University of Central Florida – 2023 – PDR – Report

4000 Central Florida Blvd, Orlando, FL 32816
Knights of Experimental Rocketry

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1. Summary

1.1. Team Summary

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Certification Level: 3

Hours Spend:

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1.2. Launch Vehicle Summary

Our official altitude that we will be targeting is 5507 feet. The motor we will be using to launch our rocket is an Aerotech K1000T. Our rocket is eighty-one inches in length and a diameter of 5.1 inches. The mass of the rocket with the motor is 23.58 pounds. The rocket's nose cone and upper tube will be made of fiberglass which the coupler, switch band, and lower tube will be made of carbon fiber. The recovery systems include the main parachute, the drogue parachute, coupler tube and nose cone. The coupler tube will include the commercial altimeters that are capable of dual deployment events. The nose cone will house the GPS tracker to track the rocket.

1.3. Payload Summary

The payload's goal is to safely land a camera capable of taking high-quality imagery parallel to the horizon, spanning 360 degrees. The payload – dubbed the Payload Integrated Launch Log (P.I.L.L.) - is composed of a polycarbonate tube with two domed edges spanning a length of ten inches, with a cumulative weight of five pounds; alternatively, a clear composite is being proposed for the PILL's outer casing, however, that remains to be determined. In order to act as a gimble, the PILL will function as a rolling cage, with a weighted half-cylinder PETG filament resting at the bottom housing all the electronics. The low center of gravity will cause the casing to roll on ball bearings and orient itself parallel to the horizon. Additional ball bearings and an axle will also allow the camera to orient itself should the PILL lands at an angle; lastly, the camera will rest on an axle controlled by a servo motor allowing it to rotate 360 degrees.

2. Changes since Proposal

2.1 Vehicle Changes

The original design for the rocket was to have an inner diameter of six inches so we could give payloads more room in the nose cone to land the nose cone and so if they went will a deployable payload it would fit in the upper tube. We also had an extended upper tube since initially the payload was going to be longer. We were also going to have a fiberglass upper tube as well as a fiberglass nose cone because we were going to need to have rf transparency in the upper tube to be able to transmit to the ground. We were going to use an L class motor due to the need for more impulse since the rocket was supposed to be heavier. We initially opted to not go with a tail cone due to added complexity initially since it would have to be a custom-made transition section. Our second design was to go with a five-inch inner diameter and have a transition section to expand to six inches to attempt to land the nose cone. The nose cone would have had deployable legs that would have required more room than what is available in five inches.

2.2 Payload Changes

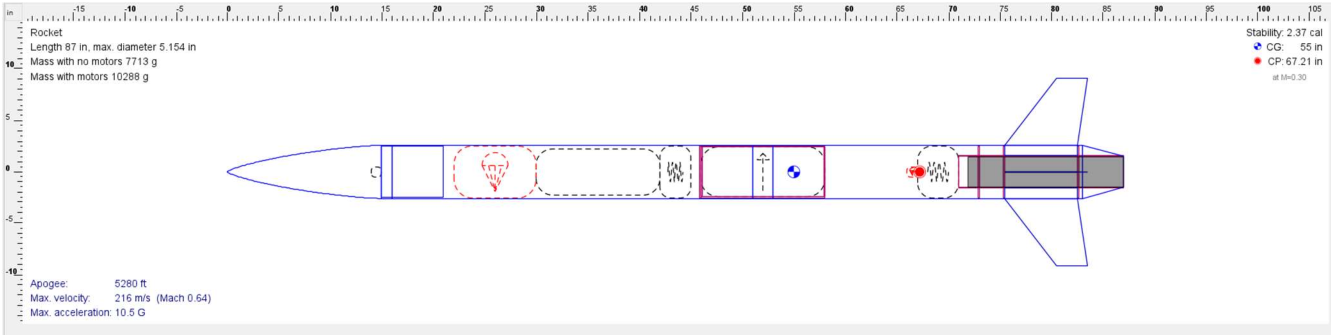
The original payload design consisted of a fiberglass nose cone capable of landing upright through the use of four spring-locked legs. The original design had no redundant means of orienting the camera in case of recovery failure: in the event the nose cone failed to land, the camera would be unable to take pictures parallel to the horizon by any means. Consequently, three subsequent ideas were proposed. The first consisted of a fiberglass upper body tube that would house the payload; inside the tube, a spherical polycarbonate gimble would be held in place allowing the camera to orient itself. The second consisted of the same nose cone design housing the payload, however, a gimble inside would account for the orientation of the camera in the case of recovery failure. The third and final idea once again consisted of landing the nose cone, however, the nose cone would be made of stronger carbon fiber and one leg would have a shorter spring causing it to purposefully tip over releasing the gimble. Landing the nose cone was deemed to be the hardest and most complex approach allowing plenty of room for failure, recovery especially would struggle greatly, and the experiments team would have much less space to work with. Having the gimble inside the upper body tube would require the use of fiberglass to allow for radio frequencies (RF) to be transmissible, raising a massive concern regarding the integrity of the structure. The final consideration was that a spherical gimble would be extremely hard to manufacture and much more prone to breakage. The PILL rolling cage was the culmination of all these ideas. Many members were opposed to the idea of landing the nose cone due to the limited space, and complexity of landing the nose cone upright, and given that the idea of having the nose cone fail on purpose seemed to make separating the nose cone null, it was met with heavy disapproval. The gimble in the main body also limited our workspace as well as forced us to design an upper body tube with fiberglass in lieu of carbon fiber. The PILL allowed for more space and since it would exit the main tube (not jettisoned as it would remain attached to the shock chord), the nose cone would not have to be landed, and the upper body tube could be made of carbon fiber if deemed necessary.

3. Vehicle Design

3.1. Missions Statement

The vehicle's primary purpose is to safely deliver the payload to the ground after reaching an altitude of 5507 feet. For the mission to be consider a success the launch vehicle will perform a stable accent, reaches 5507 feet, main and drogue deploys at designated heights, payload safely reaches the ground, and the launch vehicle recovers in a state of flight ready condition with no significant damage.

Design consideration 1:



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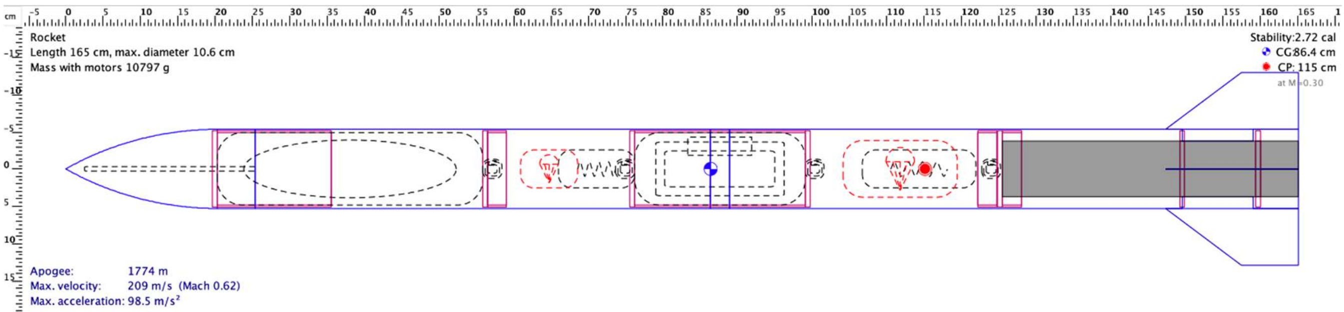


3.2. Launch Vehicle

3.2.1. Airframe & Couplers

3.2.1.1 Airframe Material Consideration

a. Fiberglass

One of the choices we have considered using for our body is fiberglass. It is commonplace in collegiate rocketry due to its capabilities of being rf transparent and having similar material properties to carbon fiber such strength to weight ratio and stiffness.

While some of the downside of fiber glass is that lower strength to weight ratio and smaller fibers it would use more material to create tube of similar thickness. Also, another downside is that there is limited option for fiberglass prepreg materials compared to carbon fiber

b. Carbon Fiber

Carbon fiber is a great choice because it has a high strength to weight ratio and stiffness to weight ratio also. The strength of carbon fiber is optimal for withstanding impacts from the ground to the rocket's airframe.

The benefit of carbon fiber is the strength to weight ratio over fiberglass. Due to the high strength to weight ratio, we can build thinner and lighter tubes than we would be able to with fiberglass. The chance of zippering happenings is reduced due to the high rigidity of carbon fiber.

The downside of carbon fiber is that it is an expensive material to manufacture with. Carbon fiber is a more dangerous material to work with due to the small particle size.

3.2.1.2. Manufacturing Options

a. Wet-lay

When considering manufacturing methods of composite structures, the most accessible option is usually hand wet lay. This is due to the composite being able to cure in room temperature which requires no type heating source unlike pre-impregnated composites. It is also an excellent choice when considering the variety of vendors who provide sheets and tubular sleeves of composites

Some of the downsides of hand wet lay is that there is no real accurate way of having mass estimates of your composite due to epoxy drippage during wet lay, voids in your composite, and the postprocessing of your tubes (sanding).

b. Prepreg

Prepreg is a good choice for manufacturing due to its ease and simplicity. One of its main advantages is that the resin and fiber are already combined before lamination, leading to little possibility of human error. Manufacturing using prepreg often comes with curing via an autoclave. This autoclave uses pressure to prevent void formation and leaves even less room for human error. The process also often results in an aesthetically pleasing design. A downside of the prepreg process is the need for expensive equipment such as an autoclave, and the cost of fiber can be relatively high as well.

But in our case, we would access a composite research lab at UCF that is willing to provide vacuum bagging materials and autoclave which would reduce cost.

3.2.2. Coupler

3.2.2.1 Material Consideration

a. Fiberglass

One of the choices we have considered using for our coupler is fiberglass. It is commonplace in collegiate rocketry due to its capabilities of being rf transparent and having similar material properties to carbon fiber such strength to weight ratio and stiffness.

While some of the downside of fiber glass is that lower strength to weight ratio and smaller fibers would mean we would have to use more material to create tubes of similar thickness. Also, another downside is that there is limited option for fiberglass prepreg materials compared to carbon fiber.

But when considering the coupler there wouldn’t be a need for rf transparency since our telemetry unit would be in our nosecone.

b. Carbon Fiber

Carbon fiber is a great choice because it has a high strength to weight ratio and stiffness to weight ratio also. The strength of carbon fiber is optimal for withstanding any forces during ground impact.

A Benefit that carbon fiber is the strength to weight ratio over fiberglass. And due to the high strength to weight ratio, we can build thinner and lighter tubes than we would be able to with fiberglass. The chance of zippering happenings is reduced due to the high rigidity of carbon fiber.

3.2.3. Nose Cone

3.2.3.1 Shape Considerations

b. Ogive

An ogive nosecone is designed based on the geometry of a circle. This being that the initial radius of the nosecone is the radius of the rocket body tube, and its curve is tangent to the end of the body tube. This design is beneficial for its ease of manufacturing, but unlike a conic nosecone, it has a greater volume and lower drag force.

c. Elliptical

An elliptical nosecone is designed similarly to an ogive nosecone, but instead of being based on a circle it is based on an ellipse. The initial radius is also the same as the rocket body tube, but the curve is not tangent to the rocket body tube. This design has low drag force and great volume, but it is harder to manufacture the tip of the nosecone.

d. Parabolic

A parabolic nosecone is designed similarly to an ogive nosecone, but instead of being based on a circle it is based on a parabolic function's curve. This design is chosen for having low drag force and considerable volume.

e. Von Kármán

A Von Kármán nosecone is a variation of a Haack nosecone. This shape is mathematically derived for the sole reason to minimize drag to the absolute minimum. The nosecone is not perfectly tangent to the rocket body tube, but it approaches tangent to the point that it can be considered tangent for all intents and purposes. This design was chosen for its considerable volume and low drag.

3.2.3.2 Material Consideration

a. Fiberglass

One of the choices we have considered using for our nosecone is fiberglass. It is commonplace in collegiate rocketry due to its capabilities of being rf transparent for which a telemetry unit can be housed in.

While some of the downside of fiber glass is that due to its lower strength to weight ratio and smaller fibers you would have to use more material to create tubes of similar thickness.

b. Carbon Fiber

Carbon fiber is a great choice because it has a high strength to weight ratio and stiffness to weight ratio also. The strength of carbon fiber is optimal for withstanding impacts from the ground to the rocket's airframe.

Benefits that carbon fiber are the strength to weight ratio over fiberglass. Due to the high strength to weight ratio, we can build thinner and lighter tubes than we would be able to with fiberglass. The chance of zippering happenings is reduced due to the high rigidity of carbon fiber.

The downside of carbon fiber in this case is that there would no option to house telemetry unit in nose cone which would lead to further complications in our recovery coupler.

3.2.3.3. Manufacturing Options

a. Female molds

The female molding process involves a concave mold with a thermoplastic sheet laid inside it. The female mold has the advantage of having more precise outer dimensions, and sharper detail in these dimensions is possible. Female molds are mostly used when the outer dimensions take priority over the inner dimensions. Another advantage of female molds is that drafts are not required in many cases. Depending on the design and use case, a female mold could be more expensive to design and manufacture than with male molds.

b. Male molds

The male molding process involves a convex mold with a thermoplastic sheet laid on top. The resulting parts have more precise inner dimensions than a female mold but may have limited detail on the outer exposed surface. Drafts may be required for proper removal of the part from the mold. Is generally less expensive than female molds.

3.2.4. Bulkhead

3.2.4.1 Material Considerations

a. Birch Plywood

Birch Plywood is a very common material to use for bulkheads. It's a sturdy and reliable choice, made with thin layers of wood securely glued together. Some of their advantages are that they have little to no voids, as well as having a high strength. It is also much easier to work with and manufacture. It can be quite heavy, however, and can still break under high stress in recovery.

b. G10 Fiberglass Plates

Fiberglass plates are far stronger than that of plywood in much thinner pieces. It can be a bit more costly and difficult to work with, however. Another strength of G10 Fiberglass

Plates is that it can be much more resistant to things such as the effects of black powder charges, which birch plywood may not hold up well against.

3.2.5. Launch Lugs

Launch lugs are hollow cylinders that constrain a rocket to the launch rod. They provide the rocket stability before and during liftoff, and make the rocket stay parallel to the launch rod. However, these are used mainly in low-power rockets. Larger rockets require more rigid guidance, especially in windy conditions.

One consideration for how the rocket will have rigid guidance against a launch rail is the use of conformal rail guides on the launch rail. This will allow the rocket to be launched from a stiff launch rail. Additionally, conformal rail guides can produce a lower drag because of their lower frontal areas. However, these will need to be surface mounted to the rocket and will need to be aligned perfectly to prevent binding. If the rail guide gets partially inserted into the rail's fingers, the rocket twists. When trying to twist off the rail guide, a torque force results and is higher with longer rockets. This can cause the guide to snap off.

On the other hand, rail buttons do not require as much precise alignment as rail guides do. These are attached on the outside of the rocket to ride along the launch rail. Also, they are more forgiving of any rough handling when positioning the rocket onto the pad, as they are less likely to snap off when twisting the rocket.

3.2.6. Fins

a. Trapezoidal

The trapezoidal fin for our rocket is due to the low amount of induced drag, the high capability for creating correcting lift, and the ability to airfoil the root and tip. Having a fillet on the leading edge of the fin and a chamfer on the trailing edge of the fin creates an efficient airfoil that creates a smooth flow of air and a higher coefficient of lift. The straight lines of the trapezoidal shape allow for easy CNC manufacturing compared to more complex shapes. A possible drawback of the Trapezoidal fin is a lower apogee.

b. Elliptical

Theoretically Elliptical fins have the lowest amount of induced drag, which would allow for a higher apogee. However, the large amount of tapering on the fin makes an elliptical shape less effective at creating lift. This creates a more unstable rocket as there is not as much restorative force to correct the flight path of the rocket. This makes an elliptical the best choice in a rocket that is attempting a high altitude on a day with very minimal wind. Hard to manufacture and integrate

c. Clipped Delta

The Clipped Delta fin has a similar drag and lift to the Trapezoidal fin. It has the benefit of having less drag at subsonic speeds due to the long root chord compared to Trapezoidal. This allows for a higher total apogee, but the disadvantage that comes with this is a less structural wing. It allows for more vibrations which could affect stability.

