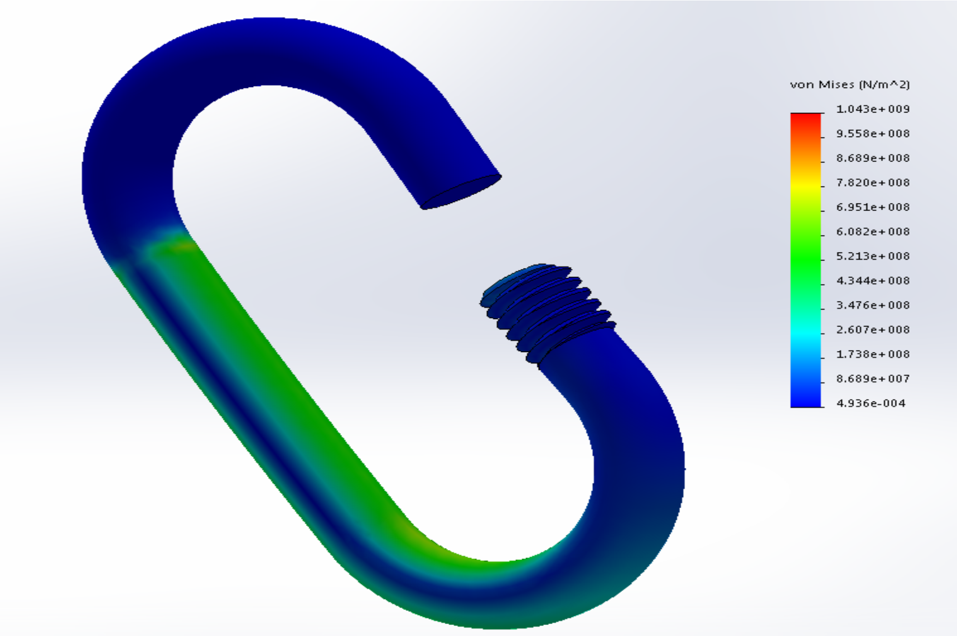


Fig 3B.4: Von Mises Plot on the Quick-Link with an Applied 500 pound Axial Load

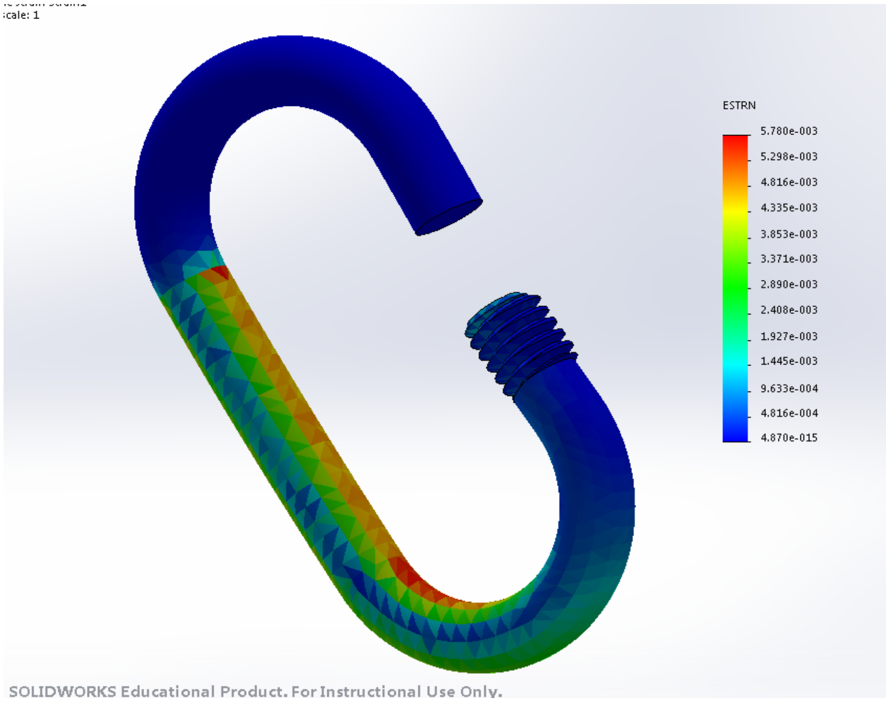


Fig 3B.5: Stress in the Quick-Link with a 500 pound Axial Load

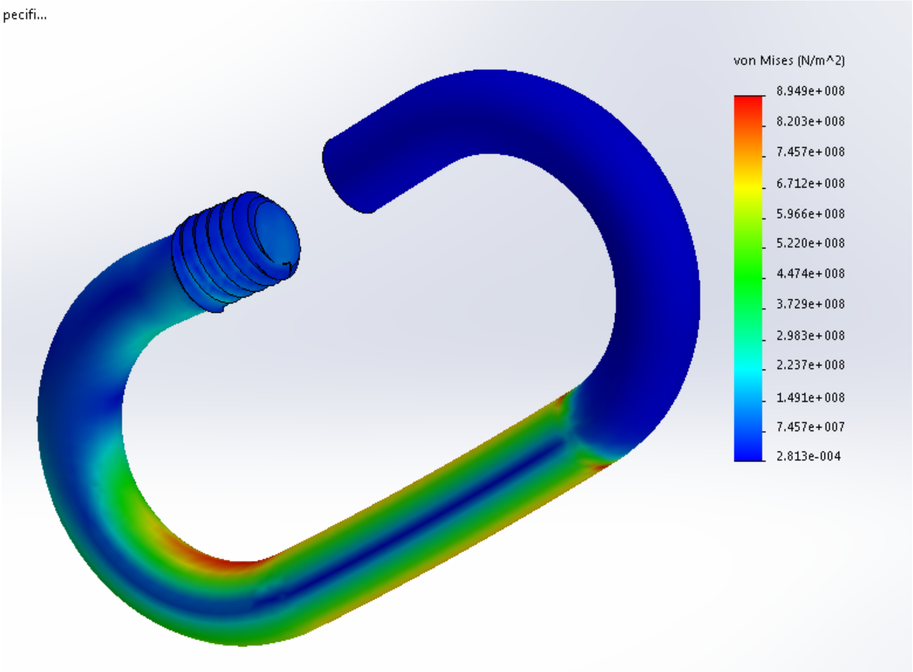


Fig 3B.6: Von Mises Plot on the Quick-Link with an Applied 700 pound Axial Load

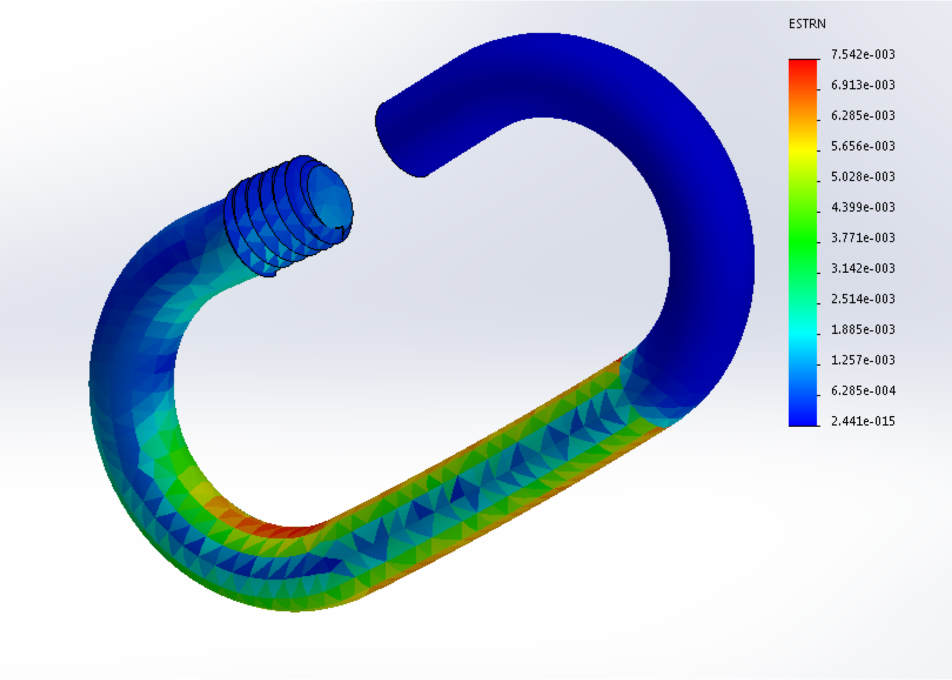


Fig 3B.7: Stress in the Quick-Link with a 700 pound Axial Load

Fig 3B.8: Strength Test of a 1/4” Quick-Link

To ensure flight safety, we performed a series of strength tests on both the quick-links to be used as well as the shock cord to be used.

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.

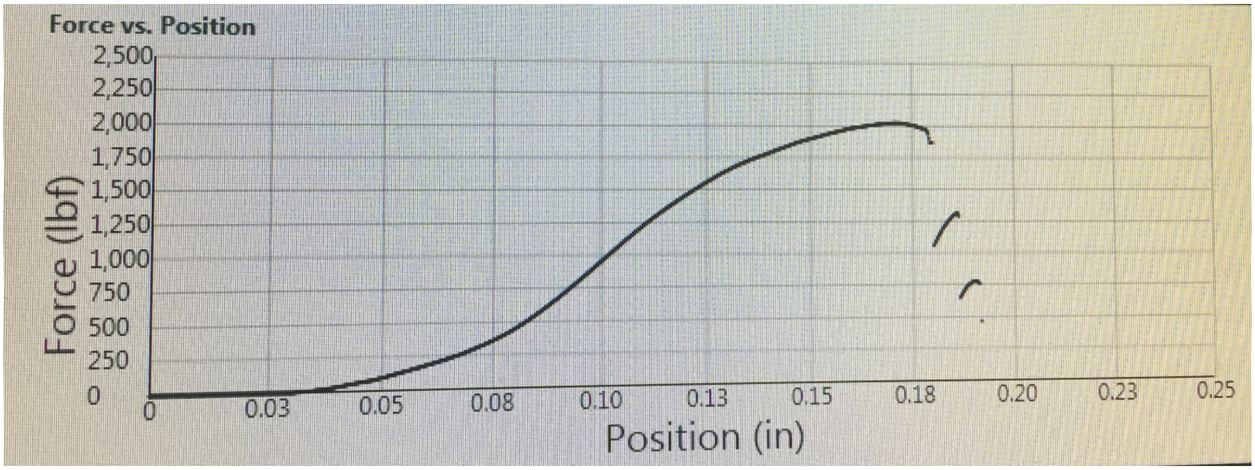


Fig 3B.9: Force vs. Position Graph of ¼” Quick-Link Strength Test

Fig 3B.10: Quick link after the test was performed, as seen above the failure was in the threads rather than the structure of the quick link.

Shock Cord

For the shock cord we have decided to use the Tubular Nylon 1”. 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 inch 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 CDR to ensure component strength. Below are the results of the tests performed in the lab.

Fig 3B.11: Strength Test Performed on the 1” Tubular Nylon Shock Cord

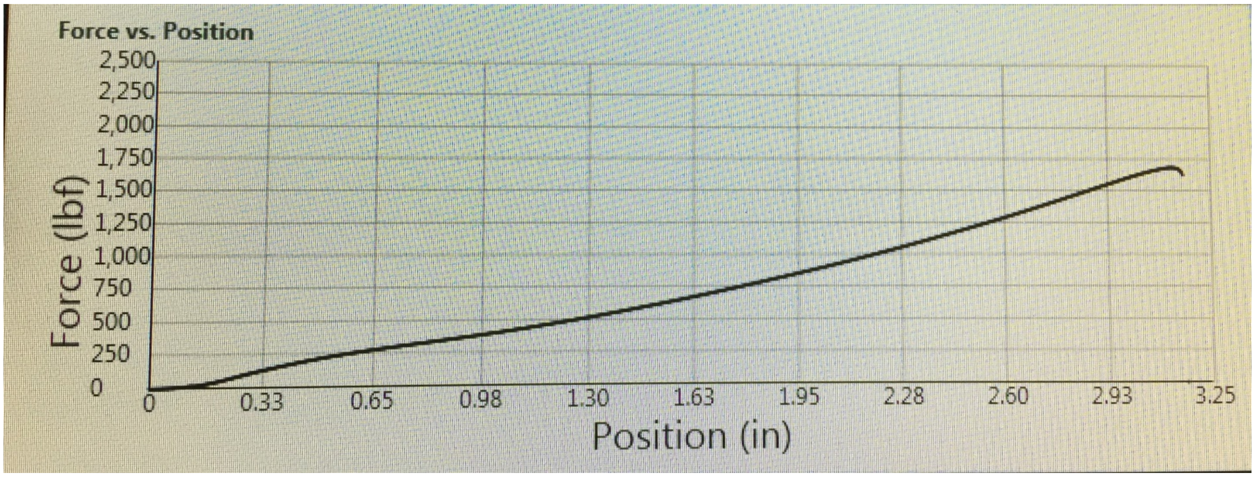


Fig 3B.12: Force vs. Position Graph of the 1" Tubular Nylon Shock Cord

3B.3 - Parachute Calculations

Our parachutes we plan to use are elliptical parachutes by Medicutes, a local company that gives us a discount on parachutes that he hand sews and makes. 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.

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

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

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

$c_d = 1.6$

$m = 22.844\ lbs$

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

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

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

$$A = \pi r^2$$

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

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

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

So according to our calculations we would need a parachute of 121.24 inches in diameter. Our other alternative parachute could be an iris-ultra parachute made by Fruity Chutes with a coefficient of drag of 2.2. This increased coefficient of drag would allow us to decrease the diameter of the main parachute by a significant amount to a diameter around 96 inches.

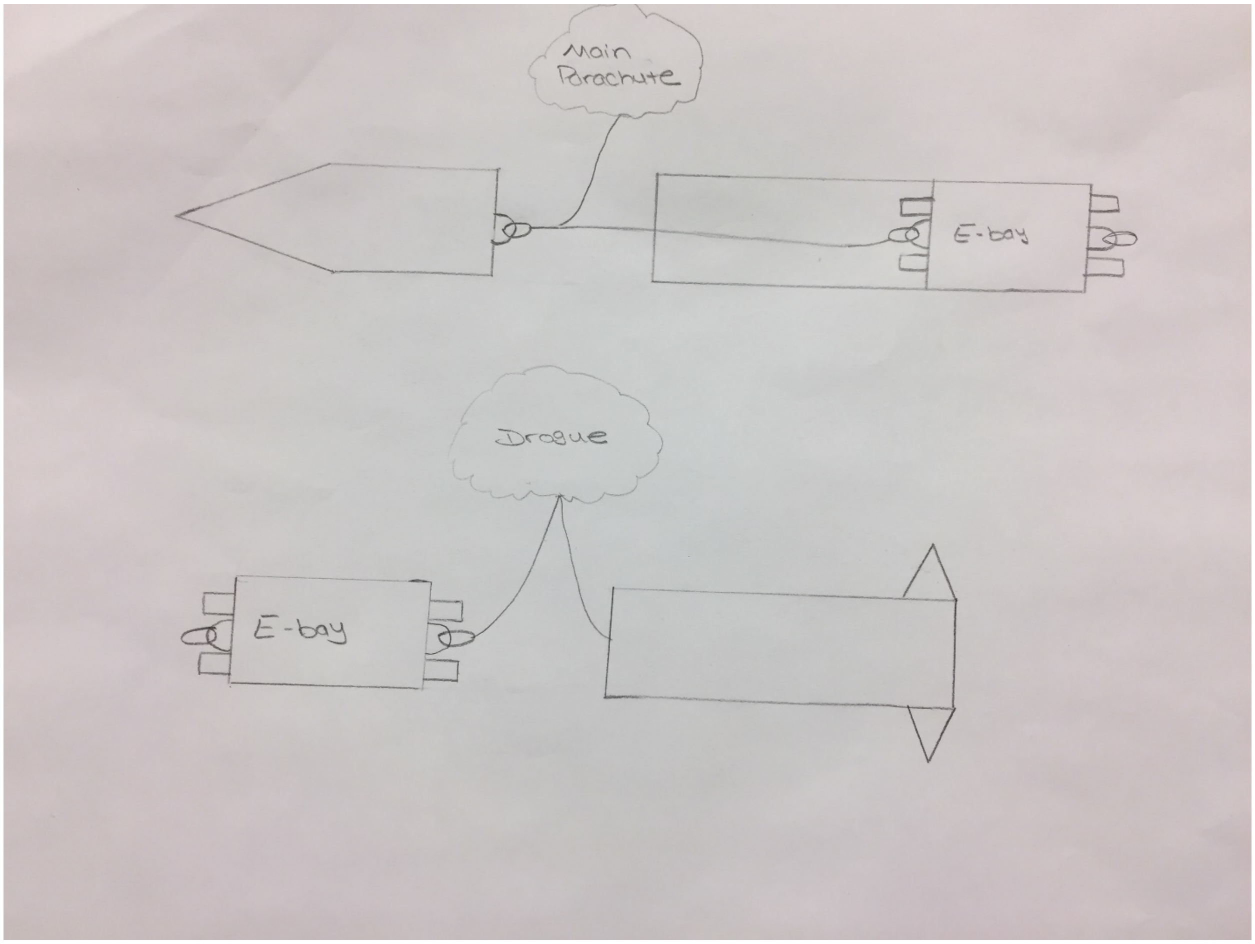


Fig 3B.13: Parachute Design

The rocket will launch with a goal apogee of 5,280 feet. Upon decent, the rocket body will split into three segments, releasing the drogue and the main parachute. The drogue which is 24 inches in diameter will deploy at apogee and the main parachute will deploy at 600 feet. After landing on the ground, the nose cone and the top body tube will separate which will allow the rover to exit the rocket and open the solar panels for charging.

3B.4 - 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 back 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.