3.2.7. Motor

3.2.7.1. Motor Selection

a. Aerotech K1000T

Mass	5.74 lbs.
Maximum Thrust	1674 N
Apogee with Motor	5507
Burn Time	2.4 s
Propellant Type	Blue Thunder

b. Aerotech K560W

Mass	6.05 lbs.
Maximum Thrust	753.7 N
Apogee with Motor	5224
Burn Time	4.1 s
Propellant Type	White Lightning

c. K780R

Mass	6.47 lbs.
Maximum Thrust	965 N
Apogee with Motor	4876
Burn Time	3.0 s
Propellant Type	Redline

d. L850W

Mass	8.25 lbs.
Maximum Thrust	1866.2 N
Apogee with Motor	8513
Burn Time	4.4 s
Propellant Type	White Lightning

3.2.8. Centering Rings

a. Birch Plywood

One material we considered for centering rings was birch plywood due to the lower cost and easier to manufacture than G10 fiberglass plate. Birch plywood has a significantly lower cost compared to the same sheet size as G10 fiberglass plates. With plywood we can use the laser cutter at the University of Central Florida to machine the center rings. A disadvantage that birch plywood has is a lower tensile strength when compared to G10 fiberglass plate.

b. G10 Fiberglass Plate

The other material that we consider for centering rings was G10 fiberglass plates due to higher strength when compared to birch plywood. Some downsides of G10 fiberglass plates are that it has a much higher cost than birch plywood, it is also not as easy to get, you must order G10 fiberglass plates online. G10 fiberglass plates are also harder to manufacture since we cannot use the laser cutter at the University of Central Florida. We have access to a CNC machine, but it is not as precise as the laser cutter.

3.3.9. Electronics Bay

3.3.9.1. Altimeter

a. MissileWorks RRC2+

The MissileWorks RRC2+ is a small and cost-effective option for an altimeter. With low running power and a good range of 3.6 to ten volts for output strength, it is a reliable option for a redundant altimeter that is simple and inexpensive. However, it lacks the ability to interface with an operating system, making it harder to retrieve flight data and configure it during preflight operations. Additionally, it only has a limited number of presets, reducing flexibility.

b. MissileWorks RRC3 Sport

The MissileWorks RRC3 Sport is a more powerful altimeter that can output three different 3.6-to-ten-volt signals during flight, making it extremely flexible. In addition to that, it is also configurable using WindowsOS. That allows for precise presets that will allow the events to happen when the ground team decides what is best. Compatibility with Windows also allows for the collection of detailed flight data and the creation of graphs post-flight. All of this makes the RRC3 Sport a great option for a main or redundant altimeter. However, it is larger than the RRC2+ making it less viable if space is an issue. Additionally, the RRC3 Sport also runs at 35ma while it is armed, making it an incredibly power-hungry component that may not be able to last for the duration of the pre-flight depending on the battery chosen.

c. PerfectFlite StratoLoggerCF

The PerfectFlite StratoLoggerCF is a reliable and available option that many schools and people have used before in their flights prior to this competition year. It is small, yet still has a range of four to twelve volts for two signal outputs. It is also configurable using both WindowsOS and MacOS, allowing for a more precise setup pre-flight and the ability to collect and graph flight data post-flight. The StratoLoggerCF also runs on 1.5ma and includes brownout protection. This makes the StratoLoggerCF a great option for a main or redundant altimeter.

3.3.9.2. Batteries

a. 9-volt Batteries

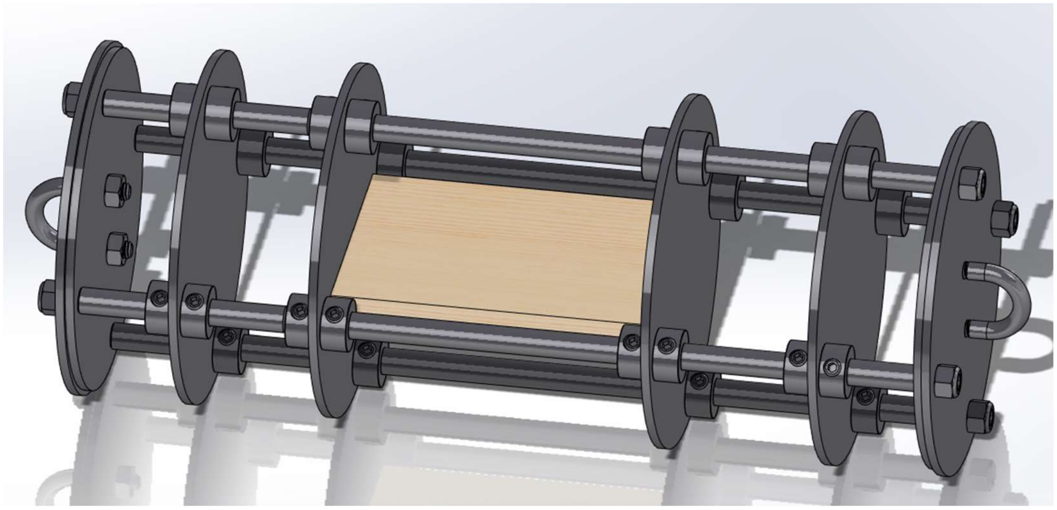
9-volt batteries are an easy and accessible method of powering the altimeters that we decide to use. Many altimeters are easily powered using them. It is simple to fasten them either using zip ties or to use a dedicated holder that we make or buy. Connecting them is just as simple with 9-volt connectors easily purchasable from many online retailers or in hardware stores. However, 9-volts do not have the longest battery life. This means that depending on the length of time that the altimeters must stay armed and their power consumption, the 9-volt battery may not have the power required to power them for the duration of the flight as well. Additionally, they cannot be recharged, so new batteries must be bought after each flight.

b. LiPo Batteries

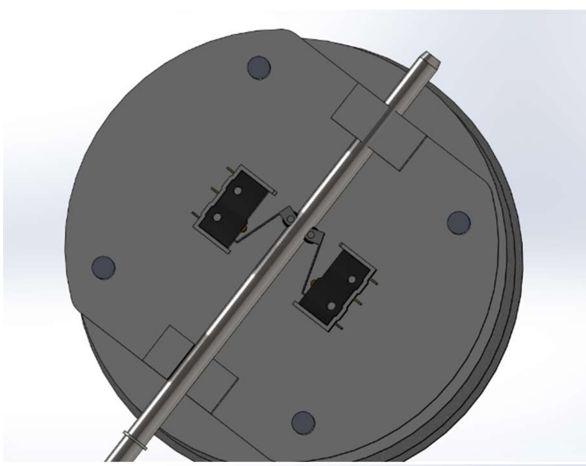
LiPo batteries come in many different sizes and voltages, making them more flexible than 9-volt batteries. They are also rechargeable, potentially lowering the number of batteries that must be bought. A decently sized LiPo battery of 300mAh would be able to power the RRC3 Sport, the most power-hungry altimeter chosen, for over eight hours, making LiPo batteries a good option for powering the altimeters for long periods of time. However, while they can be recharged, the proper method for doing so is more complicated than simply buying more batteries. Additionally, LiPo batteries are significantly more expensive than 9-volt batteries, making them a much less appealing option when the budget is a concern.

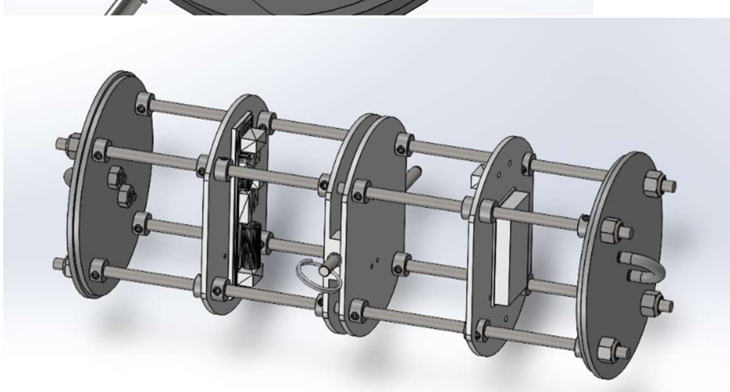
3.3.9.3 Electronics Bay Design

For the design of the electronics bay, we had considered two possibilities: designing a vertical sled to mound the electronics between two plates in the recovery as well as mounting the electronics directly on the plates. The first design for the electronics bay has four centering rings and contains a "sled" in between two of the centering rings. It would be out of 3in x 4.63in plywood placed vertically between them. We would have all the electronics on this sled. This would make managing the parts easier if they were all close together. Therefore, this will make the wiring less complex, and the altimeter can be placed vertically. A vertically placed altimeter is more efficient at calculating the change in pressure compared to an altimeter lying horizontally. However, despite such benefits, the negative to the sled is that the workspace would be tighter, so it is harder to physically work on.



The other design idea has six centering rings, two of which serve as the pin module, but no sled between them. Instead the two of the centering rings on the inside would be placed closer together and contain the electronics between them and on the centering rings. This design makes the electronics bay easier to construct. It uses less materials and there is still sufficient space for all the electronics despite not having a sled. With this idea, we can also use plates to hold the limit switches in place for the recovery pin to arm. This removes the human error of trying to drill holes for the screws for the switches as the plates are 3D-printed with holes.





3.3. Recovery Subsystem

3.3.1. Parachutes

3.3.1.1. Parachute Shapes

The parachute shape we have chosen is a Parabolic shape. Our alternate ideas to the parabolic were hemispherical and cruciform shapes. The parabolic shape has many advantages that the others do not possess. One of those advantages is that a parabolic parachute, by design, solves two issues. Spin and Oscillation. This is because of its "X" like design. When the parachute is deployed and catches air, it lets some of that airflow spill out onto 4 corners. Because of those 4 corners, the parabolic-shaped parachute keeps 100% of its surface area while retaining stability in flight. Therefore, there is no need to cut holes into the parachute to increase airflow to prevent oscillation and spinning. The main disadvantage of a parabolic parachute is that it doesn't slow as fast as a hemispherical or a cruciform shaped parachute

The main advantage of a hemispherical parachute is that it has the highest drag coefficient per unit diameter length. This is because drag is proportional to the area of the parachute, and a perfectly circular shape maximizes area (given a specific diameter). The disadvantage of this parachute shape comes from the fact that the parachute traps too much air, resulting in a high-pressure zone underneath the parachute. This high-pressure air destabilizes the parachute as it attempts to escape from any edge of the parachute (the perfect circle results in no easy escape route). When using a hemispherical parachute this must be accommodated for via holes in the parachute that allow air to escape. Secondly, the circular shape means it has no proper way to resist spinning without further modification to the chute. Cutting enough holes in the chute to negate the disadvantages of a hemispherical design begins to negate the original benefits of this parachute (maximized surface area), which is why we chose to move away from this design.

A cruciform-shaped parachute is like a hybrid of parabolic and hemispherical shapes. It could also be called a Hemi-cubicle shape as it looks like half a cube. The benefit of such a shape is that it's more effective at slowing down an object in free fall due to it having the highest amount of surface area. However, the cubicle resembles also means a high amount of air pressure is trapped and therefore will cause an exaggerated amount of oscillation. This is remedied by having oval-shaped holes in each of the four edges. By placing holes in those areas, they act like relief holes to decrease the air pressure build. Although it helps reduce air pressure, it also decreases drag. This is because the corners are where the air pressure build-up is highest. The center of the parachute is the second-highest area of pressure, but the air spreads to the edges as it expands.

3.3.1.2. Parachute Material

The elected parachute material is a .66oz Nylon Ripstop for both primary (main) and drogue parachutes. Nylon Ripstop is a reinforced nylon material fabricated to withstand the various demands of outdoor conditions, namely heavy winds and areas of high friction by adding a crosshatch pattern of reinforcement yarns. These reinforcement yarns stop tears in the unreinforced areas of the Nylon from spreading to other sites, hence the name Ripstop. Therefore, every tear is localized and contained so that the damage remains at a minimum. In addition to its durability, it is also lightweight. Only weighing 4.878oz for our 96 inches diameter main parachute. Another benefit to our chosen material is that it can easily be packed into a compact volume of space.

Alternatives for the primary and drogue parachute material was a 1.1oz Nylon Ripstop. While it is the same as the .66oz Nylon Ripstop, it has some notable differences. With an equivalent diameter for the primary parachute, it weighs 10oz. That is an increase of 51% in weight compared to our elected choice. It is also much harder to pack into a small volume of space due to its higher weight per square yard of material. The benefit of the lightweight material to make it compact is what solidified our decision to go with the .66oz Nylon Ripstop material.

3.3.1.3. Parachute Sizing

The main parachute has a diameter of 244 cm, the drogue parachute has a diameter of 45.7 cm, we chose this sizing of parachute by calculating the drag required to reach a descent time below 80s which will give us an impact velocity below 7.9 m/s. For these calculations we used the drag equation D = Cd(rV^2/2)(A). After making these calculations we then used OpenRocket to test our calculations which gave us a descent time of 68s and an impact velocity of 6.33 m/s which meets the requirements stated by the NASA SL guidelines.

3.3.2. Shock Cord

The shock cord will be manufactured from either tubular nylon or tubular Kevlar. There will be two shock cords, an upper and a lower placement for the shock cord. The upper shock cord will be 300 inches in length and will be placed in the upper tube below the payloads section of the rocket. It will be attached to the main parachute via quick links. On the other hand, the lower shock cord will be 360 inches and will be placed in the lower tube. This shock cord will also be attached to the drogue parachute via quick links.

Tubular nylon is much more elastic than tubular Kevlar, therefore, the shock during parachute deployment will be drastically reduced. Moreover, Tubular nylon is not as abrasive on the airframe when compared to Kevlar, which will reduce the chances for the rocket to get zippered. Further, nylon is not heat resistant and will degrade quickly, hence, some method of fire protection on the nylon is necessary. The elasticity of tubular nylon brings the possibility of sections of the rocket bouncing back and colliding with each other. On the other hand, tubular Kevlar is much more heat resistant and will be able to withstand the heat from the ejection charges. Additionally, tubular Kevlar has a stronger tensile strength than nylon and thus will have a better chance of not breaking/snapping. Note that Kevlar is not as elastic as nylon and will not stretch out as much. This means that the instantaneous force when the parachute deploys may be too much for the Kevlar in terms of stretching out. A disadvantage of using Kevlar for the shock cord is that it can be difficult for the material to hold a knot, however, this can be helped by adding glue. Lastly, when comparing costs between the two materials, Kevlar is significantly more expensive than using nylon.

Other ideas involve using a mix of both Kevlar and nylon for the shock cord. The first idea was to use a single shock cord that consists of both Kevlar and nylon. The side of the shock cord next to the ejection charges would be Kevlar due to its heat-resistant materials. Meanwhile, the other side would be made from nylon to take advantage of its elastic nature. The second idea was to utilize two shock cords parallel to each other. One of the shock cords will be made of Kevlar, while the second shock cord will be made from nylon. The nylon shock cord will be shorter than the Kevlar shock cord. This is due to the fact that the nylon shock cord will reach impact first, therefore, it will use its elastic nature to absorb more force. This way the Kevlar shock cord will not have as much force to stretch it out, securing the integrity of the Kevlar shock cord while benefiting from its strong tensile strength.