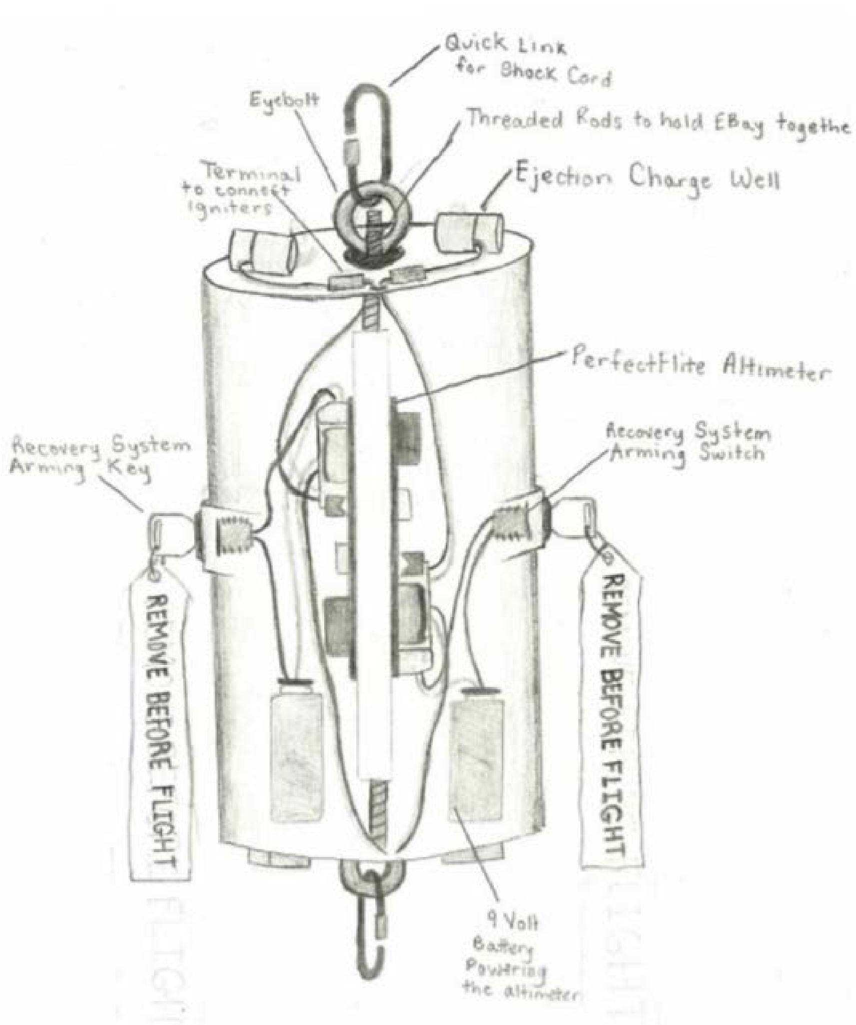


Fig 3B.14: Electronics Bay Diagram

Subsection 3C: Mission Performance Calculations

3C.1 – Flight Profile Simulations

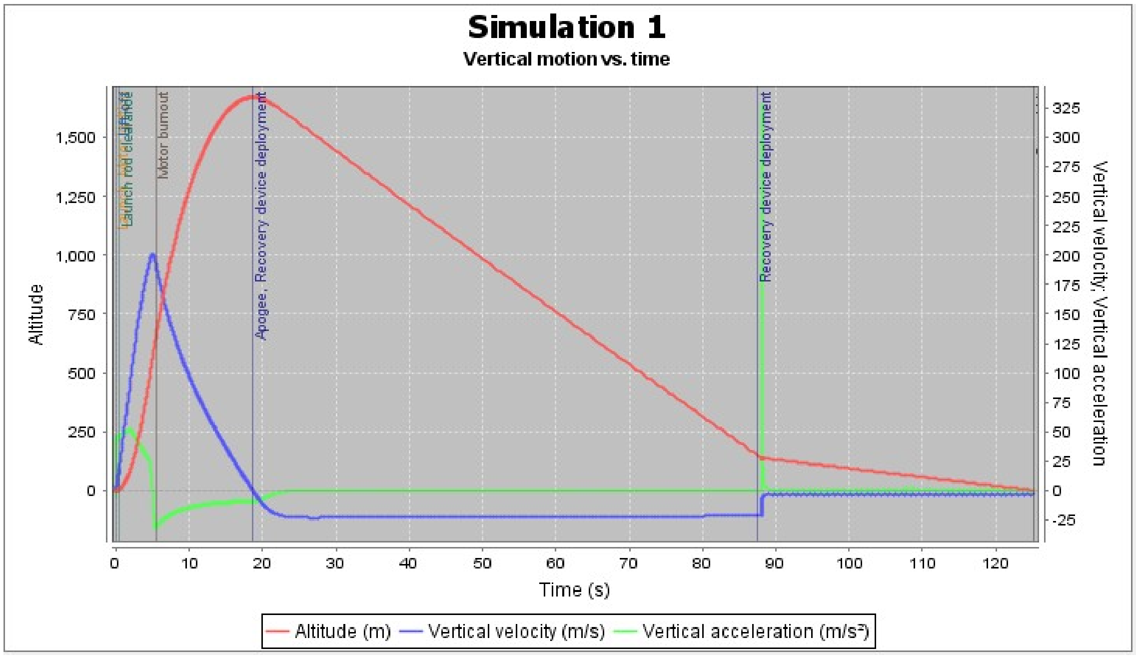


Fig 3C.1: Vertical Motion, Velocity, and Acceleration vs. Time

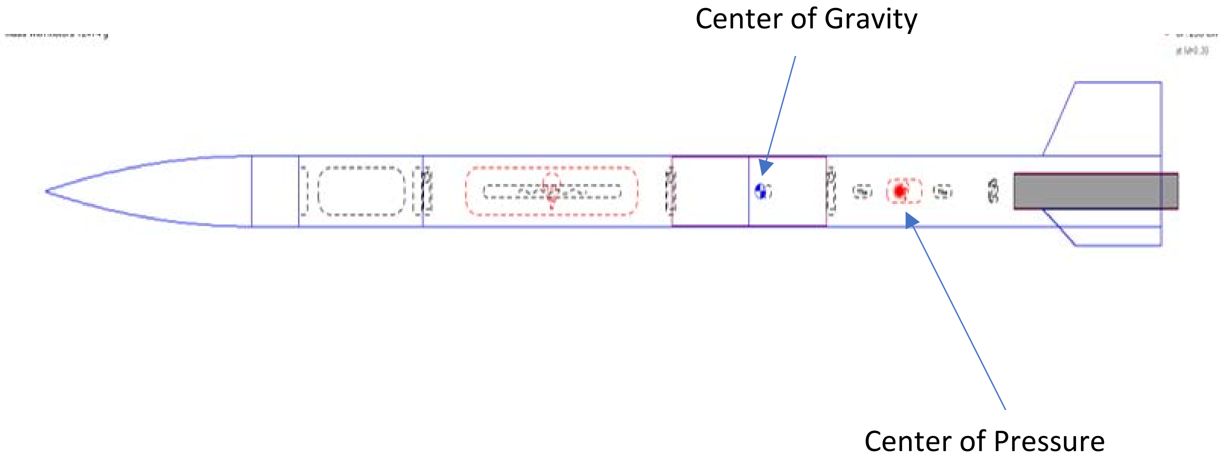
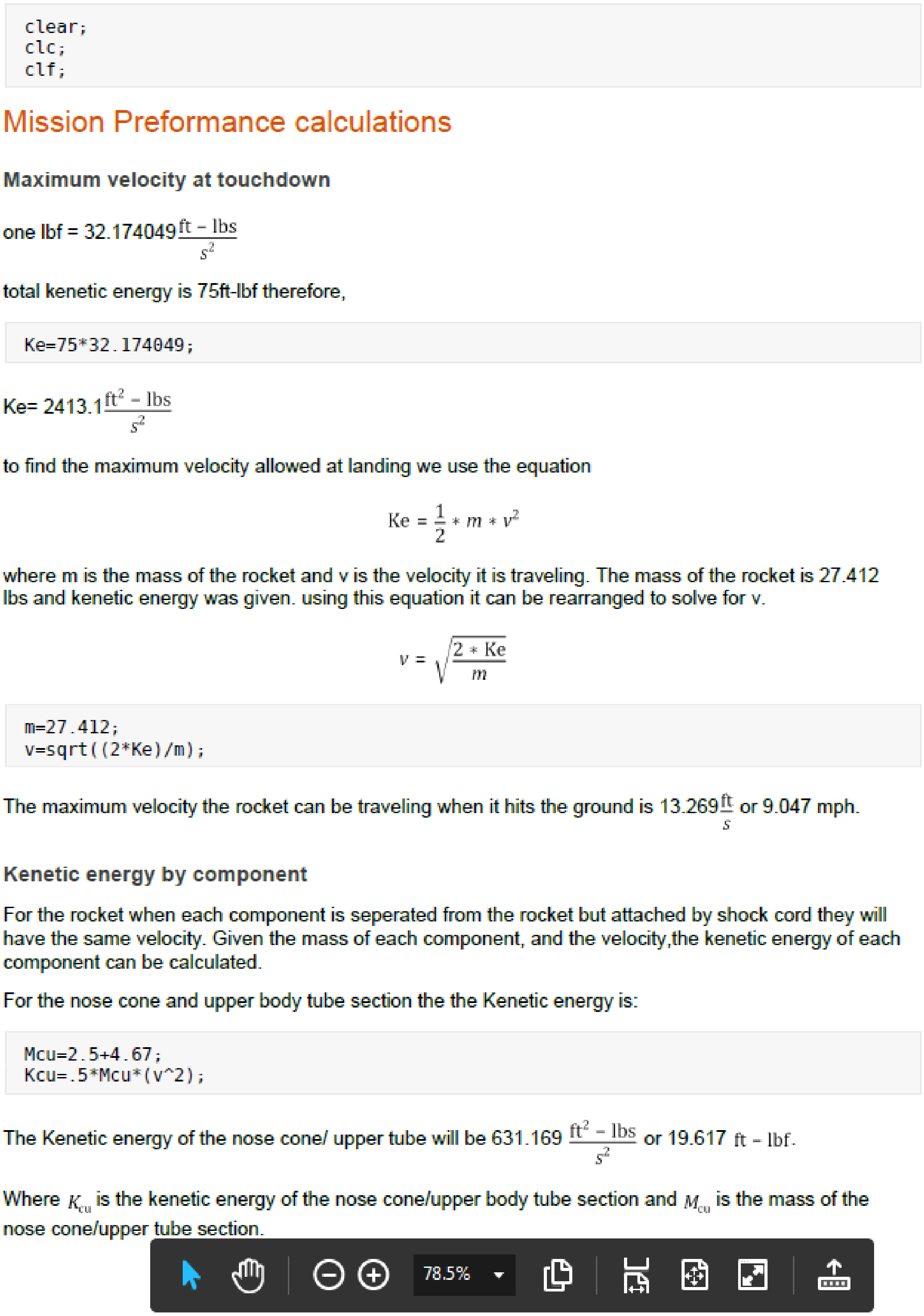


Fig 3C.2: Center of Gravity and Center of Pressure Markers

3C.2 – Various Calculations



```
clear;
clc;
clf;
```

Mission Preformance calculations

Maximum velocity at touchdown

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

total kenetic energy is 75ft-lbf therefore,

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

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

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

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

where m is the mass of the rocket and v is the velocity it is traveling. The mass of the rocket is 27.412 lbs and kenetic energy was given. using this equation it can be rearranged to solve for v.

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

```
m=27.412;
v=sqrt((2*Ke)/m);
```

The maximum velocity the rocket can be traveling when it hits the ground is 13.269$\frac{\mathrm{ft}}{s}$ or 9.047 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+4.67;
Kcu=.5*Mcu*(v^2);
```

The Kenetic energy of the nose cone/ upper tube will be 631.169 $\frac{\mathrm{ft^2-lbs}}{s^2}$ or 19.617 $\mathrm{ft-lbf}$.

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 548.421 $\frac{\mathrm{ft}^2 - \mathrm{lbs}}{s^2}$ or 17.045 $\mathrm{ft} - \mathrm{lbf}$.

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=14.012;
Kl=.5*Ml*(v^2);
```

The Kenetic energy of the lower tube will be 1233.5 $\frac{\mathrm{ft}^2 - \mathrm{lbs}}{s^2}$ or 38.338 $\mathrm{ft} - \mathrm{lbf}$.

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:

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

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=4.67;
Dut=79.3;
Mmt=6.23;
Dmt=180.7;
Mlt=14.012;
Dlt=304.2;
Mt=27.412;
```

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

The center of mass for the is 213.558 cm or 84.0780 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:

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

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

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 2.85.

Burnout altitude

To find the burnout altitude without drag, motor burntime, average rocket mass, and average thrust is needed. the motor is made by cesaroni technology type 3419L645-P. with a burntime of 5.30 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=22.844/32.174049;
mp=4.568/32.174049;
m=mr+.5*mp;
```

the average mass of the rocket is 0.7810 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.

```
T=145.9;
g=32.174049;
t=5.3;
Ba=.5*((T/m)-g)*t^2;
```

the burnout altitude of our rocket is estimated to be 2171.9 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 819.577 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 12611 feet.

Time of apogee

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

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

Where t was defiined above as the motor burntime.

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

the time of apogee is 30.77 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:

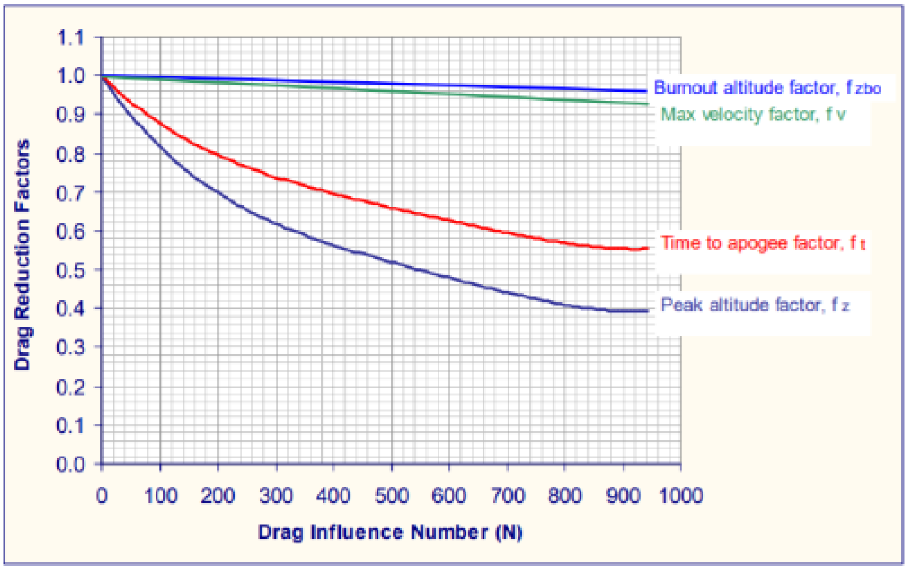
$$N = \frac{C_d * D^2 * B_V{}^2}{24353 * m_r}$$

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 17.23 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 745.8 ft/second or mach 0.667 and 2063.3 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 5044.2 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=176.4;
a=Tmax/(mr);
```

The maximum acceleration for our rocket is 248.4 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=22.844;
Vtd=sqrt((2*mp*g)/(p*Ad*Cd));
```

Vtd is the terminal velocity of drouge which is estimated to be 71.39 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 12.3658 ft/s or 8.431 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 62.25 seconds.

Time of main

The equation is the same as above.

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

time of decent for the drouge parachute is 48.52 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 128 seconds.

Drift calculations

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

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

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=27.412;
aw=Fw./mw;
```

After solving for the acceration of 0, 0.0403, 0.0807, 0.121, 0.161 ft/s^2 it is plugged into the following equation to find the drift distance.

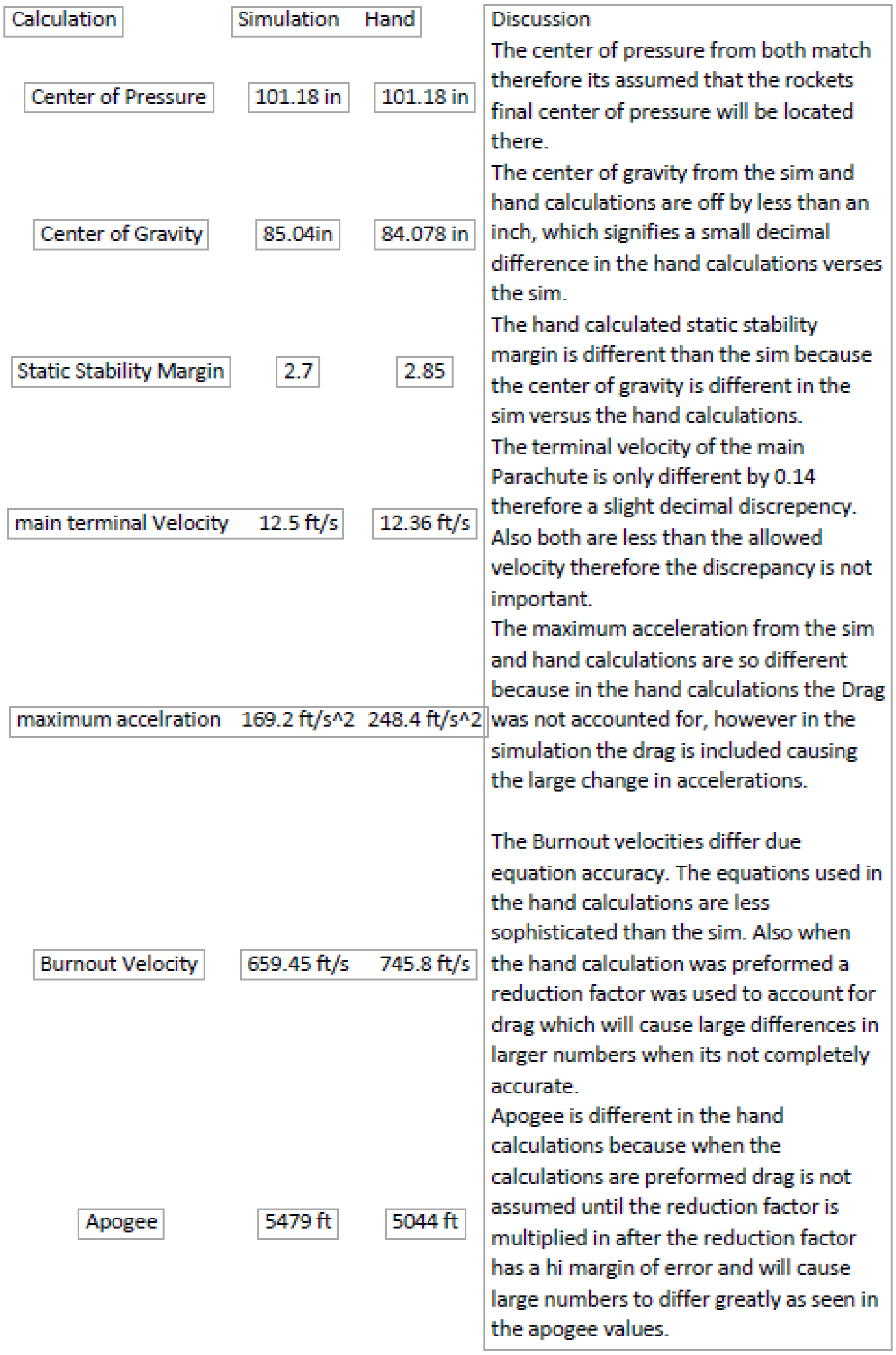
$$x = \frac{1}{2}\left(a_w\right) * t^2$$

where t is the total flight time.