3.3.3. Ejection Charge

In the avionics bay, FFFFg black powder canisters will be on coupler bulkheads between two body tube sections. Each parachute will have both a primary and backup charge, with the backup charge being redundant if the primary charge is insufficient for proper ejection. Forward charges on the coupler will be for the primary parachute and aft charges are for the drogue chute respectively, sized based off the interior volume of the rocket body. Ideal primary charges for the main chute and drogue chute have been calculated to be 3.9 grams and 1.5 grams respectively, with redundant charges being 5.1 grams and 2.1 grams respectively. These primary charges were chosen to produce 50% of the rated force of the shear pins to ensure reliable shearing, with backup charges producing an extra 5 psi of pressure should the primary charges fail to produce proper separation. Black powder is used due to its light weight, relative ease of use, reliability, inexpensiveness, and ease of obtainment compared to other explosives or high-pressured gas systems. FFFFg powder specifically is being used due to a faster burn rate, and thus higher pressures, than coarser grains.

The charges will be attached to a coupler such that detonation will result in the parachute being forced into the airframe, shearing the pins and releasing the parachute.

3.3.4. Packing Methods

To begin properly packing the parachute we will start by raising the parachute and checking that all lines are straight and untangled. The parachute will be laid out on a flat surface to check every connection is secured to the parachute and shock cord.

The “Burrito” method to pack the parachute. Gather the lines to one side, pinch the center of the canopy and pull tight to straighten out the canopy and the lines. Roll from the top of the parachute down to the center. Once at the middle fold the left inward to the center followed by the right side to the center. Then continue rolling to the bottom of the canopy. Twist the canopy and slowly wrap the lines neatly around it.

Another method for packing is the “Z” method. lay out the parachute then gather the lines and organize the parachute flat. Fold each side repeatedly toward the center. Organize it so the diameter is 15% of the diameter of the parachute size. Fold the parachute from top down in three sections so it appears to make a "Z" shape. Pull the fabric from the underside of the parachute around the side and over the top. make a crease in the center of the fold. Bring the line up 1/3 of the crease then wrap the lines around the parachute smoothly.

3.3.5. Fasteners

3.3.5.1. U-Bolt

Bolts will be secured to bulkheads on each end of the coupler, which will in turn be used to attach shock cords and parachutes for rocket recovery. U-Bolts were chosen over Eyebolts as by having two attachment points, not only is the shock force of separation distributed across two points on the bulkheads rather than a singular point, but there is no open slot on the bolt that the cord could potentially be yanked through or requiring weld to shut.

3.3.5.1. Eyebolt

An eyebolt was not considered for the design due to only having a single attachment point to the airframe, thus increasing pressure and risk of failure, as well as having an open slot in the bolt that would require weld or bending (both of which introduce structural weaknesses in the bolt itself), lowering the effective strength of the bolt itself as well.

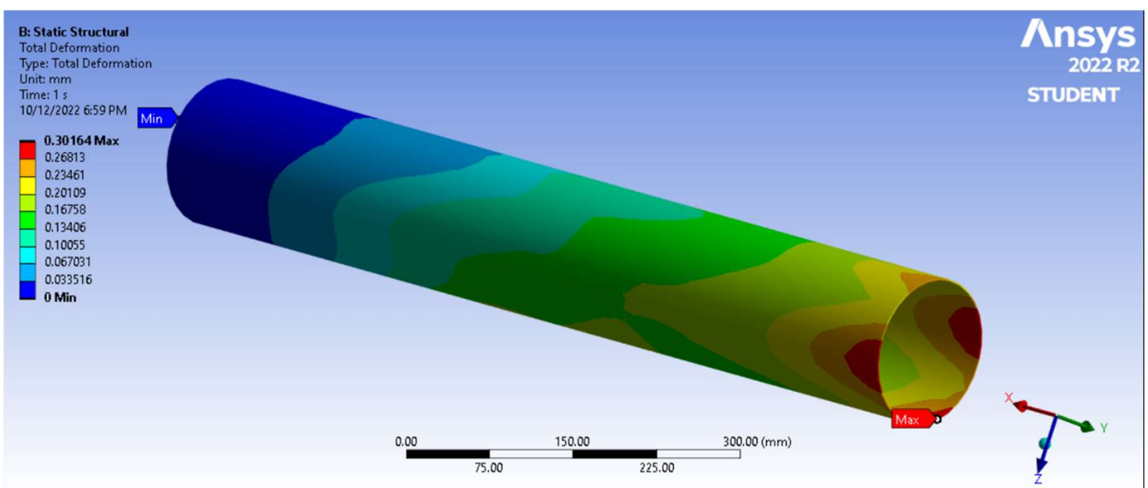
3.3.5.2. Shear Pins

A set of Nylon 4-40 shear pins will be used to attach the coupler and body tube, chosen due to being standard within the industry and thus are both easily obtainable and inexpensive. The primary force that will be acting to separate the body tube pre-separation will be atmospheric pressure differential, which was calculated to be approximately 72 pounds of force based off launch altitude, target apogee, launch site climate, and temperature-altitude gradients. Each shear pin will withstand 50 lbs., so to maintain a safety factor of approximately 3 as well as to ensure necessary black powder charges will not produce excessive pressure, a set of 4 shear pins will be on the forward section of the coupler and 3 on the aft.

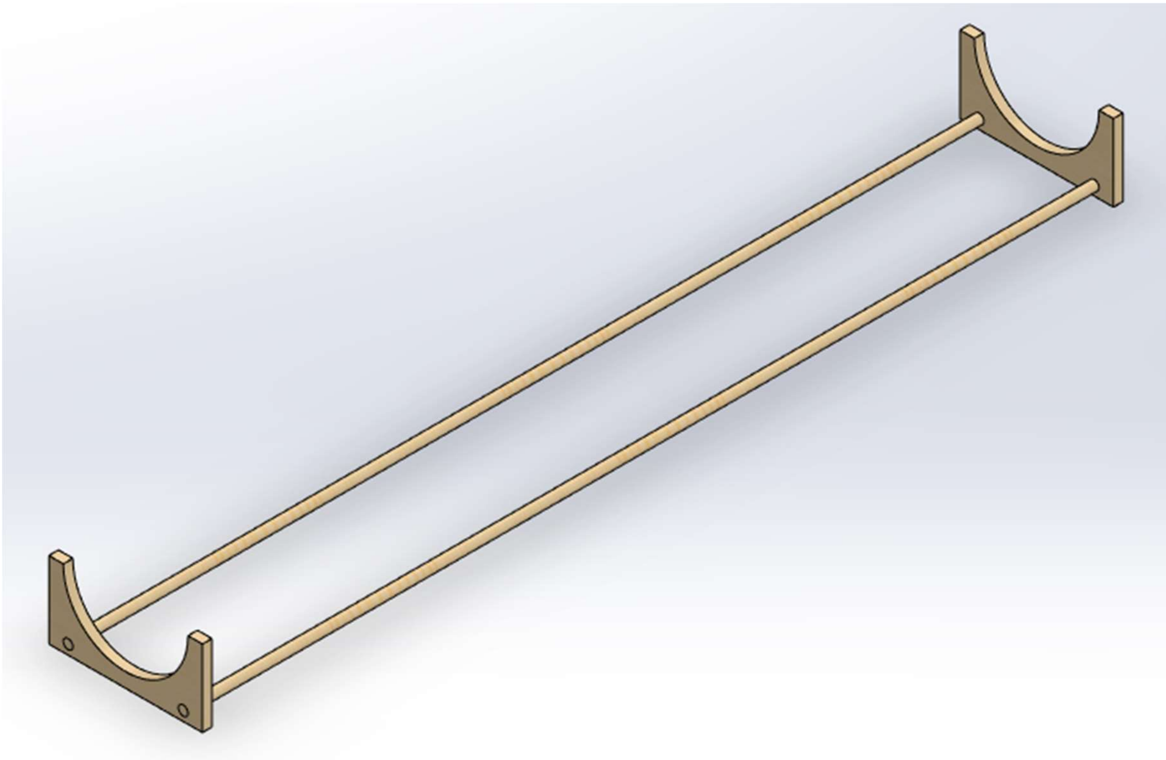
3.4. Leading Vehicle Design

3.4.1. Airframe

For the airframe we are going to be using carbon fiber. Both upper & lower tube will be made of carbon fiber due to carbon fiber's high strength to weight ratio and since there is no need to have RF transparency. The upper tube of the rocket will have a length of 35 inches and the outer diameter will be 5.1 inches, and the inner diameter will be 5 inches. The lower tube will have a length of 30 inches and an outer diameter of 5.1 and an inner diameter of 5 inches.



To manufacture the two sections, we will be using prepreg sheets. We chose this method because the tubes can be manufactured more consistently and have much less variation between each tube than if we were to impregnate the sheets ourselves, as well as have much better estimates beforehand of the thickness and tolerances since the epoxy will already be in the fibers. We will be laying the prepreg sheets on an aluminum mandrel, to prep the mandrel for the sheets we will use car wax and then a layer on mylar followed by frekote to help the epoxy not bond to the mylar. Typically using prepreg is very expensive due to the need to use vacuum bags and an autoclave but since we have that kind of access, we only need to purchase the prepreg fibers, gum tape and mold release which makes the cost very similar to that of wet laying the tubes. The image below shows how we will put the airframe tubes in the autoclave.



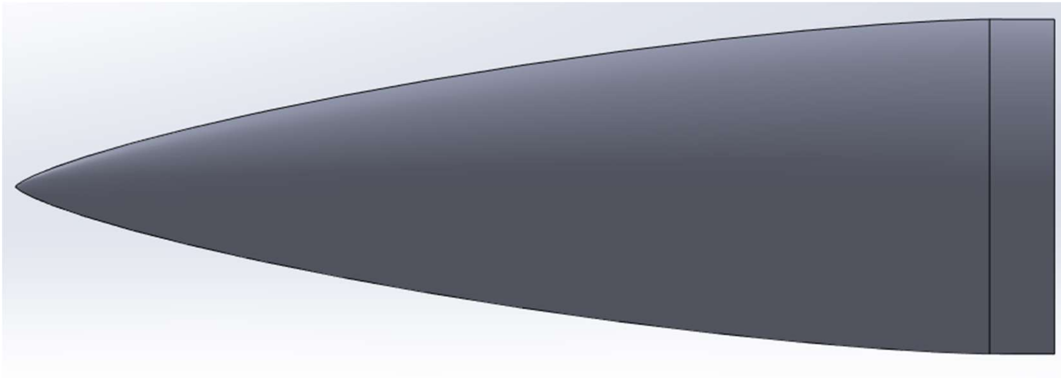
3.4.2. Coupler

The coupler will be made of carbon fiber for the rigidity that is needed. The coupler experiences a lot of bending stress, and it needs to be able withstand that stress. The coupler will have a length of 12 inches, an outer diameter of 4.998 inches and an inner diameter of 4.8 inches.

The coupler will be manufactured out of prepreg carbon fiber sheets. We use a similar aluminum mandrel to the airframe tube one but we will machine the outer diameter down so we can make a coupler out of it. If we bought a commercial coupler it would have to lose of a fight since the outer diameter on commercial couplers are made for 5 inches inner diameter tubes and our tubes will be a tad bit bigger than 5 inches.

3.4.3. Nose Cone

The nosecone design we are choosing to go with is a Von Karman shape. It is theoretically one of the best designs to minimize drag. The length of the nose cone from the base to the tip will be 15 inches and will have a base diameter of 5.1 inches. We will be using prepreg fiberglass for the nose cone since we need RF transparency for GPS tracker.



3.4.3.1 Nose Cone Material & Mold Decision Matrix

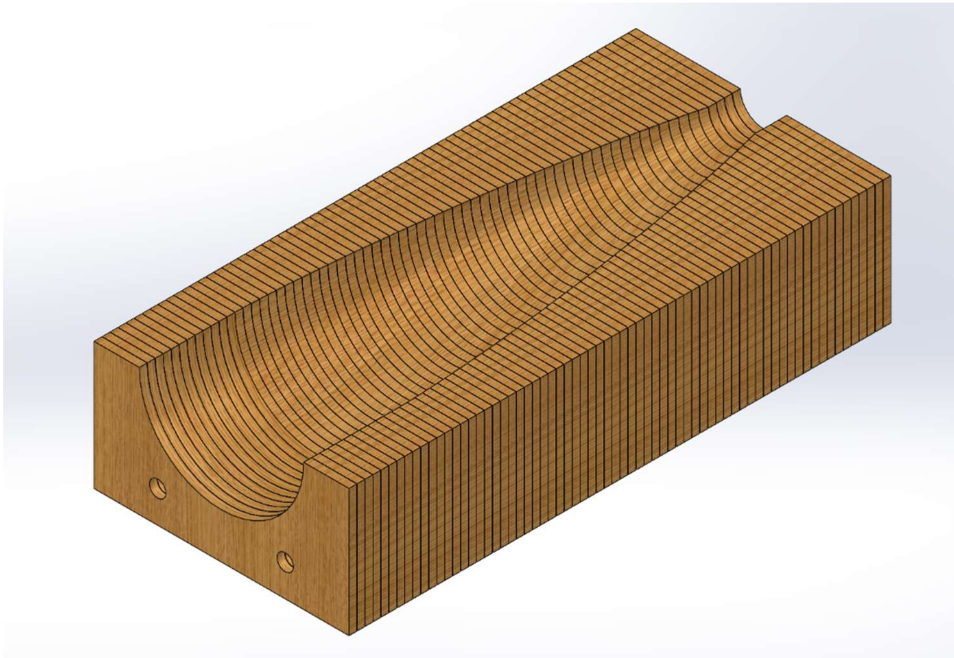
Importance	Rating
0.5 – Optional	1 – Worst
0.75 – Desired	2 – Average
1 – Required	3 – Best

Criteria		**Female Mold**		**Male Mold**	
Wants	Importance	Rating	Total	Rating	Total
Cost	0.75	2	1.5	3	2.25
Tolerance	1	3	3	1	1
Feasibility	0.75	2	1.5	3	2.25
	Total	7	**6**	7	**5.5**

Criteria		**Carbon**		**Fiberglass**	
Wants	Importance	Rating	Total	Rating	Total
Cost	0.75	3	2.25	2	1.5
Strength	0.75	3	2.25	2	1.5
Feasibility	1	2	2	3	3
RF	1	1	1	3	3
	Total	8	**7.5**	7	**9**

We ultimately decided to manufacture the nosecone out of a split female mold made of MDF boards. This was mainly because the outer dimensions will be more accurate with a female nose cone. We will need to sand the MDF mold until there are no ridges in them since cross sections of the mold would have to be Laser cut at UCF TI LAB which will affect the finish product. After applying a sealant and mold release, we would use our wet-lay method

We are also choosing to make our nosecone out of fiber glass since we are nosecone, we ultimately choose to house our telemetry unit inside of the nosecone. Also since fiberglass sheets are thinner than carbon fiber which means it is more moldable and it conforms better to the female mold than carbon fiber



3.4.4. Bulkhead

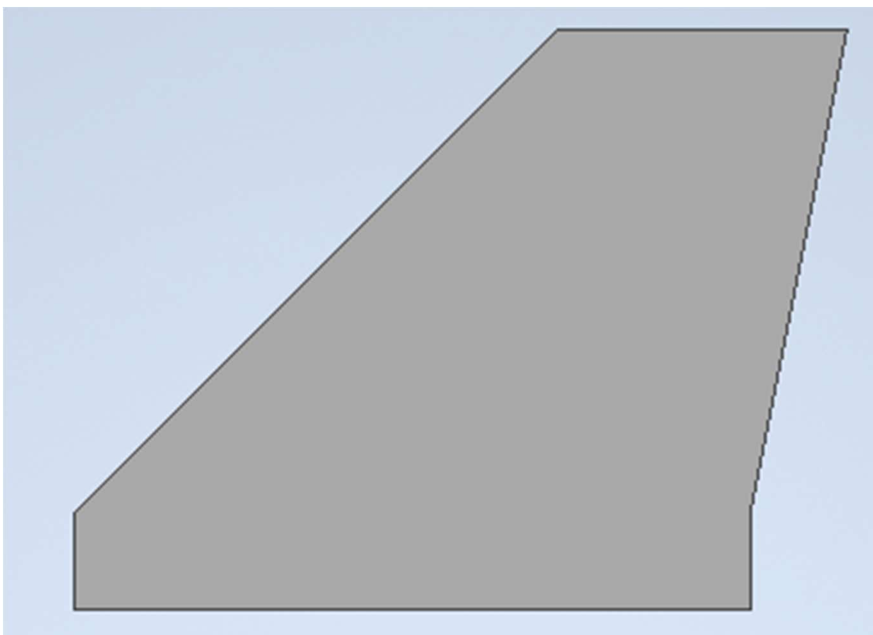
For the bulkhead we decided to go with G10 fiberglass plates due to their high strength. Since the bulkheads will be a load bearing structure for recovery, we decided that it was not worth the risk of using weaker material just because it was going to be cheaper and easier to use. The recovery section is one of the most important parts of the rocket because it allows us to safely recover the rocket. Safety is one section you do not cut corners on just to decrease cost. We also decided that fiberglass plates will be able to withstand the corrosive black powder after serval firing and testing.