```
t=128;
X=0.5*aw.*t^2;
```

The drift distances for 0, 5, 10, 15, 20 mph are 0, 330.5,661, 991.5, and 1322 ft respectively.

3C.3 – Calculation Methods and Support Discussion on Calculations



Calculation	Simulation	Hand	Discussion
Center of Pressure	101.18 in	101.18 in	The center of pressure from both match therefore its assumed that the rockets final center of pressure will be located there.
Center of Gravity	85.04in	84.078 in	The center of gravity from the sim and hand calculations are off by less than an inch, which signifies a small decimal difference in the hand calculations verses the sim.
Static Stability Margin	2.7	2.85	The hand calculated static stability margin is different than the sim because the center of gravity is different in the sim versus the hand calculations.
main terminal Velocity	12.5 ft/s	12.36 ft/s	The terminal velocity of the main Parachute is only different by 0.14 therefore a slight decimal discrepency. Also both are less than the allowed velocity therefore the discrepancy is not important.
maximum accelration	169.2 ft/s^2	248.4 ft/s^2	The maximum acceleration from the sim and hand calculations are so different because in the hand calculations the Drag was not accounted for, however in the simulation the drag is included causing the large change in accelerations.
Burnout Velocity	659.45 ft/s	745.8 ft/s	The Burnout velocities differ due equation accuracy. The equations used in the hand calculations are less sophisticated than the sim. Also when the hand calculation was preformed a reduction factor was used to account for drag which will cause large differences in larger numbers when its not completely accurate.
Apogee	5479 ft	5044 ft	Apogee is different in the hand calculations because when the calculations are preformed drag is not assumed until the reduction factor is multiplied in after the reduction factor has a hi margin of error and will cause large numbers to differ greatly as seen in the apogee values.

Section 4: Safety

4.1 – Risk and Assessment of Project Requirements

In our safety analysis, we developed a series of two scales on which the likelihood and severity of the risk were measured. These two scales adhere to the following guidelines…

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

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

Risks	Likelihood of Risk *(1-10)	Severity of Risk *(1-5)	Impact on Project Progress	Mitigations
Going over-budget	6	4	Delay of rocket progress due to the need for more time to fundraise	The team will carefully use all materials, order only the parts needed, keep track of materials, and use the budget wisely. The team will be diligent in fundraising endeavors.
Rocket exceeds NAR regulations (max. 14500ft altitude).	8	5	Possible fines or other penalties would result from an infraction of the sort.	The team will use a special launch site in Maryland for all model and full scale rocket launches in accordance to NAR guidelines.
Tripping and falling hazards	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 of floor.

Unforeseen rocket design complications	5	5	Delay of rocket design and rocket building progress	The team will design a stable rocket based on the locations of the center of pressure and center of gravity. The team will also have a NAR representative check rocket design.
Unforeseen payload design complications	7	5	Delay of payload design and production.	The team will design a payload that will be effective for the size body tube that is used and double-check that the components of the payload are properly wired and attached.
Complications during transportation of participants and materials to SL or practice launch sites	5	4	Delay of rocket progress due to rocket repairs or cancellation of practice flights because of extensive damage.	The team will make sure that the launch date is known in advanced and that all 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	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 before launching.

Injury could occur during Exacto knife usage.	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.
Adhesion to materials or self	7	2	Minor injury and very minor delay of rocket progress could occur.	The team will exercise proper caution when handling adhesive material and will not use too much of the material.
Burning caused by soldering iron usage	4	2	Minor injury and delay of progress.	The team will use soldering iron in a proper manner and use safety gear.
Shortage of rocket building materials	4	3	Major delay due to the need to order new material and wait for it to ship.	The team will double- check all materials before ordering and enforce a checklist while parts are being used.
Design prototype fails due to mechanical complications.	4	2	Delay of launch testing data and overall rocket progress.	The team will work meticulously to ensure that all components are made to the design specifications given.
The rocket parachute does not deploy and rocket returns unsafely to the ground.	3	4	We lose a rocket and must build another one, losing work time and time to launch.	The team will carefully insert the parachute and make sure there is enough heat shields the ground material to prevent flame up.
Accidental combustion of rocket materials	3	3	In addition, possible injury and a delay of	The team will keep 25 feet away from electrical outlets,

			rocket-building progress could occur.	open flame, and the indoor magazine.
Abrasions and bruises caused by belt sander	3	2	Minor injury and delay of progress.	The team will keep hands and clothing away from the sandpaper.
Team communication failure	3	4	Rocket/payload may be built incorrectly or too many of one part may be made, causing a slight to major delay of progress or loss of material.	Every team member will have access to other members' email addresses and have the ability to talk during the school day.
Commitment complications among team members	3	5	Loss of time or team member if the complication is too great.	The team will make sure all team members make this their first priority and plan accordingly.
Motor ignition delay	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	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.
Late completions of part(s) of reports.	3	3	Delay of designated section of report, leading to an unfinished report.	The team will use timetables and maintain continuous contact in order to ensure completions in a timely fashion.
Improper usage of chemicals/chemical choice.	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.
The payload may get lodged in rocket such that it comes down with the rocket and yields no usable data.	2	2	We will need to redesign, rebuild, or reload the payload. This would delay the progress of construction.	The team shall ensure that the payload is properly installed.
Injury could occur while using coping saw.	2	2	A leave of absence of a team member could occur due to minor or severe injury and possibly delay the rocket-building progress.	The team will be aware of limbs and fingers when using this tool.
Allergic reactions to chemicals involved in rocket production	2	3	Minor or severe chemical burns of team members and possible delay	The team will make all students aware of each other’s allergies and stay away from possible allergens.

			of rocket progress could occur.	
Injury during drill press usage	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	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.
Team estrangement because of lack of cooperation	2	4	Delay of rocket progress.	The team will talk calmly and will not fight with one another. The team will respect each other and themselves.
Misuse or mishandling of hazardous materials	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.
Accidental partial or complete destruction of building site	2	5	Damage to work environment, additional expenditures for repairs, possible progress delay.	The team will ensure that safety guidelines from NAR and the MSDS are being followed.

Inhalation of dangerous fumes	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.
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.