3.4.5. Launch Lugs

We chose to go with rail buttons because they are more forgiving with slight misalignment. They are also cheaper due to the ability to be 3D printed or made of Delrin. We chose not to go with launch lugs because they do not provide enough rigidity and strength that is needed for a high-power rocket. We opted to avoid using conformal rail guides due to the need to be perfectly aligned. If you do not get conformal rail guides aligned perfectly, they will cause binding on the rail, if binding occurs, the rail guides will get stuck and either break off or the rocket would just get stuck on the pad. Rail buttons are a more familiar concept to our team, so it made more sense to stick with a proven design.

3.4.6. Fins

We chose to go with a swept back trapezoidal fin for our rocket due to the low amount of induced drag, the high capability for creating correcting lift. We also chose a swept back trapezoidal fin due to the ease of manufacturing on a CNC machine compared to the more complex elliptical fin shape.



3.4.7. Motor

After we considered different motor options, we decided to use the Aerotech K1000T due to its high thrust that it provides. The high thrust will be beneficial in hitting our apogee target because the faster your are moving the less likely the wind is the blow you off course. The K1000T was the only high thrust motor that was able to keep us within the altitude range of four thousand to six thousand feet.

Mass	5.74 lbs.
Maximum Thrust	1674 N
Apogee with Motor	5507
Burn Time	2.4 s
Propellant Type	Blue Thunder

3.4.8. Centering Rings

We have decided to use birch plywood for our centering because it has a lower cost, is easy to machine and readily available. The concern with strength will need be an issue because we are going to be doubling up on .125in thick birch plywood to create a .25in thick centering ring. Also, with G10 fiberglass plates there is a health concern but with wood there is not as much as a risk. The lab at the University of Central Florida has a vacuum when laser cutting wood that it will route the air outside instead of us breathing it in.

3.4.9 Electronics Bay

3.4.9.1: Altimeters

When constructing the electronics bay, three altimeters were taken into consideration; The MissileWorks RRC2+, a small and cost-effective ten-volt altimeter, The MissileWorks RRC3 Sport, an upgrade to the last mention as it allows for three different outputs with a range of 3.6 and ten-volt gauge, and lastly the PerfectFlite StratoLoggerCF, known for its range of four to twelve volts with two signal outputs.

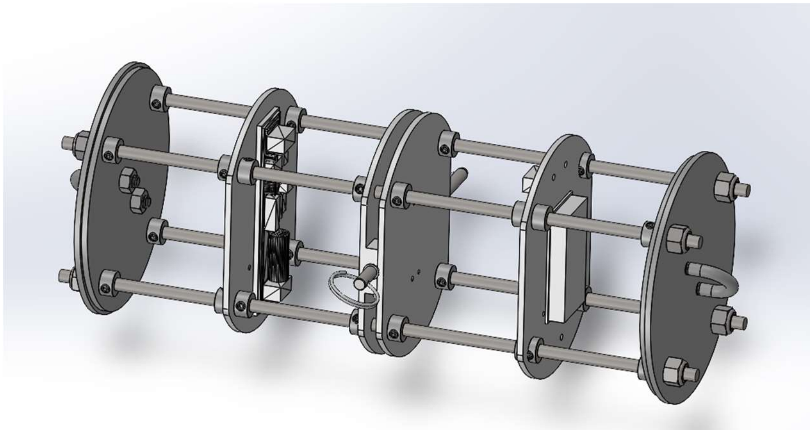
There were key differences among the choices such as the RRC2+ not being compatible with windows, as well as its inability to interface with operating systems. Thus, making it harder to retrieve flight data and configure it during preflight operations. Both RRC3 and LoggerCF utilize windowsOS and can summon precise setups for pre-flight and data collection.

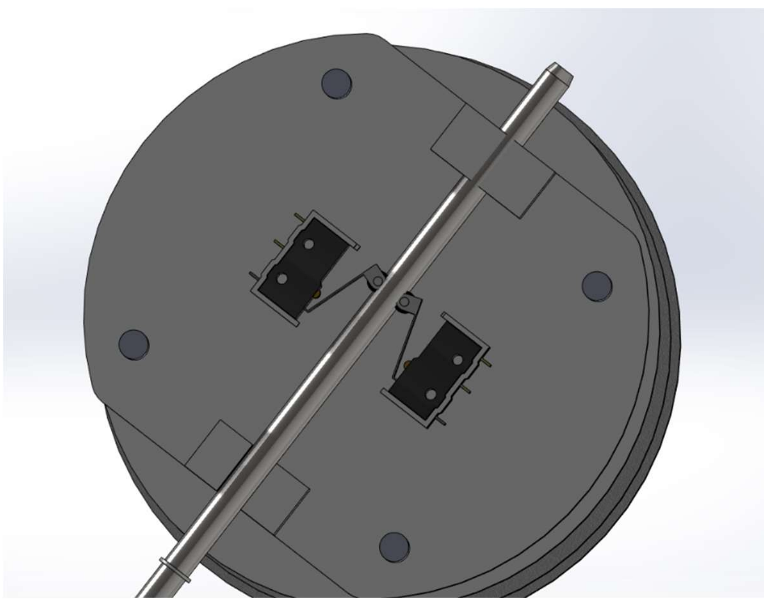
3.4.9.2: Batteries

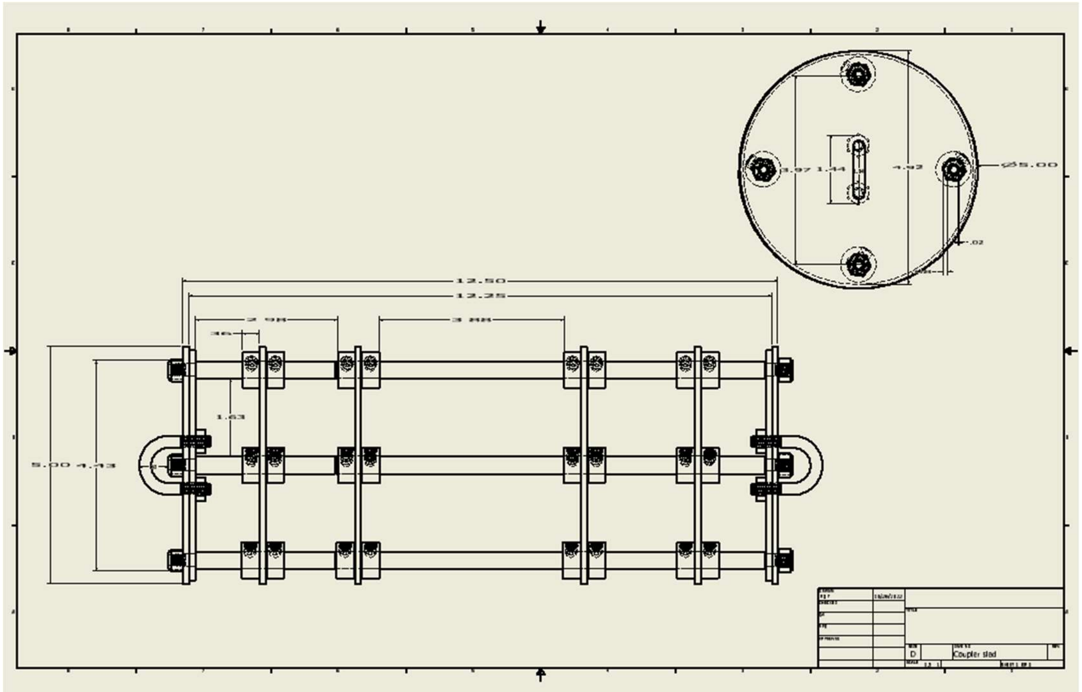
For the batteries supplying the altimeters, the two choices were one Duracell 9V battery for each altimeter or one Rhino 300mAh LiPo battery for each altimeter. With Duracell 9V batteries, the team has experience with these batteries making the manufacturing process simple. The main reason not to use the 9V batteries is to make sure the altimeters are still working while waiting on the launch pad for a maximum of 2 hours. On the other hand, the Rhino 300mAh LiPo batteries are rated to last longer than the 2 hours listed. With this, the team also has experience dealing with LiPo batteries which in turn makes manufacturing straight forward as well. Hence, why we chose to go with the two Rhino 200mAh LiPo batteries.

3.4.9.3: Electronics Bay Design

For the design of the electronics bay, there will be six centering rings for which two will serve the purpose of acting as the pin module. This design involves placing the electronics directly on the plate, therefore, there will be no need for the sled. In the middle, there will be two centering rings that will be placed close together. These two centering rings will have a 0.25-inch gap, where all the electronics will be contained. Overall, this means that the electronics bay will be easy to construct. In addition, this design means that there will be less materials needed as there is no need for the sled. This also means that there will be a weight reduction while having plenty of space to work with even without the sled. Furthermore, the plates will be utilized to hold the limit switches in place for the recovery pin to the arm. This allows us to remove the risk of human error that comes from drilling holes for the screws as the plates will be 3D-printed. Not having a sled is just as efficient when it comes to space needed for the electronics, and it is easier to build and just as easy to manage the electronics and their wiring. Because of this reasoning we have elected to use the model without a sled for the electronics bay.







3.4.9.4. Material for Electronics Bay

When considering the material for the electronics bay, we were between using plywood along with a 3D-printed holder for the electronics and battery or using a 3D-printed bay to hold the electronics. Our final decision was to 3D print the bay as we were eliminating the extra step in manufacturing which was to screw the electronics bay into the plywood. By having the electronics bay 3d printed with the plates in recovery, we can also ensure that human error is removed with the placement of electronics.

With having the plate 3D-printed with a guideline for electronics, the 3D printer material was between using PLA or PETG. We had decided to go with PETG as PETG is heat resistant. This is important since the inside of the rocket may reach hot temperatures.

3.4.10. Drogue Parachute

An alternative option for the drogue parachute selected for the Asclepius rocket is the 18" elliptical parachute, via Fruity Chutes Inc. The main parachute option that we chose is the Rocketman Parachute. The reason we chose the Rocketman parachute instead of the 18" Fruity Chute is because of the limited amount of space. The Rocketman parachute was designed by the manufacturer to be folded into compact spaces and be deployed efficiently. The Rocketman also weighs far less than the 18" Fruity Chute: Rocketman being .32oz and 18" Fruity Chute being 1.7oz. Lastly, the drag coefficient for the Rocketman is less than the 18" Fruity Chute: .97 to a 1.5 to 1.6 drag coefficient. With these conditions in mind, the Rocketman fits the needs of our rocket.

3.4.11. Main Parachute

A comparison was made between Rocketman's 96in standard parachute, the Iris Ultra 84in standard parachute, and Rocketman's High Performance 84in CD 2.2 Parachute. We decided to go with Rocketman's 96in standard parachute as compared to the other two parachutes, as the parachute is bigger. The 96in parachute is also less expensive than the other two which will give more budget to vital parts of the project. Certain experienced members of the team have experience with this parachute as well, which will give us more knowledge on the strengths and weaknesses of the parachute as a team.

3.4.12. Shock Chord

The finalized material that will be used for the shock cords is tubular Kevlar. Therefore, the shock cord in the upper tube will be 300 inches of tubular Kevlar and be attached to the main parachute via quick links. Meanwhile, the lower tube's shock cord will be 360 inches of tubular Kevlar and will be attached to the drogue parachute via quick links. The reason for utilizing tubular Kevlar is due to its resistance to heat, which will be produced by the denotation of black powder charges. Furthermore, tubular Kevlar has a strong tensile strength and will have a higher success rate with not snapping when compared with tubular nylon. The lack of elasticity that tubular Kevlar has is a concern, however, it is believed that the Kevlar's strong tensile strength will be more beneficial than the low tensile strength of the tubular nylon despite its elasticity. Thus, when the drogue parachute and the main parachute are deployed the tubular Kevlar will be more successful than the tubular nylon. In addition, working with Kevlar can be demanding to work with because Kevlar cannot hold knots, however, this issue can be solved by utilizing glue. In conclusion, when comparing Kevlar to nylon the benefits outweigh the disadvantages.

3.4.13. Shear Pins

A set of Nylon 4-40 shear pins will be used to attach the coupler and body tube, chosen due to being standard within the industry and thus are both easily obtainable and inexpensive. The primary force that will be acting to separate the body tube pre-separation will be atmospheric pressure differential, which was calculated to be approximately 72 pounds of force based off launch altitude, target apogee, launch site climate, and temperature-altitude gradients. Each shear pin will withstand 50 lbf, so to maintain a safety factor of approximately 3 as well as to ensure necessary black powder charges will not produce excessive pressure, a set of 4 shear pins will be on the forward section of the coupler and 3 on the aft.

3.4.14. Ejection Charges

In the avionics bay, FFFFg black powder canisters will be on coupler bulkheads between two body tube sections. Each parachute will have both a primary and backup charge, with the backup charge being redundant if the primary charge is insufficient for proper ejection. Forward charges on the coupler will be for the primary parachute and aft charges are for the drogue chute respectively, sized based off the interior volume of the rocket body. Ideal primary charges for the main chute and drogue chute have been calculated to be 3.9 grams and 1.5 grams respectively, with redundant charges being 5.1 grams and 2.1 grams, respectively. These primary charges were chosen to produce 50% of the rated force of the shear pins to ensure reliable shearing, with backup charges producing an extra 5 psi of pressure should the primary charges fail to produce proper separation. Black powder is used due to its light weight, relative ease of use, reliability, inexpensiveness, and ease of obtainment compared to other explosives or high-pressured gas systems. FFFFg powder specifically is being used due to a faster burn rate, and thus higher pressures, than coarser grains. The charges will be attached to a coupler such that detonation will result in the parachute being forced into the airframe, shearing the pins and releasing the parachute.

3.4.15. Packing Method

We will be using the z-fold method because z-fold you are able to get a controlled deployment. By neatly z-folding the parachute you are able to get a more repeatable result compared to when rolling the parachute up like a burrito. To integrate the parachute with the Nomex fire blanket protector we will be using a burrito type method in such that the z-folded parachute sits within the blanket and you fold the blanket over the parachute like you would with a burrito.