Electrocution during electrical outlet usage	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.
Accidental ingestion of rocket materials	1	5	Minor to severe injury, delay of progress, possible loss of material.	Only experienced students should work with dangerous materials under proper supervision.
Design prototype fails due to issues with design.	1	5	Delay of rocket progress and report progress.	The team will go through a design check before finalizing specifications to prevent minute errors that would result in such an occurrence.

4.2 – Personnel Hazard Analysis

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.

Metal Lathes

Before operating the lathes, remove all jewelry, confine long hair, and remove or roll up long sleeves or any article of clothing that could become caught in the work. Also, obtain an instructor's permission before using the lathe and ensure that safety glasses are covering your eyes. Make all changes with the power off. Center the material so that it will not spin off-center. Firmly secure all of the material to a machine. Use the proper speed for the task at hand. Use the correct, sharpened tools. 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.

Baldor Grinder/Buffers

Before using the grinder and buffers, put on safety glasses, check that the spark shield is intact, and obtain an instructor's permission to use it. Keep hands away from the spinning wheel. Adjust the tool rest to the proper height and always use it. If an injury occurs during its usage, turn off the machine, inform an instructor of the injury, and then have the rest of the students in the classroom sit outside I the hallway to avoid being in the way of instructors and medical personnel helping the student.

4.2A – NAR and FAA Code

For the purposes of this project, regulations imposed nationally by the FAA and within the state of Pennsylvania due to the adoption of National Fire Protection Agency (NFPA) codes are relevant and will be complied with.

FAA Regulations

In accordance with FAA Regulations outlined in Part 101 Subpart C:

- No member shall operate an unmanned rocket in a manner that creates a collision hazard with other aircraft.
- No member shall operate an unmanned rocket in controlled airspace.
- No member shall operate an unmanned rocket within five miles of the boundary of any airport.
- No member shall operate an unmanned rocket at any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails.
- No member shall operate an unmanned rocket at any altitude where the horizontal visibility is less than five miles.
- No member shall operate an unmanned rocket into any cloud
- No member shall operate an unmanned rocket within 1,500 feet of any person or property that is not associated with the operations or between sunset and sunrise.

4.2B – Plan for Motor Handling and Storage

Rocket motors will be purchased through our NAR level II 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.

4.3 – Preliminary Failure Modes and Effects Analysis

Hazard	Likelihood of Risk *(1-10)	Severity	Impact on Project Progress	Mitigations
The payload may get lodged in rocket such that it	2		We will need to redesign, rebuild, or reload the payload. This	The team shall ensure that the payload is properly installed.

comes down with the rocket and yields no usable data.			would delay the progress of construction.	
The rocket parachute does not deploy and rocket returns unsafely to the ground.	3	4	We lose a rocket and must build another one, losing work time and time to launch.	The team will carefully insert the parachute and make sure there is enough heat shields the ground material to prevent flame up.
Injury may occur if rocket is miss aligned on launch pad.	3	5	The loss of the rocket and other materials used to create rocket, time, and money.	The team will be aware of the alignment of the rocket and to properly make sure it is correctly aligned.
When the rocket has hit the ground payload doors get suck.	5	3	The rover will not leave during competition making us loss out on points.	The team will test the doors in multiple positions to make sure the doors will open.
Accidental combustion of rocket materials.	4	4	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.
Payload door opens up in flight.	2	2	The rocket trajectory would change directions causing our team to loss time, money, and points	The door will be lock and have a failsafe so that the door will not open.

Launch preparation failure causing rocket to burn the engines	1	4	This would make our team loss time, money, and possibly the rocket.	The safety captain will double check rocket launch making sure rocket will launch correctly.
Wires that are connected to ignition pad are not connected correctly making the rocket not launch.	4	2	It would delay the competition, our team would loss time, and possibly make errors when relaunched.	Our team will have a person who will double check their work when on launch pad to make sure rocket will successfully launch.
Just after rocket hits apogee the ebay fails to deploy.	2	5	It would make our team loss a rocket.	Make sure ebay is correctly set up.
Rover having to travel over uneven terrain.	7	2	Our rover will not be able to complete its task.	Our team will design our rover can overcome uneven terrain.

4.4 – Environment Risks

Risks Environment	Likelihood of Risk *(1-10)	Severity	Impact on Project Progress	Mitigations
Wind	4	3	Possible to have the wind push the rocket off angle or when the parachute is out could make it not land	The team made calculations making sure our center of gravity and center of pressure were more than 4

			where we want it.	inches away from each other.
Rain	5	1	We lose a rocket and must build another one, losing work time and time to launch.	Make sure the rocket is covered and don't launch if it starts raining.
Uneven terrain	10	3	Rocket would take off incorrectly, and it's possible the team could drop the rocket making us loss time and money.	The team will be aware of the alignment of the rocket and to properly make sure it is correctly aligned.
Tree's	7	3	Our rocket could get stuck in a tree making our teams having to climb the tree risking injury, or we could loss the rocket.	The team will be aware of possible trees and wind direction. Then making sure we have a poll extender to reach up to the rocket so no students will have to climb the tree.
Bushes	2	2	Rocket could get entangled in bush making our payload not successfully complete its mission.	The team will keep
Vehicles	2	4	Could possibly flip over.	The team will be aware of big humps making sure not to put the car in a situation to cause the car to flip over.

Vehicles affecting the environment.	2	1	The land would be ripped or the car could get suck making drag mark in ground trying to get the car out.	The team will only use designated road to drive on. If necessary we need to drive off road than we will make sure we are not affecting the land.
Environment affecting the vehicle.	3	1	The car could get stuck damaging the axial or any other parts of the car and trees/bushes scrape the car.	The team will be completely quit when driving off road making sure driver doesn't ruin the car.
Rocket possible hitting nearby houses.	2	4	It could damage the house or possibly the rocket.	The team will keep more 1500 feet away from any homes.
Sunny day	8	2	It can damage your eye's if you stare at the sun for too long or it can hurt your eye is 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.

4.5 – Project Risks

`Going over designated budget	Medium	High	Reduce costs on certain parts of the rocket/fundraise further.	Lesser quality components for building. Less time for report due to fundraising.

Running late on report	Medium	High	Spend extra time on various aspects of report.	Less time in building/designing rocket in order to pick up the slack on the report.
Functionality issues with rocket/payload	Low	High	Make sure design is fully comprehensive and functional.	Time would be taken from other aspects of the project to fully survey the designs.
Incorrect time management in building	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.

4.6 - Technical Challenges and Solutions

Technical Challenge	Solution