3.5 Mission Performance Predications

3.5.1 Kinetic Energy

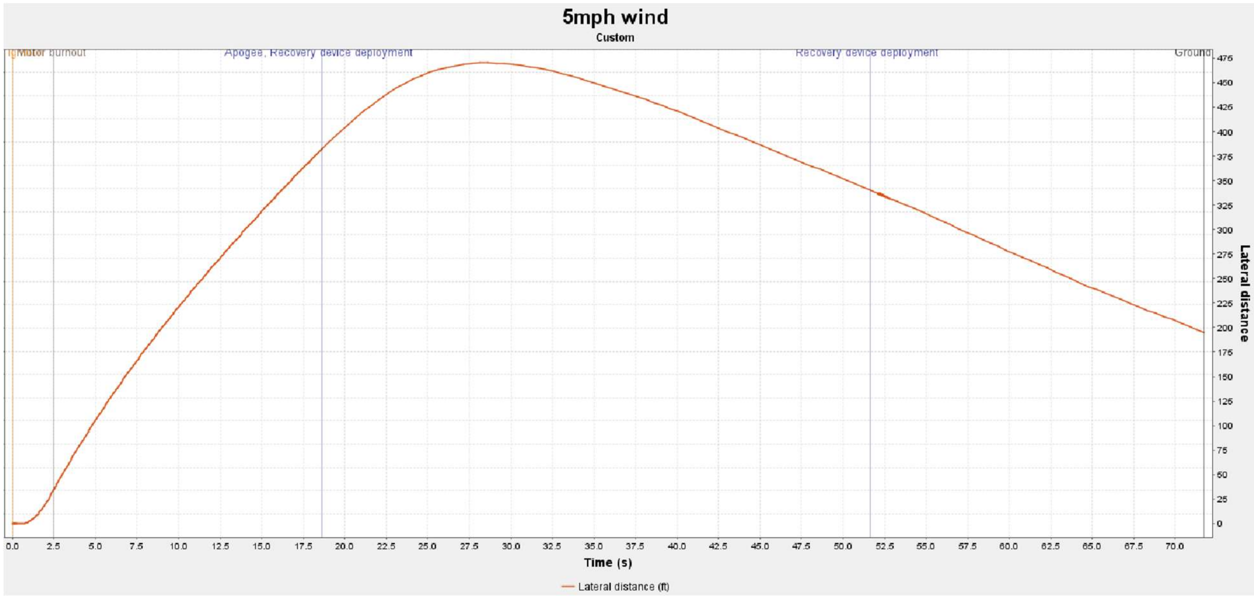
Kinetic Energy Upon Landing			
Section 1: 26.85 ft-lbs	Section 2: 36.59 ft-lbs	Section 3: 31.74 ft-lbs	Section 4: 21.32 ft-lbs
Kinetic Energy Under Drogue			
Section 1: 1721.19 ft-lbs	Section 2: 2345.48 ft-lbs	Section 3: 2098.79 ft-lbs	Section 4: 1366.54 ft-lbs

3.5.2 Descent Time

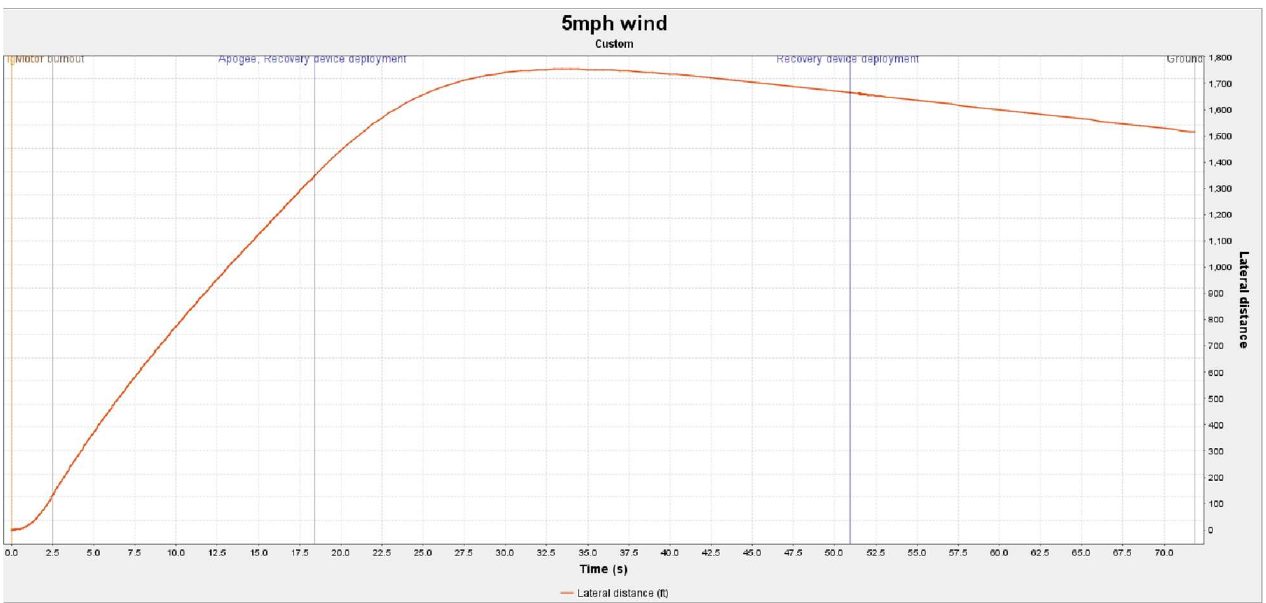
Descent Time

PDR Finalized Design			Simulation Results		
Test	Launch Angle (deg)	Wind Speed (mph)	Time Under Drogue (s)	Time Under Main (s)	Total Time (s)
1	0	0	33	20.32	53.32
2	0	5	32.99	20	52.99
3	0	10	32.51	23.14	55.65
4	0	15	32.5	21.13	53.63
5	0	20	32	21.84	53.85
6	5	0	32.5	22.84	55.34
7	5	5	32.5	20.95	53.45
8	5	10	32	22.16	54.16
9	5	15	31.5	23.41	54.91
10	5	20	31.38	20.36	51.74
11	10	0	32	21.35	53.35
12	10	5	31.5	21.13	52.64
13	10	10	31	21,64	52.65
14	10	15	30.33	20.26	50.59
15	10	20	29.68	21.79	51.47
16	15	0	30.99	19.67	50.67
17	15	5	30.22	19.89	50.12
18	15	10	29.59	20.18	49.78
19	15	15	28.64	22.49	51.14
20	15	20	27.76	21.6	49.36

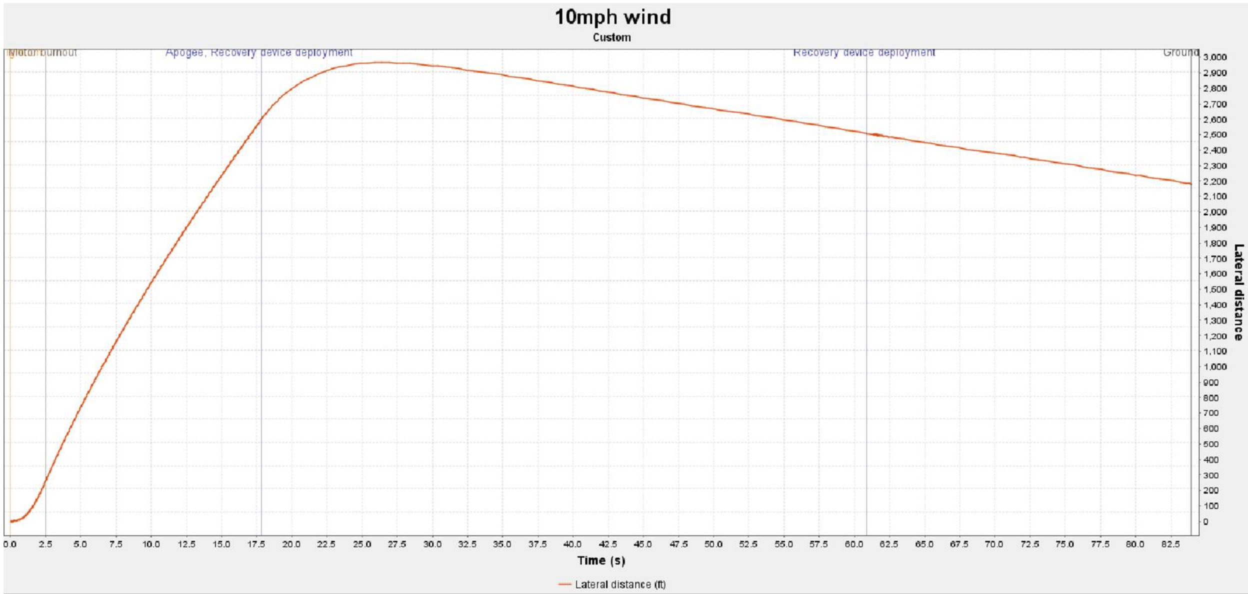
3.5.3 Drift Calculations



5mph with no launch angle



5mph with 5 degree launch angle



10 mph with 10 degree launch angle

For all test of drift we have done we have gotten below 2500’ every time. The shortest we got was 200’ while the longest drift we have gotten was 2200’. One way to decrease the drift would be to not to be angle the rod more than five degrees or use a bigger drogue parachute.

3.5.4. Launch Day Target Altitude

Our official altitude is 5507 feet that we will be launching to on launch day.

3.5.5 Flight Simulation

Apogee Simulations

PDR Finalized Design			Simulation Results	
Test	Launch Angle (deg)	Wind Speed (mph)	Apogee (ft)	Max Velocity (ft/s)
1	0	0	5701	691
2	0	5	5688	691
3	0	10	5650	690
4	0	15	5600	690
5	0	20	5508	687
6	5	0	5650	692
7	5	5	5586	692
8	5	10	5503	691
9	5	15	5440	690
10	5	20	5342	689
11	10	0	5492	693
12	10	5	5401	693
13	10	10	5242	692
14	10	15	5138	691
15	10	20	5012	690
16	15	0	5239	694
17	15	5	5099	694
18	15	10	4943	694
19	15	15	4821	693

20	15	20	4642	692

Insert graph from OpenRocket

4. Payload

4.1. Selection, Design, and Verification

4.1.1. System Overview

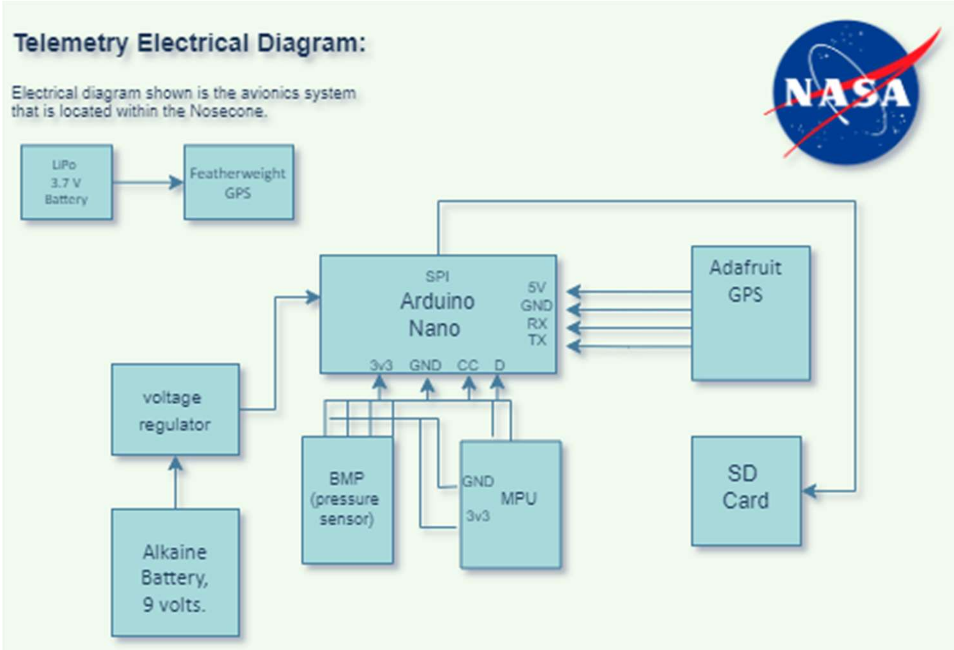
Our Payload System has been designed in such a way that the Experiments sub-system and Telemetry sub-system of the team could function fully independent of each other. All our Telemetry and Avionics will be in the nose cone – telemetry will also be handling the secondary camera. At the tip of the nose cone is the GPS, at the base is a custom flight computer, and in the shoulder would be the secondary camera; telemetry will also be arming commercial altimeters for the recovery sub-system. On the other hand, Experiments is largely located in the upper tube. The Payload Integrated Launch Log (PILL), a polycarbonate rolling cage, will be hoisted by a shock absorption mechanism with wings doubling as a centering ring. Inside the PILL will be a PETG filament casing housing the Experiments camera, microcontroller, and rotation mechanism. Telemetry will be aiding in the Radio Module integration for the Experiments sub-system; other than this, both sections remain capable of operating autonomously under this design.

4.1.2. Subsystem Overview

4.1.2.1. Telemetry Overview

The telemetry team is focused on the internal avionics system of the rocket. For our design, we have researched the various components necessary to a functioning flight computer, along with several sensors to collect and transmit data during the rocket's flight. As it stands, our flight computer will be housed in the nosecone, sitting above our drogue parachute and experiment capsule.

4.1.2.1. Telemetry Electrical Diagram



4.1.2.2. Experiments Overview

The experiments team has developed a compact self-contained camera system, dubbed the P.I.L.L. (Payload. Integrated. Launch. Log.). This system will fulfil the team's science goals of capturing a panoramic view of the landing site with various filters. The PILL contains a camera capable of rotating 360 degrees, a Raspberry Pi for image processing, a radio system to receive RF commands from NASA, and several additional key components. With the use of ball bearings and gravity balancing, the PILL will aways orient the camera parallel to the horizon independent of the exterior housing.

4.1.3. Manufacturing Plan

4.1.3.1. Telemetry Manufacturing Plan

The first step in our manufacturing plan was to enter a preliminary design phase. During this time, we researched different Commercial Off-The-Shelf instrumentation through the lens of practicality and cost and began to cement what our avionic system would look like. After extended consideration, we decided on using the Featherweight GPS tracker, Arduino Nano, MPU 6050, BMP 280, and an SD card reader. Though we also decided on using a custom PCB board, which would be modeled in the Eagle software. Within this timespan, we also began to draw up basic wiring designs and potential pin layouts for our Arduino Nano. We also began preliminary cad work, which included adding models of the previous components we selected for weight and designing a metal rod that attached itself from the metal nose cone tip to the base of the nose cone. The purpose of this rod being to stand as a foundation to which we could attach a sled where the GPS would be up top, and the flight computer would be at the base. With this preliminary design phase done, we are preparing to order our components and enter a testing phase by mid-November. Within this phase, we will be using Breadboards to wire up our components and test potential wire and component layouts. Once we have gotten a good visual representation of what our wiring will look like, tested our preliminary code and different libraries which will be from the Arduino IDE system, and made sure none of our components are faulty we will start the actual manufacturing process and order our custom PCB board. For this phase which is expected to begin in the early weeks of December, we'll be switching to the custom PCB board, uploading our finalized and revised code to the Arduino Nano by USB, and running a few final tests to make sure all our components are still working.

4.1.3.2 Experiments Manufacturing Plan

The experimental payload consists of an outer casing, electronics sled, and electronic components. The outer casing will consist of a 4-inch diameter ¼-inch thick polycarbonate cylinder (sourced from McMaster-Carr) and two 4-inch diameter polycarbonate domes (sourced from Amazon). The polycarbonate cylinder will be cut from its stock length of 1-ft to form a 6-inch-long part. The cylinder and two domes will be threaded on a lathe, allowing the parts to be screwed together for easy maintenance. The required machining for the outer casing will be performed by the UCF machine shop. The electronics sled will be manufactured on a fused filament fabrication (FFF) 3D printer using PETG filament. 3D printers will be provided by the UCF Innovation Lab. The electronics sled will feature mounting holes for all electrical components, which will be secured with machine screws and rubber standoffs to reduce vibrations. All electronic components will be Commercial Off-The-Shelf (COTS) products, including a Raspberry Pi, a Pi camera and lens, a servo motor, a real-time clock module, a battery hat, a radio dongle, and an antenna. Code for the electronic components will be written entirely in Python due to its syntax and ease of use. OpenCV (Open Computer Vision) will be utilized for vision processing. An initial functional prototype of the experimental payload is planned to be completed by mid-November. This prototype will be subjected to various testing, including drop tests, longevity tests, and functionality tests.