The recovery system electronics interfering with the payload electronics.	The payload will be designed so that it won’t emit radio or magnetic waves. This will prevent the recovery system from failing. The payload will be separated from the recovery system so that it will not cause inadvertent failure or excitation of the recovery system electronics.
Autonomous Control of the Rover	We will consult carious electrical engineers and electrical engineering faculty to make sure that we are able to build the rover so as to function properly.
Creating a rocket that won’t go over 5280 feet.	Design the rocket to fly one mile high or slightly over under perfect conditions. This is accounted for due to the highly probable case that the rocket will weigh 10 -15 percent more than calculated values. Therefore in experimental launches you will have factors, such as air resistance, that will cause drag.
Designing a rocket that can house a payload and chutes that won’t get stuck or tangled during deployment	Design the rocket so that the ejection charges effectively deploy the parachutes and also the payload. Place them in the correct order, or place, in the rocket so that they are successfully deployed.
Designing a strong fin system.	We will perform many stress tests on the fin can system we are using on the rocket and perfect the design.

Designing an external access to switch connected to the altimeter to ignite the ejection charges	Consult a Level 2 or Level 3 NAR/TRA representative on the procedure needed for the particular ejection system that was chosen. We should have safe access to the switch on the altimeter that ignites the ejection charges. It shouldn't affect the recovery system or the flight of the rocket.

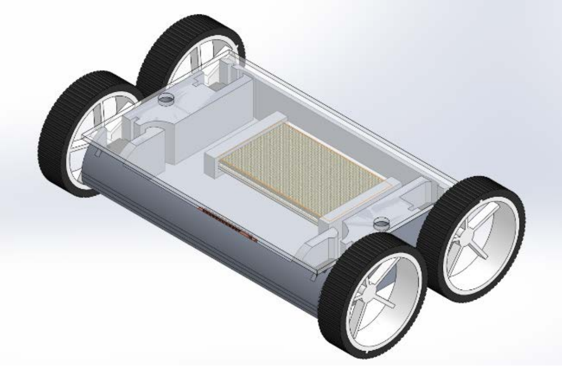
Section 5: Payload

5.1 - Payload Criteria

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.

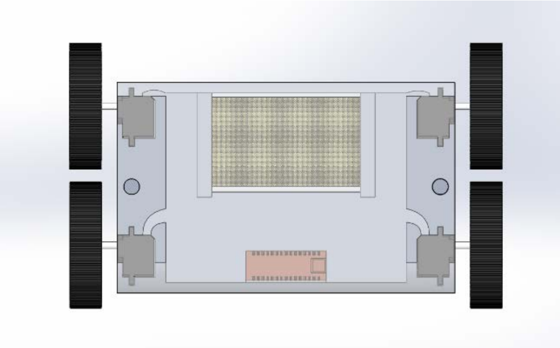
5.2 – Payload Designs

Design #1: "The Sparta Lander"



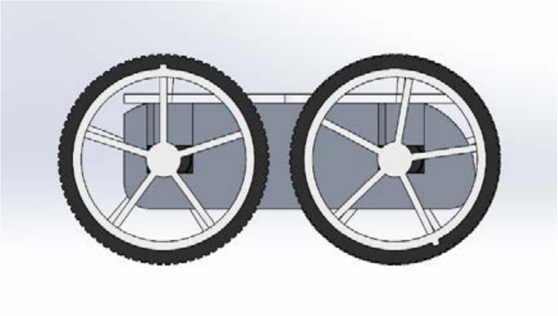
Isometric View

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.

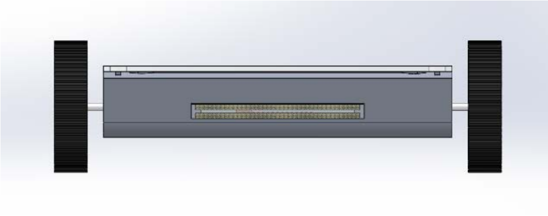


Top View

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.



Side View (left)



Front View

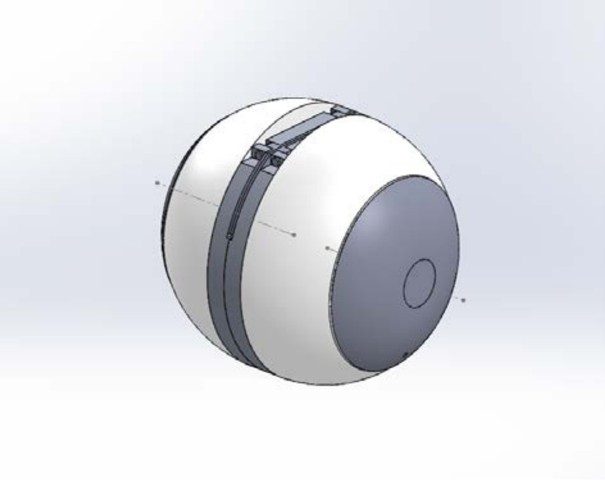
In this view, the concealed solar panel tray is visible. Upon arrival at the final destination, the tray will eject outward until 2.12 inches of solar panel is visible. The panel tray is dual sided and houses two identical solar panels, allowing the orientation of the panel tray to be independent and 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 initial design changed when it was hypothesized that the middle cylinder would rotate instead of the tires when obstacles are encountered. Hence, the four wheeled version was designed using SolidWorks and is displayed above. The servo motors are made in SolidWorks using metric measurements, however the rest of the design is in English inch units. The errors in the spacing visible in the top view are due to this measurement conflict and will be resolved when fabrication commences. Upcoming testing will dictate location of ultrasonic sensors and other electronic internal components.

This design lacks in several areas however. The horizontal limitation of the body tube means the vehicle has a width limit, making the front-to-back wheelbase very small. This makes the insertion of the device into the body tube of the launch vehicle a balance issue and will have to be addressed once the specifics of the payload are known. The sideways deployment of the payload will require a solenoid and will draw upon power stored inside the nosecone.

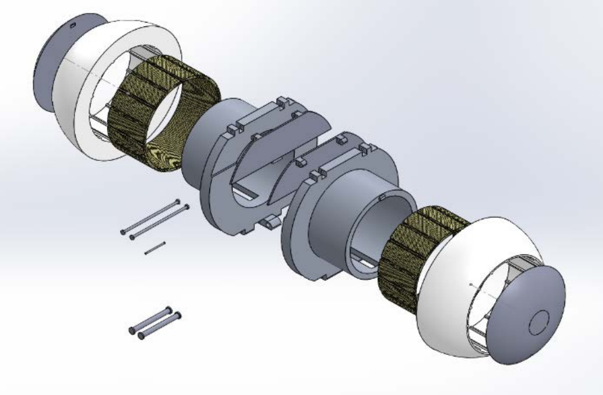
As the chosen payload, the build and design team has agreed that the functionality is above that of other designs and is well within the abilities of the team to fabricate and program.

Design #2: The Hamster Ball



Isometric View

This view displays the isometric view of the “Hamster Ball” design. This design is based on a spherical build of two symmetrical hemispheres, each containing a motor, a battery, Arduino, and several sensors. The rotating tires, shown here as white polyurethane, would be driven from the inside, much like a hamster running on the internal surface of a sphere. The solar panels would be deployed from the top by the two halves disconnecting at the middle and falling outwards, exposing the inside surfaces.



Isometric Exploded View

This exploded view of the “Hamster Ball” design shows the internal layers of components needed to make the design function. The tires would be driven by motors rolling along the bottoms of the geared inner hubs, shown as golden carbon fiber in the picture adjacent. The pins holding the hemispheres together are custom length and width, designed for the task specifically.

5.3 – Design Research

The “Hamster Ball” design originated from the idea of a circular payload fitting very neatly inside the cylindrical body tube of the rocket. The deployment of the payload vehicle would have been simple; roll it out and drive it directly out of the tube. However, the design was scrapped by our electrical engineering consultant for the following reasons:

1) *The space inside the central hubs is too small to house an Arduino, a single motor, and a power source.*

2) *The programming of a two wheeled design is simple, but the balance of the rover is too erratic to provide a consistent course. An internal gyroscope would be needed and the space internal is insufficient.*

3) *The heat generated by the motors would be an issue if the rover became stuck. The high power demanded by motors powerful enough to overcome a reasonable sized obstacle would cause internal damage to wiring in such a cramped space.*

In addition, the mechanical manufacturing of the components of the rover to build it are unreasonably expensive and difficult to fabricate. The functionality of the rover would suffer with too many variables to be truly useful to complete the task assigned. The design lacks in these specific areas:

1) *The contact area with the ground by the tires is very small and not much clearance is provided to the central hubs.*

2) *The traction between the motors and the inner hubs is prone to slip if resistance is met.*

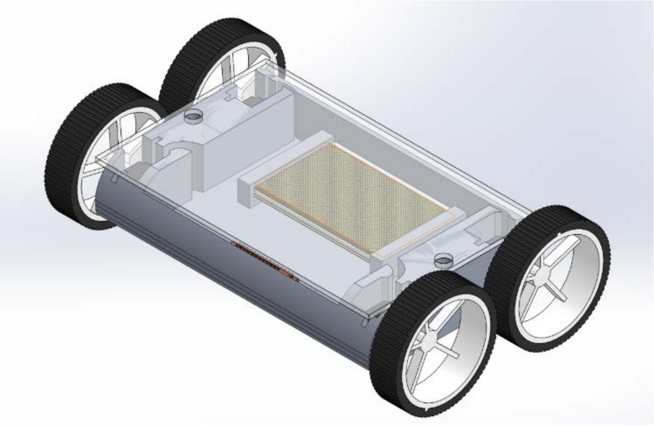
3) *The disconnection of the two halves might not fully expose the solar array within and therefore does not complete the task assigned.*

For the reasons listed above, the “Hamster Ball” design was scrapped by the payload design team for “The Sparta Lander” design shown previously.

5.4 – Current Payload Design “The Sparta Lander”

Electrical Parts:

- -Arduino Nano
- -Ultrasonic sensor
- -Servos
- -Voltage regulator
- -Solar panels
- -GPS



System Overview:

The vehicle will consist of a four servo motors that will be attached to each wheel. The ultrasonic sensors will be attached to the front of the vehicle to alert the vehicle of any obstacles in its path. These sensors will communicate to the motherboard (Arduino) to instruct the vehicle where to go. A GPS will monitor how far the vehicle has traveled and when the vehicle travels approximately 1.5 meters, the vehicle will deploy a tray that has solar panels attached. Figure 1 shows a block diagram of the system.

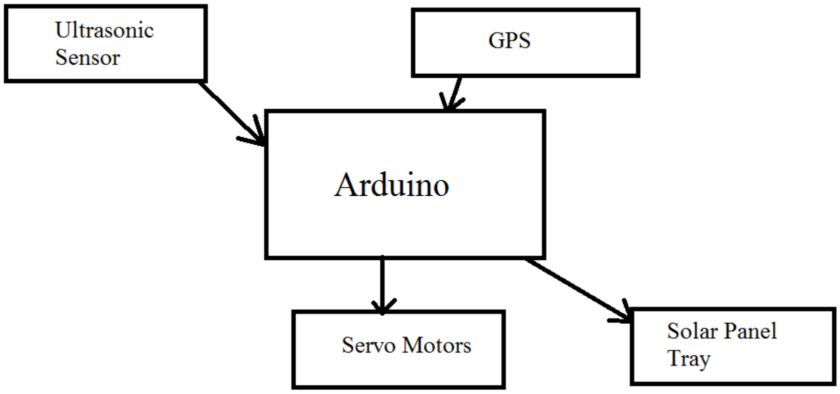
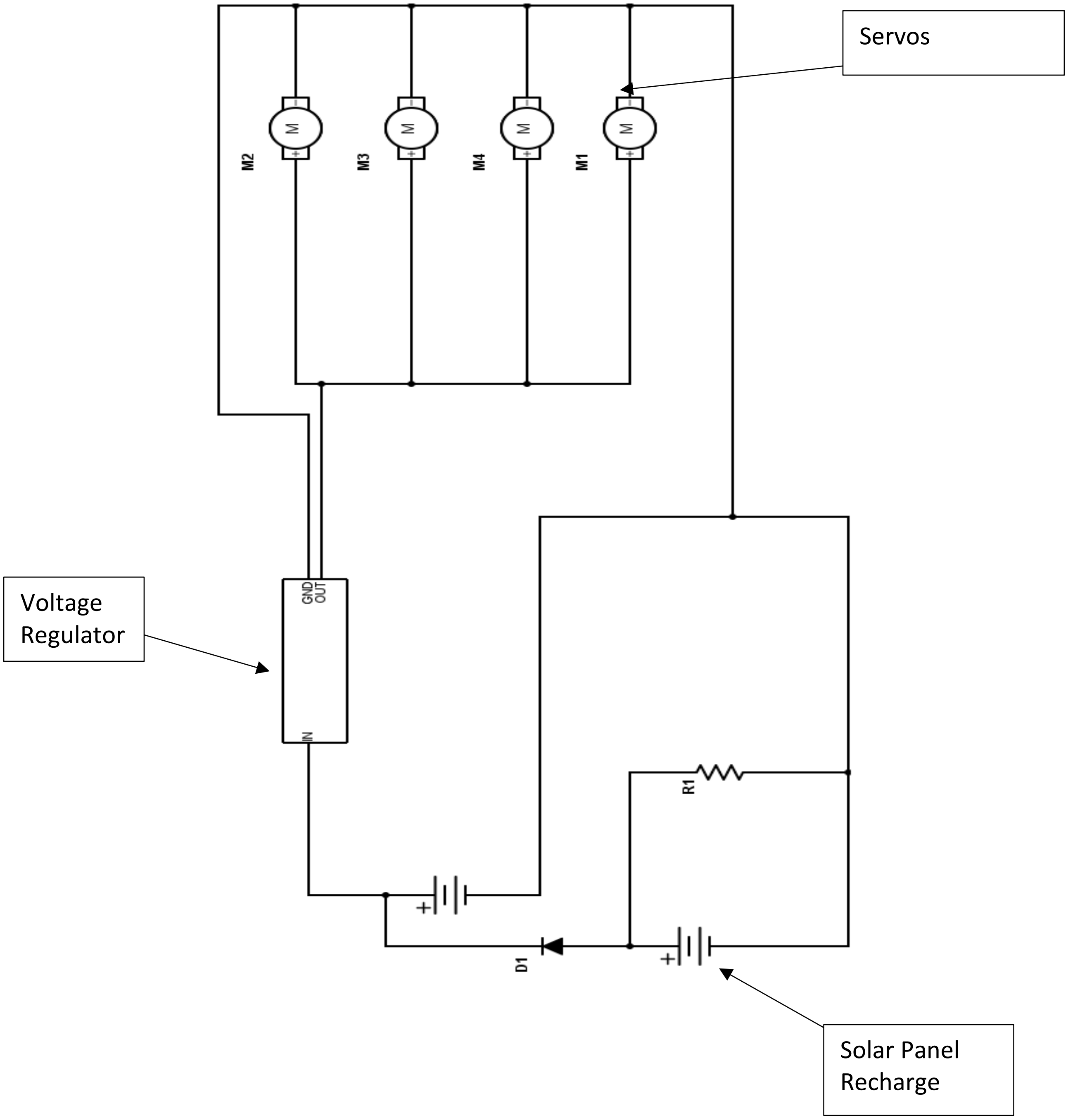


Figure 5.1: Block diagram of payload

The ultrasonic sensor uses a high frequency sinusoid that measures the how far objects are from the sensor. This will determine if the vehicle will have to turn via servos. The circuit drawn below in Appendix A delivers the power to the servos and recharges the battery. This circuit consists of a voltage regulator that drops the voltage to 5V to supply power to the Arduino which also conserves power. The Arduino is not in the circuit diagram but will be tied into the power circuit after the voltage regulator. The Arduino will control which direction the servos spin but the power will be provided by the battery. Appendix B shows the code logic that controls where the vehicle should move. With this logic the vehicle will avoid obstacles that could prevent the vehicle from reaching its destination. The mission of the payload is successful if the vehicle travels approximately 1.5 meters from the rocket and then deploys the solar panels.