4.1.4. Verification and Validation Plan

The experimental payload (PILL) will undergo extensive testing to validate its functionality, ensure all parts can withstand expected forces, and identify any failure points. Once the system is fully constructed, each camera function will be tested and repeated. Images taken with the camera will be evaluated to ensure they meet all requirements. Once each individual component is verified, the code will be tested and run through all cases to catch any bugs. Next, the PILL will be left powered on and operational for multiple hours to simulate sitting at the launch pad. Finally, the PILL will undergo drop testing, starting from a few feet high and building up to a multi-story drop with a parachute. This will simulate the actual landing conditions of the experimental payload, ensuring all parts function as expected and do not break.

4.1.5. FMEA and Risk Mitigation

Severity Index

The severity index ranges from a scale of 1-10, the higher the score, the more severe the effect, of the potential failure mode.

Probability Index

The probability index ranges from a scale of 1-10, the higher the score, the higher the probability the potential failure will occur.

Detection Index

The detection index ranges from a scale of 1-10, the higher the score, the less likely our current design control is capable of detecting said point of failure were it to happen.

ID	Potential Failure Mode	Severity	Probability	Detection
A1	Parachute covers PILL	10	5	4
A2	PILL Casing breaks on impact	7	2	3
A3	Rotation Servo failure	10	1	3
A4	Radio Receiver failure	10	4	1
A5	Camera Failure	10	4	1
A6	Microprocessor Failure	10	4	2
A7	PILL fails to roll	5	7	3
A8	Ball bearings pop out of socket	5	6	10
A9	PILL is severed from shock cord	10	2	10
B1	Disconnected/Broken Wires	9	2	9
B2	Program Bugs/Errors	7	9	1
B3	Accelerometer failure	4	6	7
B4	Gyroscope failure	4	6	7
B5	Barometer Failure	4	6	7
B6	SD Card Reader Failure	7	6	7
B7	Feather Weight GPS fails	6	2	8
B8	Redundant Adafruit GPS fails	4	6	2
B9	Shock Absorption mechanism catches on case	3	9	2
C1	Optical distortion from Pill casing	4	10	1

Risk Priority Number (RPN) Calculation

RPN = Frequency x Severity x Detection

The Risk Priority Number index ranges from 1-1000, the higher the total score for a potential failure mode, the higher priority the potential failure mode will be considered.

ID	Severity Score	Probability Score	Detection Score	RPN (1-1000)
A1	10	5	4	200
A2	7	2	3	42
A3	10	1	3	30
A4	10	4	1	40
A5	10	4	1	40
A6	10	4	2	80
A7	5	7	3	105
A8	5	6	10	300

A9	10	2	10	200
B1	9	2	9	162
B2	7	9	1	63
B3	4	6	7	168
B4	4	6	7	168
B5	4	6	7	168
B6	7	6	7	294
B7	6	2	8	96
B8	4	6	2	48
B9	3	9	2	54
C1	4	10	1	40

Order of failure modes to address.

Failure Mode	Risk Priority Number
A8	300
B6	294
A9	200
A1	200
B3	168
B4	168
B5	168
B1	162
A7	105
B7	96
A6	80
B2	63
B9	54
B8	48
A2	42
C1	40
A4	40
A5	40
A3	30

4.1.6. Performance Characteristics

Factors that would affect the launch are extreme temperatures, severe rain, and strong winds. In Huntsville, Alabama, the weather during launch time is typically mild with average highs of 74 and average lows of 54. These temperatures are well within the range of the electronics' optimal performance. Additionally, the chance of rain is only 30%, this means that there is a low chance that rain will affect the launch. Also, the average wind speed is 12.4 mph. This is a light breeze equivalent to wind that would rustle leaves. The payload systems would not be affected by any of these factors because they are so minor.

4.2. Science Value

4.2.1. Science Payload Objective

The Payload system has three objectives. The main objective is to fulfill the mission requirements described by the NASA Student Launch handbook: land a camera capable of receiving RF commands and taking imagery across the z-axis, parallel to the horizon. Secondary objectives include data collection and tracking. A custom flight computer consisting of an accelerometer, gyroscope, and barometer will record and store flight data; similarly, a commercial GPS would be used to locate the rocket after flight. Lastly, the Payload system is also in charge of recovery of the rocket. A dual-deployment system would serve to deploy a drogue parachute, deploy the main parachute, and help the PILL escape the upper tube.

A second camera is being considered as a secondary experiment. The proposed camera – a Run Cam Split Zero – would reside next to avionic equipment in the nose cone and record video out of an acrylic window or a drilled hole in the nose cone. The second camera would serve as promotional material for the team; although this would not be largely important to the team's social media presence, it felt a natural progression to allow all those invested in following the project the opportunity to see flight videos.

4.2.2. Payload Success Criteria

In order to consider our Payload successful, we must meet the requirements outlined in the NASA Student Launch Handbook. Particularly, our payload must be able to safely land and self-orient itself to the horizon; promptly, the camera must be able to rotate about the z-axis. Our Payload system will achieve this using a poly carbonate rolling cage with an electronics sled hoisted on two ball bearings. The camera will spin using a 1:3 geared Servo system. Certain specifics regarding hardware must be met: FOV, accepting RAFCO, etc. Additional requirements must also be met to be considered successful. Notably, the PILL must be capable of being reused whilst not compromising the rockets' ability to relaunch; however, more importantly, our custom flight computer must also take accurate flight data in order to make graphs alongside our commercial altimeters.

Sub-System	Requirement ID	Success Criteria	Status
Experiments	4.2.11.	Camera capable of rotating about the z-axis	Incomplete
Experiments	4.2.1.2.	Camera has a FOV within 100 to 180 degrees	Incomplete
Experiments	4.2.1.3.	All images taken shall have visible time stamps	Incomplete
Telemetry	4.2.1.4.	Camera must execute commands with a maximum of 30 seconds between commands	Incomplete
Telemetry	4.2.2.	Potential commands are able to be conducted in any and all orders	Incomplete
Telemetry	4.2.3.3.	Payload system shall not initiate RAFCO commands before launch	Incomplete
Experiments	4.2.4.	Payload is not jettisoned	Incomplete
Telemetry	4.2.5.	Sequence of time-stamped photos is presented in correct order Post-Launch Assessment	Incomplete
All	4.3.2.	All FAR and NAA rules and regulations are followed	Incomplete

4.2.3. Experimental Logic, Approach, and Method of Investigation

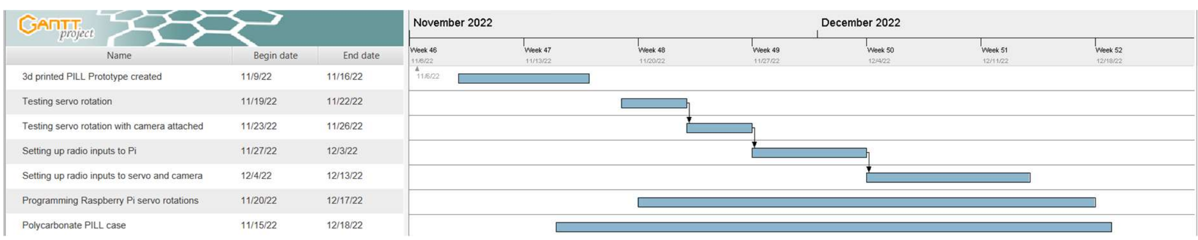
Our scientific payload will acquire the science deliverables by design in such a way that allows for accurate data point collection and transmission in real time. This means that our system will have data collection, storage, and transmission capabilities. Our sensors will be the means to collect the data and shall be attached to a microcontroller which will funnel the collected data into the SD card reader for storage and physical retrieval.

4.2.3.1 Telemetry Deliverables

Our telemetry system is focused on collecting the technical data of the flight; height, velocity, acceleration, angular momentum, distance over time, and outside air pressure. Of the components necessary to collect such information, we are going to have the BMP-280 barometer – for pressure data, an MPU-6050 for its velocity, acceleration, and angle measurement reading capabilities, and two GPS systems, the Featherweight and Adafruit Ultimate to determine where our rocket goes and to map its launch. It is important for our avionics computer to function properly so that we can accurately determine specific data points during the rocket's flight path to compare to our simulated predictions.

4.2.3.2 Experiments Deliverables

Our Experiments system is focused on capturing a panoramic image of the landing site and being able to apply filters to it based off radio signals. To achieve this, we built our casing, the P.I.L.L., to be self-orienting. Inside of the pill we will have our radio antenna that will send radio signals to our Raspberry Pi 4b. From there, based off those signals, the Pi will rotate the servo and tell the camera when to capture images. After that, the camera will send the images back to the Pi and the Pi will be able to apply filters to it.



4.2.4. Testing and Calibration Measurements

In order to prove our instruments are in working order, we have opted to purchase a breadboard to test each component before soldering them onto a custom PCB board. The breadboard allows us to connect each module to a power supply and microcontroller just to prove that the two are compatible with one another. For the GPS, we will connect it to the ground station and carry it 100ft away, then check if a signal is pointing in the direction of the GPS; if the signal from the ground station is correct, then the GPS works. For the SD card reader, we will purchase an SD card and verify if data can be successfully read. For the RunCam Split, we will attempt to take pictures with it to see if it can take photos, as well as if the photos meet the minimum resolution.

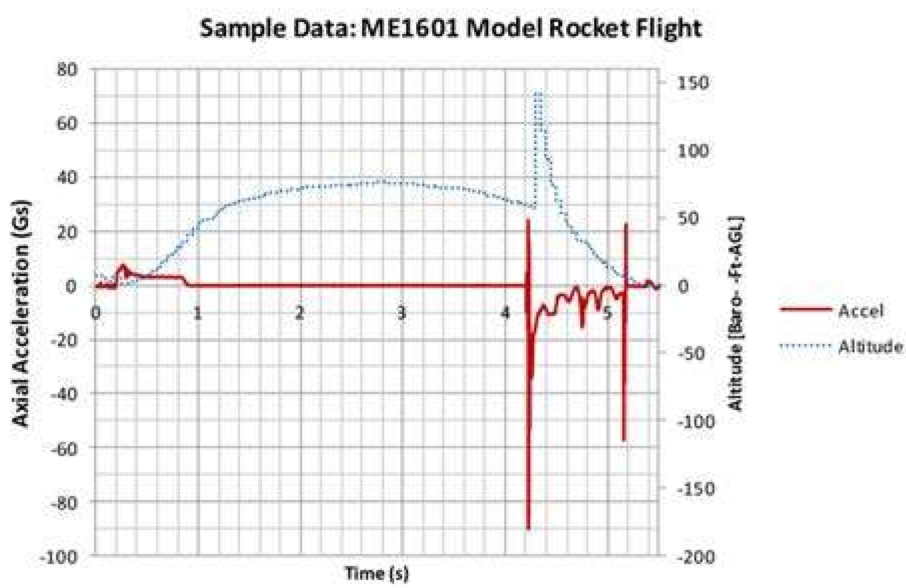
4.2.5. Precision and Accuracy of Instrumentation

Component	What is Being Measured/Purpose	Precision/Accuracy
Arduino Nano	Microcontroller for electronics	N/A
MPU 6050	Gyroscope and Accelerometer	±250, ±500, ±1000, and ±2000 °/sec for gyroscope

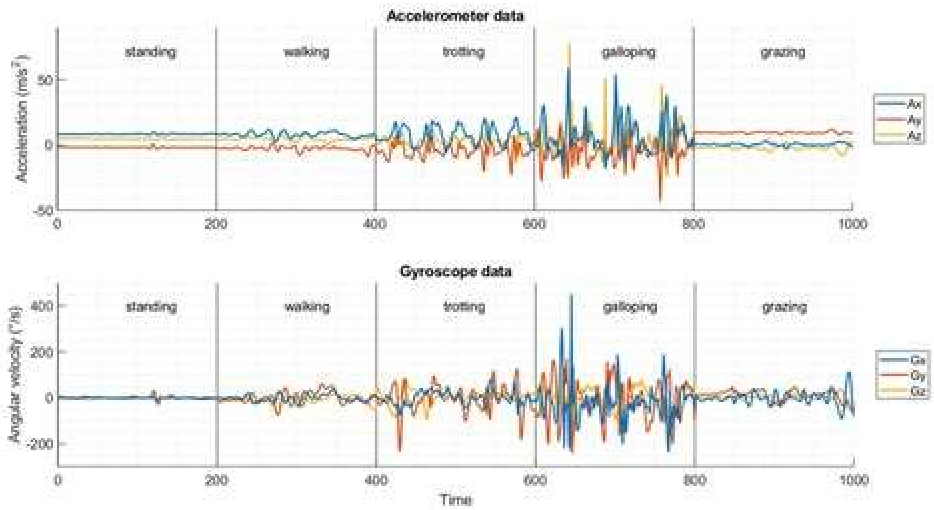
		±2g, ±4g, ±8g, and ±16g for the accelerometer
BMP 280	Barometric Sensor	±1 hPa
SD card reader	Being able to transfer data easily	N/A
Adafruit Ultimate GPS	Position Tracker	**Position Accuracy:** 3.0m **Velocity Accuracy:** 0.1m/s **Timing Accuracy:** ±20ns RMS within 100ms in one pulse
Featherweight GPS	GPS system	
RunCam Split	Capture exterior flight video	1080@60fps/1080@30fps/720@60fps

4.2.6. Expected Data & Analysis

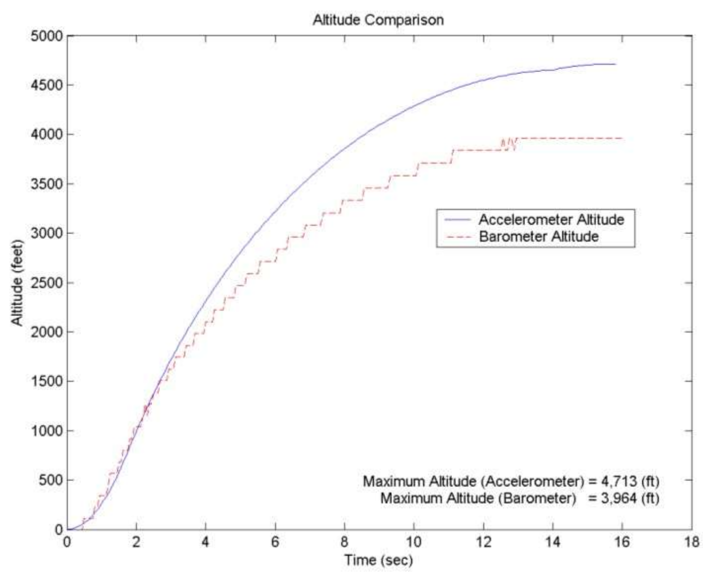
The accelerometer component of the MPU 6050 will be capable of displaying altitude – or time – versus acceleration.



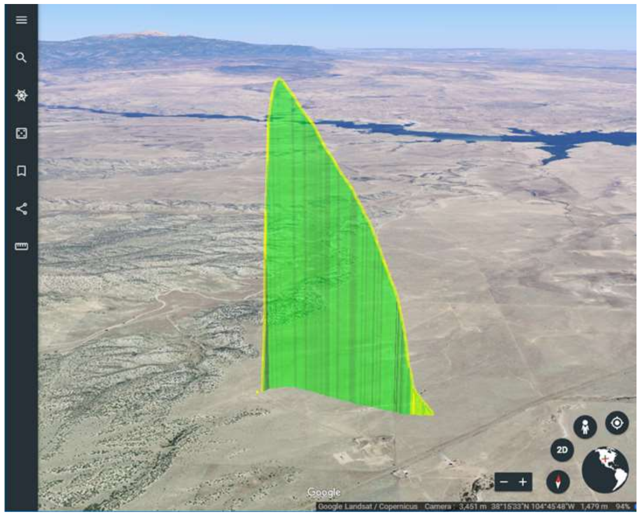
The gyroscope component would similarly plot a y-component (angular velocity) with respect to time.



A barometer would also be used to calculate altitude using atmospheric pressure. Altitude from the accelerometer and barometer would then be compared with altimeter flight data.



The featherweight GPS could also track horizontal and vertical velocity in a 3D graph. Additionally, it can show the path our rocket will take.



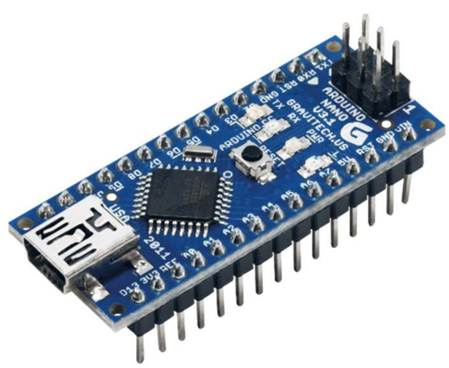
Compiling all the data from our conclusive flight computer would help us to set up a clear indicative path the rocket takes during flight. We would be able to analyze the angle and speeds of the rockets. More importantly, we could use our actual flight data to verify our simulation capabilities in OpenRocket; the hope being that comparing our predictions to the reality of flight could help us be more precise in the following years.

4.3. Telemetry Sub-System

4.3.1. Flight Computer

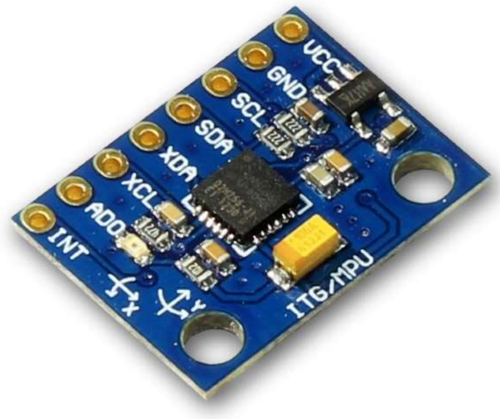
4.3.1.1. Microcontroller

The Arduino Nano comes from the open-source hardware and software company Arduino, which produces original single-board microcontrollers. We chose to use their Nano specifically because it contains the same specs as their Arduino Uno but in a much smaller form. It was designed and released in 2008, which proves its reliability for over 10 years, and instead of having to press a physical reset button before uploading data, the Nano can be reset via software on a connected computer.



4.3.1.2. Gyroscope and Accelerometer

We will be using the MPU 6050 for its ability to measure velocity, orientation, acceleration, and other features that will prove to be useful. It is simultaneously low power, low cost, and high performance with compatible electronics. We will also be able to read data that it collects in real time.

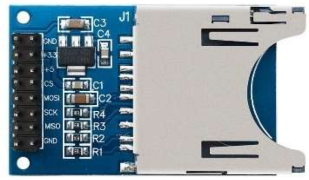


4.3.1.4. Barometer

For sensing air pressure, we will use the BMP 280 because of its small size and low power requirements to function. It is also the smallest of its predecessors as well as exhibiting the highest performance and cheapest as of now.

4.3.1.5. SD Card Reader

The objective of our project will be captured via SD card reader, which reads image data and can transfer this data. It will be inserted in the camera, then when we retrieve the camera after it takes a picture of the horizon, we will remove the SD card and plug it into a computer so we can open the picture.



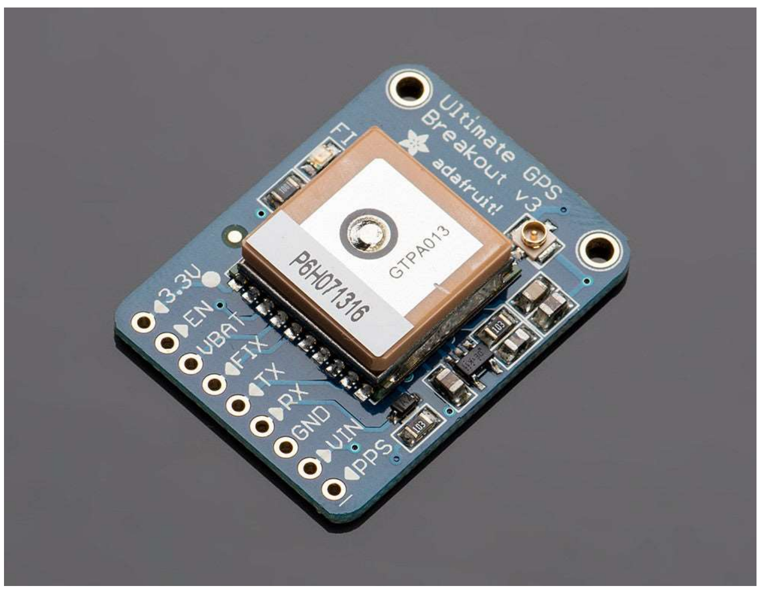
4.3.1.6. Additional Camera

In order to garner future interest in Knight's Experimental Rocketry, the telemetry team has also opted to include an external camera to capture videos and images during the rocket's flight. The camera we have selected to achieve this is the RunCam Split. At only 21.00 grams, the RunCam Split can record at a 1080p/60fps and has modular components, making it easier to replace specific parts instead of the whole module. The media captured by our external camera will be used in promotional social media for KXR and will be used to develop interest for any future engineers who might be influenced to build rockets.

4.3.2. GPS System

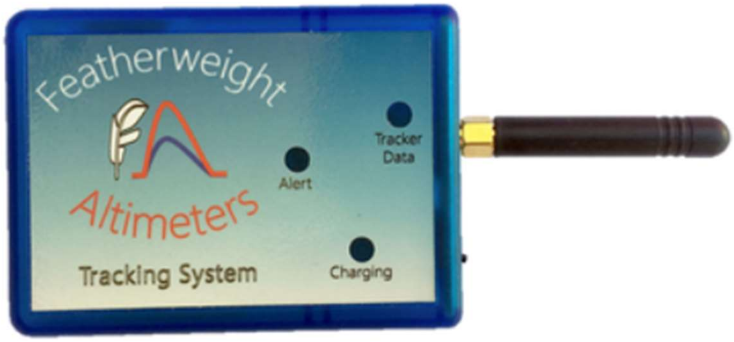
The Featherweight GPS tracker is an advanced GPS tracker that is capable of 10 GPS solutions per second. It also has an extremely long range, being able to communicate to space as well as track GPS data up to 164,042 feet (about 50 km). In addition, you can track the GPS through an iPhone by using the TestFlight app.

The Adafruit Ultimate GPS (using as a backup now) system is a quality GPS tracker that can track up to 22 satellites on 66 channels, has a built-in antenna, and can do up to 10 location updates a second. Its power usage is also incredibly low, only requiring 20 mA (microampere) during navigation.



4.3.3. Ground Station

Although unnecessary, we have opted to use a ground station for the sake of gathering flight data for the PLAR. The Featherweight GPS comes with its own ground station capable of communicating up to 164,042. The ground station can be connected to our phones through an app made by Featherweight.



4.4. Experiments Sub-System

4.4.1. Design Process and Alternatives

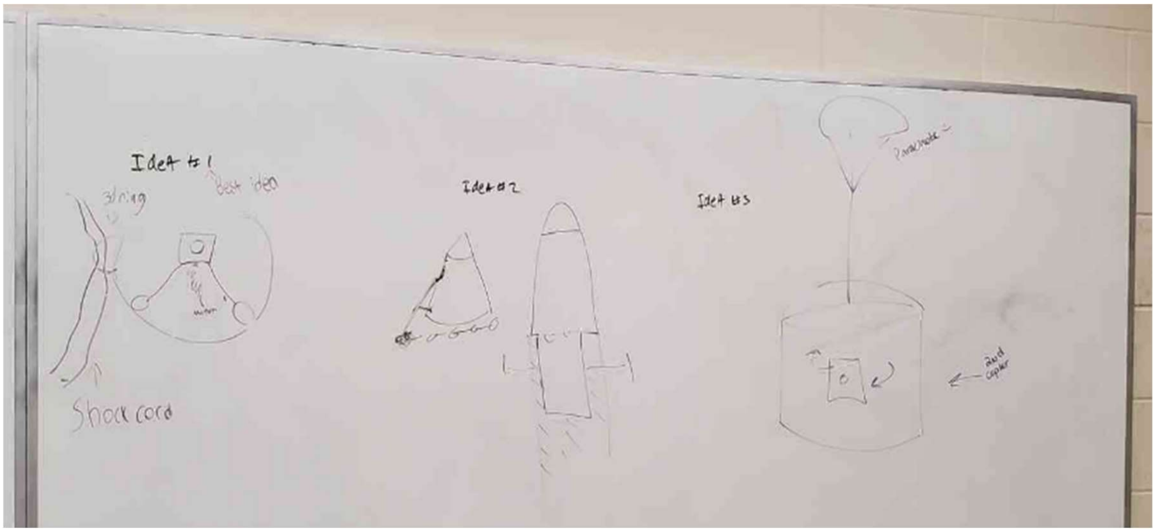
We held multiple brainstorming sessions to generate ideas. This resulted in three core concepts, one of which became our leading design. The other two are listed below.

4.4.1.1. Landing Nosecone

When initially looking at the requirements set by NASA, we thought that a multi-stage deployment strategy was the only way to go shown in figure (a). In the end, our design had about 5 separate events – which broke the NASA regulations of only 4 events allowed. We figured that a dual deployment was necessary in any iteration but opted for a 5th event to separate the nosecone and land it with our 360-degree swivel camera pointing straight up. Due to the advanced complexity of such a design, along with the fact that it violated NASA regulations, we considered different designs.

4.4.1.2. Hamster Ball"., m m

The next design that was taken into consideration was the 'hamster ball' mechanism as our team looked further into the requirements of NASA Student Launch. This mechanism was the first time we had taken into consideration the 'self-orienting mechanism' that would be used in our leading payload mechanism as shown in figure (a). The hamster ball would consist of an electronics sled suspended on the surface of the shell with 4 ball bearings to self-orient the camera parallel to the horizon. The hamster ball mechanism would be attached with an Eye bolt that would be attached to the shock cord. Due to the lack of space for the electronics inside the 4 ½ inch diameter spherical casing, this payload system was deemed undesirable.



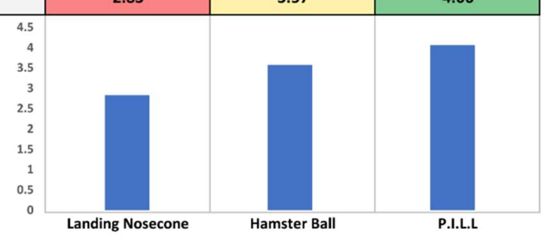
Figure(a)

Idea #1: 'hamster ball' mechanism

Idea #2: 'landing Nosecone' mechanism

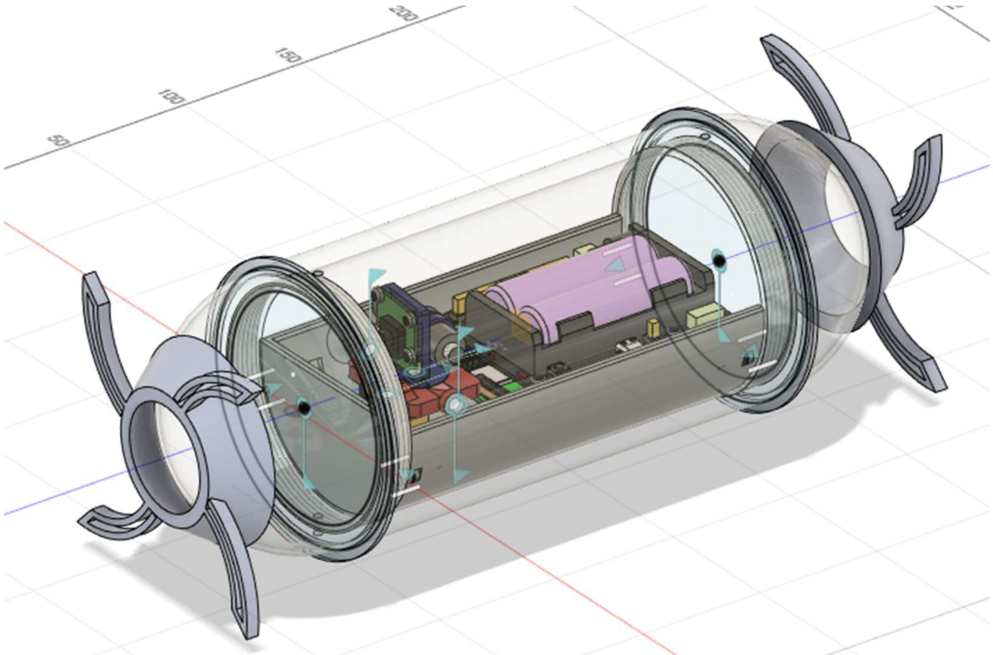
4.4.1.3. Decision Matrix

		RATINGS		
Criterion	**Weight**	**Landing Nosecone**	**Hamster Ball**	**P.I.L.L**
Overall Payload Effectiveness	6	6	5	5
Satisfies NASA Requirements	5	5	5	5
Design Simplicity	5	1	3	5
Manufacturing Simplicity	4	2	4	3
Low Manufacturing Cost	4	2	3	3
Adequate Space Requirements	3	2	1	3
Adequate Weight Requirements	3	2	3	3
Low Failure Potential	5	1	3	4
Total	**35**	**2.83**	**3.57**	**4.06**



4.4.2. Leading Design Summary

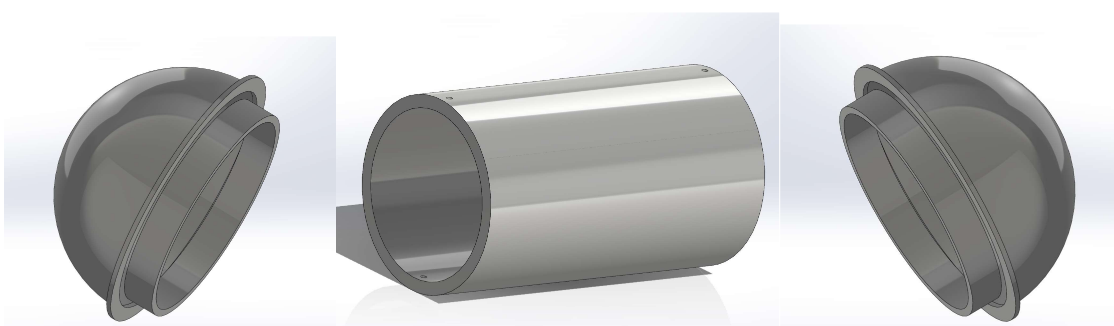
Our current design for our payload system is the P.I.L.L (or the Payload, Intergraded, Launch, Log). This design was made to satisfy our need for a self-orienting mechanism, spacing, and cost. The PILL consists of two main parts, the Outer casing and the electronics sled as shown in figure (a). The Outer Casing of our payload system is a transparent Polycarbonate cylinder that is threaded at each end and has holes to secure the two polycarbonate domes that are attached with grub screws. Each end of the dome has a silicone-based shock absorber with four wings that are used to absorb the shock that the payload will undergo upon impact. The outer casing is used as a rolling cage and aids the 'self-orientation mechanism' of the Electronics sled. The Electronics sled is a PETG filament casing that is housing the electronics used to receive and execute commands with ease. The ‘self-orientation’ mechanism of the electronics sled is composed of the sled along with ball Barings that aid in reducing the friction between the PETG filament against the polycarbonate outer casing. The electronics in cased inside the electronics sled consists of an Arducam, raspberry pi4, SDR, antenna, raspberry pi RTC, and a battery pack. The payload system will be attached to our main parachute by a cut shock cord that is secured to two eyebolts that are attached to the silicone shock absorbers.