The Arduino Nano was chosen because of the simplicity of implementation and also has a very cost efficient microcontroller. The board has an ATmega328 microcontroller that has a clock speed of 16 MHz which will allow the vehicle to make quick decisions about incoming obstacles. Another board in question was the MSP 430 by Texas Instruments. This board had a clock speed of 16 MHz but only had 16 KB of memory while the Arduino had 32 KB. The MSP 430 was also more expensive than the Arduino but had more options like built in timers and more output pins. The MSP 430 is also written in C while Arduino has its own user friendly language. Between these two boards the Arduino is sufficient enough for the vehicle's needs at a lower cost than the MSP 430.

Appendix A:

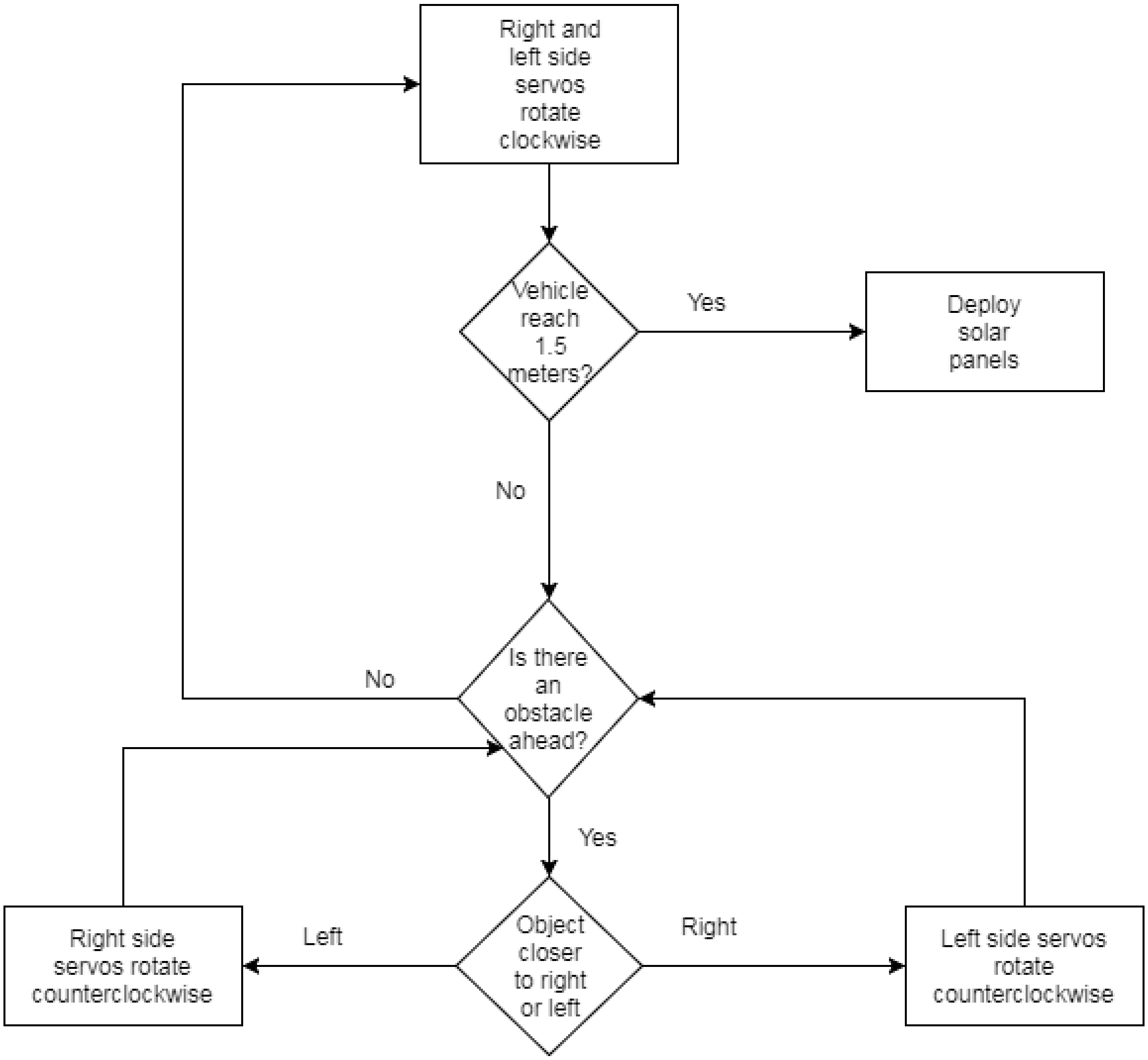


Servos

Voltage Regulator

Solar Panel Recharge

Appendix B:



Right and left side servos rotate clockwise
Vehicle reach 1.5 meters?
Yes
Deploy solar panels
No
Is there an obstacle ahead?
No
Yes
Object closer to right or left
Left
Right
Right side servos rotate counterclockwise
Left side servos rotate counterclockwise

5.5 – Payload Integration into the Rocket

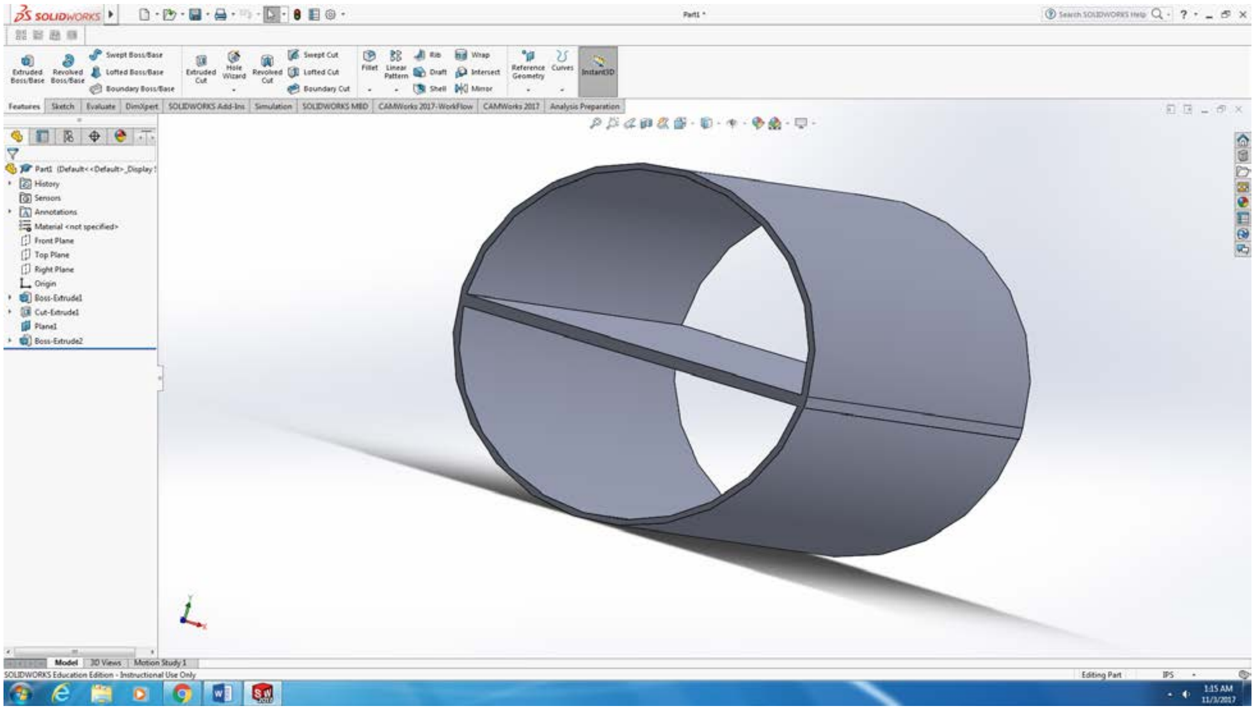


Fig 5.5: Upper Body Tube Image

“The Sparta Lander” payload will be integrated into the rocket in the upper body tube of the rocket which will be 22 inches in length. 5.5 inches of it will be taken up by the nose-cone and 6 inches will be taken up by the coupler which connects the upper body tube to the middle body tube. That leaves 10.5 inches for our payload which is an acceptable length for the team. The payload will be secured within the rocket by being placed between the constructed board and the outer body tube as seen in figure 5.5. This will ensure that the payload is unable to bounce up or down during flight. The front and rear of the rover compartment will be secured on one end by a wooden bulkhead which will be placed in the nosecone. The other side of the rover will be secured by solenoids which will be attached to the bulkhead on the coupler tube. This limits movement of the rover during flight so that it is unable to move in any of the 3-axis of rotation.

After launch and rocket landing, the nosecone and the body tube will be separated by disengaging an electromagnetic locking mechanism. Once this is done, solenoids as talked about earlier, will open thus pushing out the rover in the direction of where the nosecone was connected during flight. This is a relatively easy system that should be reliable and does not depend on the landing orientation of the upper body tube. More information on the exact solenoids and locks used will be provided in the CDR Report.

Section 6: Project Plan

6.1 – 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 PDR.
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 will be presented in the CDR.
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 was added when it was due and the PDR 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 Open 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 “CTI L-645” 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 tie 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 “CTI L-645 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 61.02 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	We plan on launching a subscale rocket before the CDR so the altimeters can be tested.
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.

6.2 - 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	

6.3 - Educational Engagement

The NASA Student Launch club at York College of PA has planned several STEM outreach events for this year. Young students are the next generation that will carry on our work in STEM fields and it is our responsibility to educate them about rockets. Our goal this year is to get as many students interested in building rockets as possible. In the future, we plan to run the following events:

1. *Field trip to the Roundtown Elementary in York*: We plan to visit the Roundtown elementary school located in York county around late September. Once there we will be educating students on how rockets work and how to build one. We will try to get the students to engage by having them build stomp rockets.
2. *York College of PA Fall Fest*: We will be running our own booth at the Fall Fest with a rocket demonstration.
3. *York College of PA Accepted Students Day*: We will be running our own booth with a built rocket for demonstration purposes. We plan to get future students here at YCP to be interested in NASA Student Launch.
4. *Collaboration with York Country Day School*: With York Country Day School, we plan to educate the students in grades 7-9 on our project. We will also be offering a rocketry building workshop in which they can build and launch their own small rocket with the assistance of YCP Rocketry Students.
    a. *YCDS TARC Team:* It is also in action to begin a TARC team at York Country Day. This will be a mentorship type activity for the team and will also create a bond between York Country Day and York College.

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. Children 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!

6.4 - 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. This initial money will help pay for the parts and transportation required for the subscale flight as well as construction of the full scale rocket. Any funds left over 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 $7,000. 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.

6.5 – Updated Schedule / Timeline

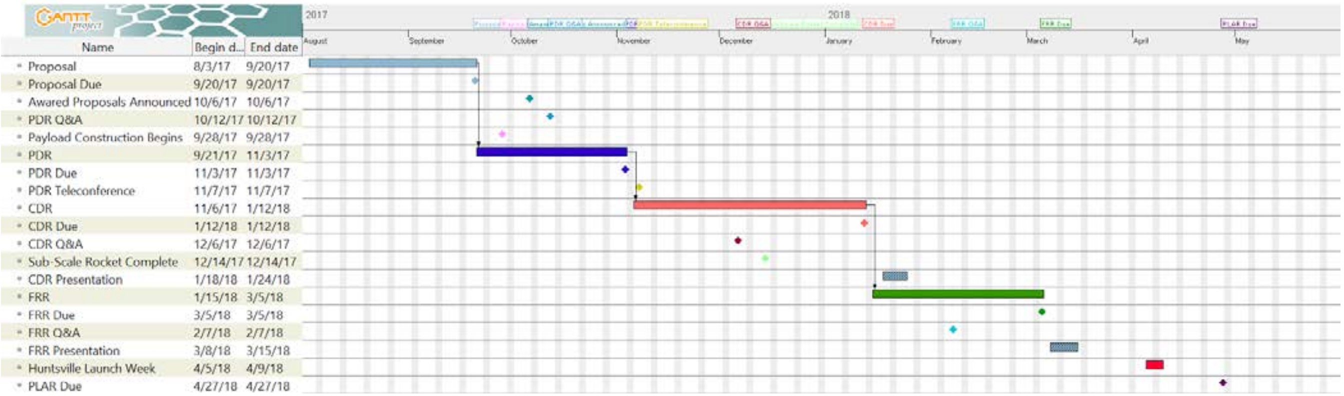
Date	Event
August 2017	
3	Year Planning and regroup
September 2017	
20	Proposal Due by 5PM
21	Rocket Final Design Plans
28	Construction Begins on Payload
October 2017	
6	Construction (Payload)
6	Awarded Proposals Announced
12	Kickoff and PDR Q + A
13	Construction (Sub-Scale Rocket)
18	Wind Tunnel Testing
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

6.6 – GANTT Chart of Team Activities and Team Schedule

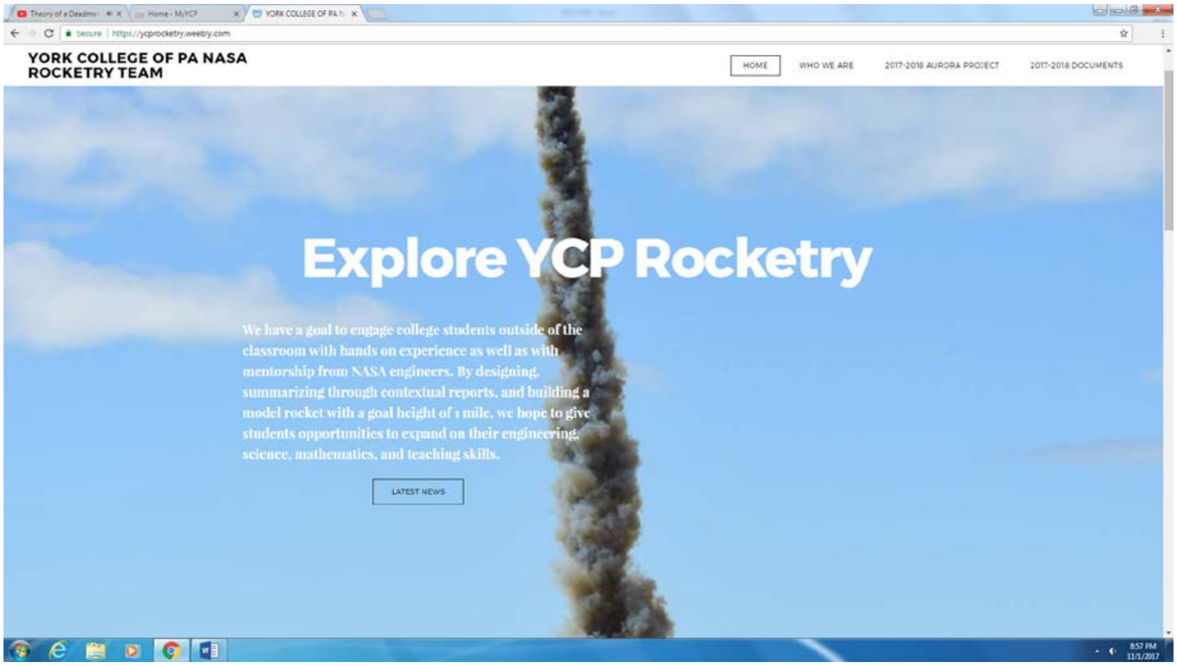


Name	Begin d...	End date
Proposal	8/3/17	9/20/17
Proposal Due	9/20/17	9/20/17
Awared Proposals Announced	10/6/17	10/6/17
PDR Q&A	10/12/17	10/12/17
Payload Construction Begins	9/28/17	9/28/17
PDR	9/21/17	11/3/17
PDR Due	11/3/17	11/3/17
PDR Teleconference	11/7/17	11/7/17
CDR	11/6/17	1/12/18
CDR Due	1/12/18	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

Fig 6.1: GANTT Chart

6.7 – Website and Team Outreach

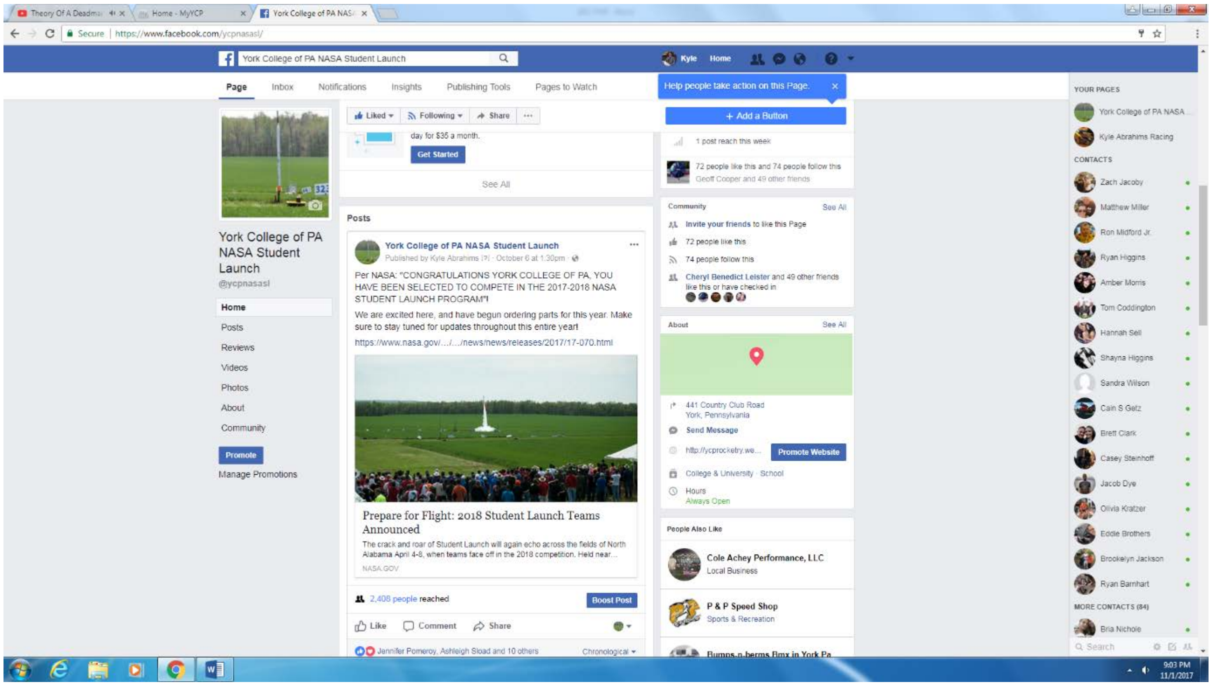
We as a team will use both our website located at www.ycprocketry.weebly.com and our Facebook page to continue to interact on social media, spread awareness about our club, and provide updates on our progress to our followers.



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 6.1: Screenshot from Website



day for $35 a month.

1 post reach this week

72 people like this and 74 people follow this
Geoff Cooper and 49 other friends

York College of PA NASA Student Launch
Published by Kyle Abrahims [?] · October 6 at 1:30pm

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!

https://www.nasa.gov/…/…/news/news/releases/2017/17-070.html

Prepare for Flight: 2018 Student Launch Teams Announced

The crack and roar of Student Launch will again echo across the fields of North Alabama April 4-8, when teams face off in the 2018 competition. Held near…

NASA.GOV

2,408 people reached

Jennifer Pomeroy, Ashleigh Sload and 10 others

Invite your friends to like this Page
72 people like this
74 people follow this
Cheryl Benedict Leister and 49 other friends like this or have checked in

441 Country Club Road
York, Pennsylvania
http://ycprocketry.we…
College & University · School
Hours
Always Open

Cole Achey Performance, LLC
Local Business
P & P Speed Shop
Sports & Recreation
Bumps-n-berms Bmx in York Pa

Figure 6.2: Screenshot from team Facebook Page