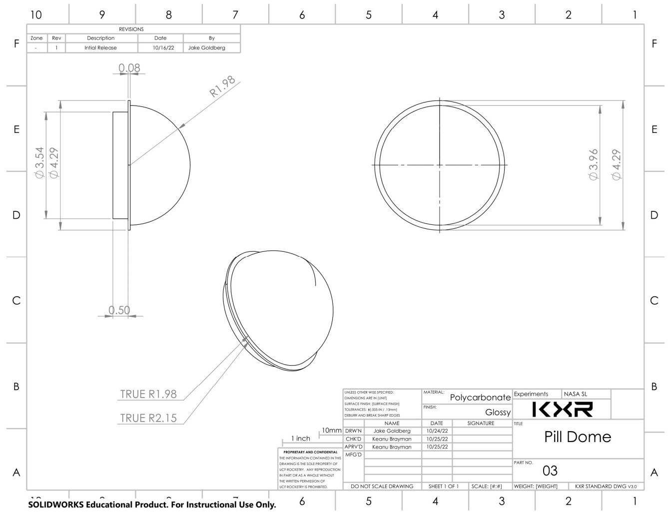


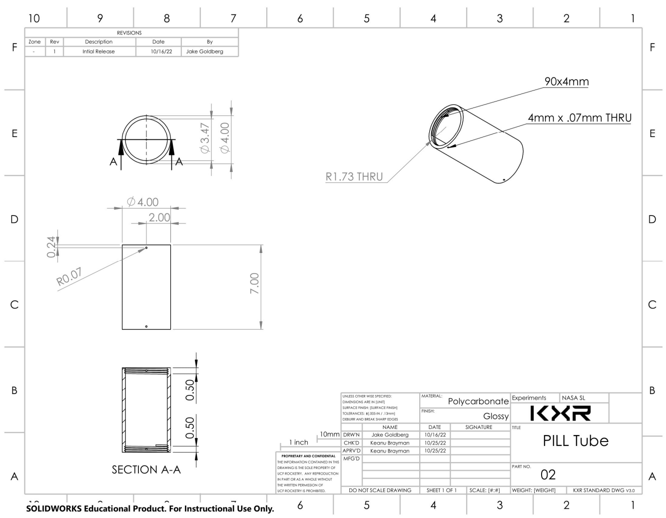
4.4.3. Outer Casing

4.4.3.1. Polycarbonate Shell

The PILL’s casing consists of a polycarbonate cylinder with two hemisphere caps. The cylinder has a length of six inches, a diameter of four inches and a wall thickness of a quarter inch. The hemisphere/ dome-shaped caps both have a radius of 2 inches and matching wall thickness of a quarter inch.







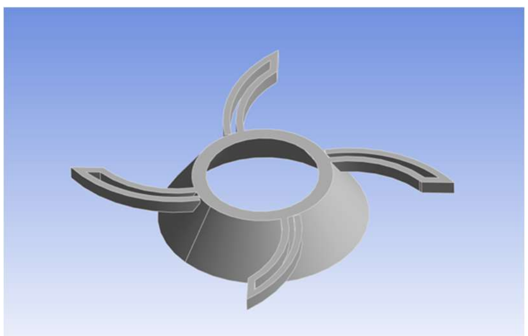
Our team had chosen polycarbonate as our material for the outer casing due to its transparency and durability. Transparency will provide a window for the camera to produce quality images and have the least disturbance possible while protecting the fragile electronics inside the hollow cylinder. For our design, our team decided that the camera needed to be concealed inside the payload to keep it safe and protected from damage while being deployed from the rocket. This was taken into consideration for all preliminary designs and remained consistent through our current design.

Furthermore, polycarbonate is our material of choice because of the material's durability, resistance to extreme temperatures and conditions. Polycarbonate is known to be very durable while also maintaining its transparent properties with a resin coating. This resin coating will reduce damage such as scratches and cracks upon impact to the ground from deploying with the main body parachute and shock chord. Although Fiberglass has transparent properties and is less expensive than Polycarbonate, polycarbonate is a better option for material because of the durability and resistance to harsh conditions. Polycarbonate can maintain its material properties under extreme temperatures ranging from –20C to 140C with the melting point being between 288C to 316C.

4.4.3.2. Shock Absorption Component

The shock absorption component of our payload mechanism went through multiple iterations that were incorporated into a final design. The preliminary designs all kept in mind the harsh conditions that our payload would face while inside the rocket, being deployed from the rocket attached to the shock chord, and landing on the ground after deployment.

In figure(a), this design showcases a shock absorber that composes of 4 ‘wings’ that are used to absorb the shock that our payload will be met with upon impact. The silicone-based wings under 50 newtons of impact force (shown in figure (b)) have been shown to reduce the impact force that the casing and the electronic components of the payload will undergo. The shock absorption components will be added onto each dome that is sealing the pill. However, a problem that had been posed was the protection of the payload system while inside the main body. The current solution to the problem faced was combining silicone shock absorption mechanism along with wrapping a flame-retardant blanket around the payload will aid in the protection of the payload while inside the main body and during deployment of the payload when ejecting out of the rocket while attached to the shock cord.



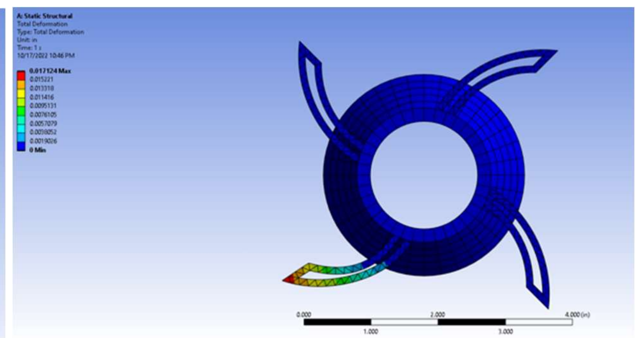


Figure (a)

Figure(b)

4.4.4. Electronics Sled

The electronics sled is the core of the PILL. It houses all electronic components, arranged to maximize space usage, provide protection from external forces, and allow for easy wire-management. The sled has ball bearings in its sides which help to align the camera parallel to the horizon. Figure (a) shows the empty sled while figure (b) shows the sled populated with electronics.

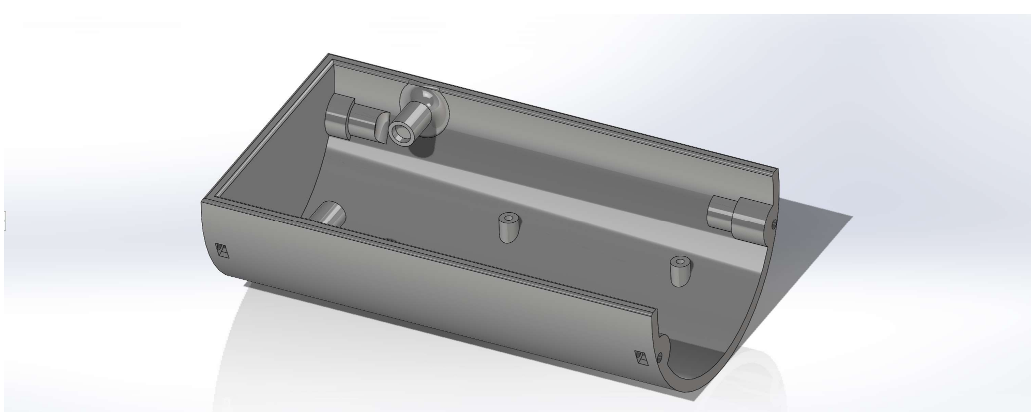


Figure (a)

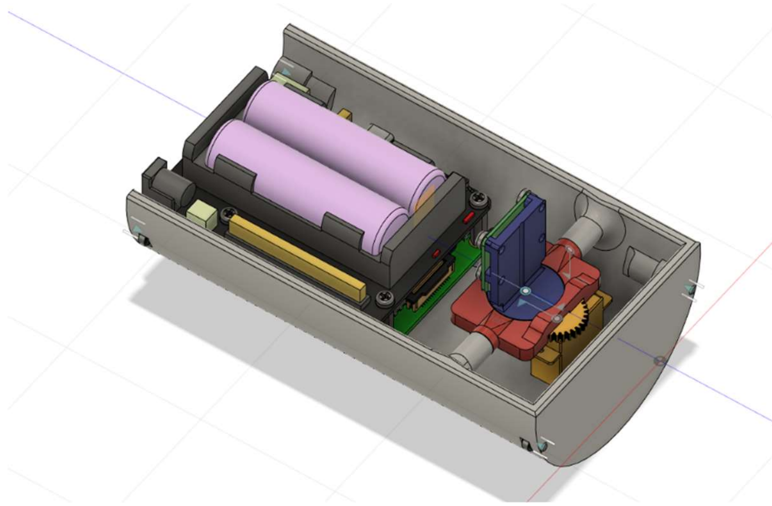
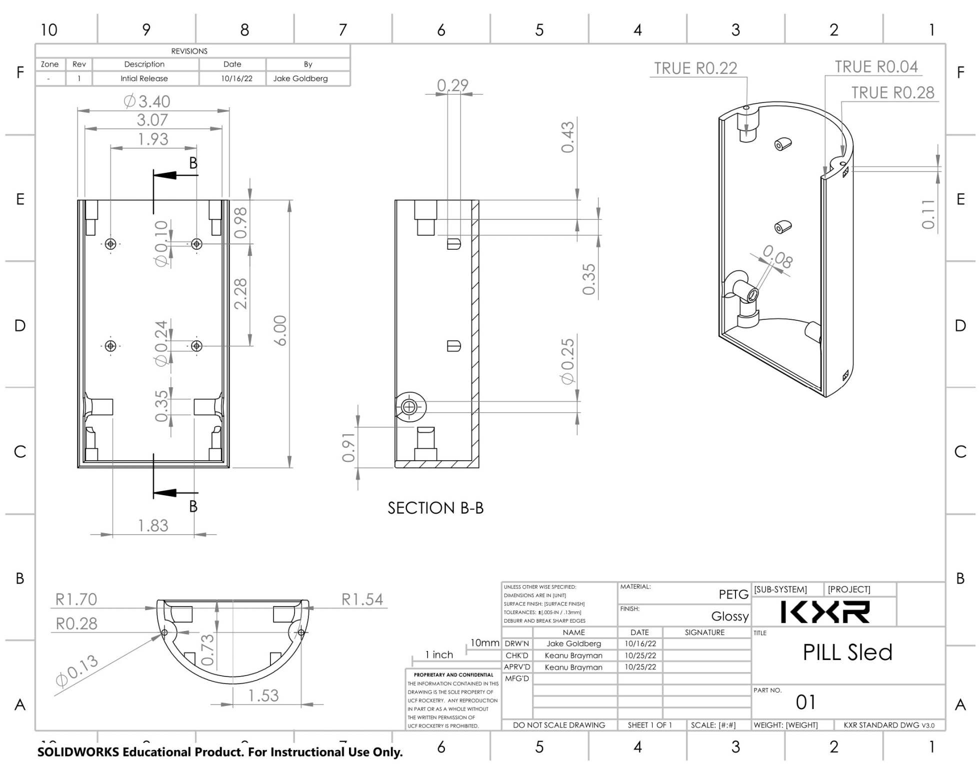
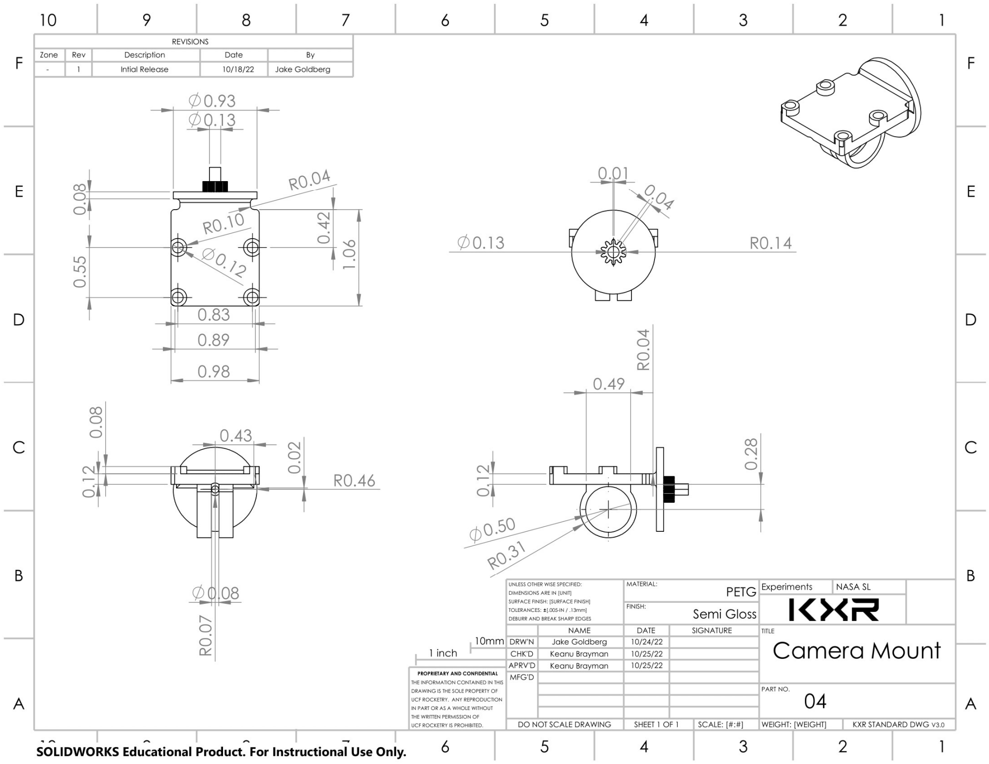
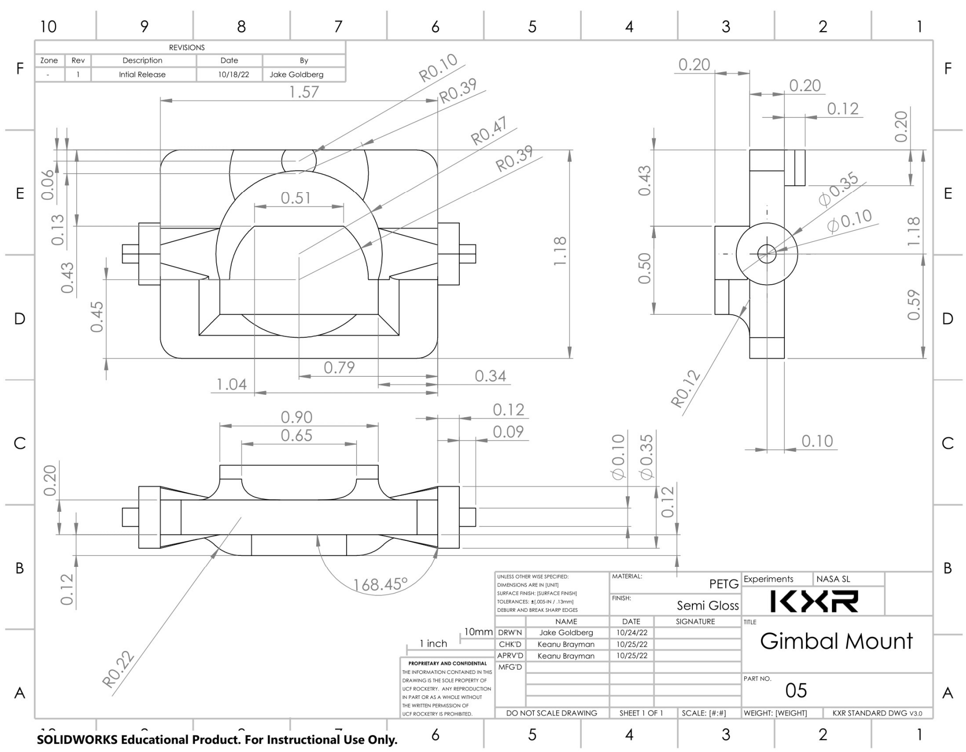


Figure (b)

4.4.4.1. Electronics Sled CAD Drawings







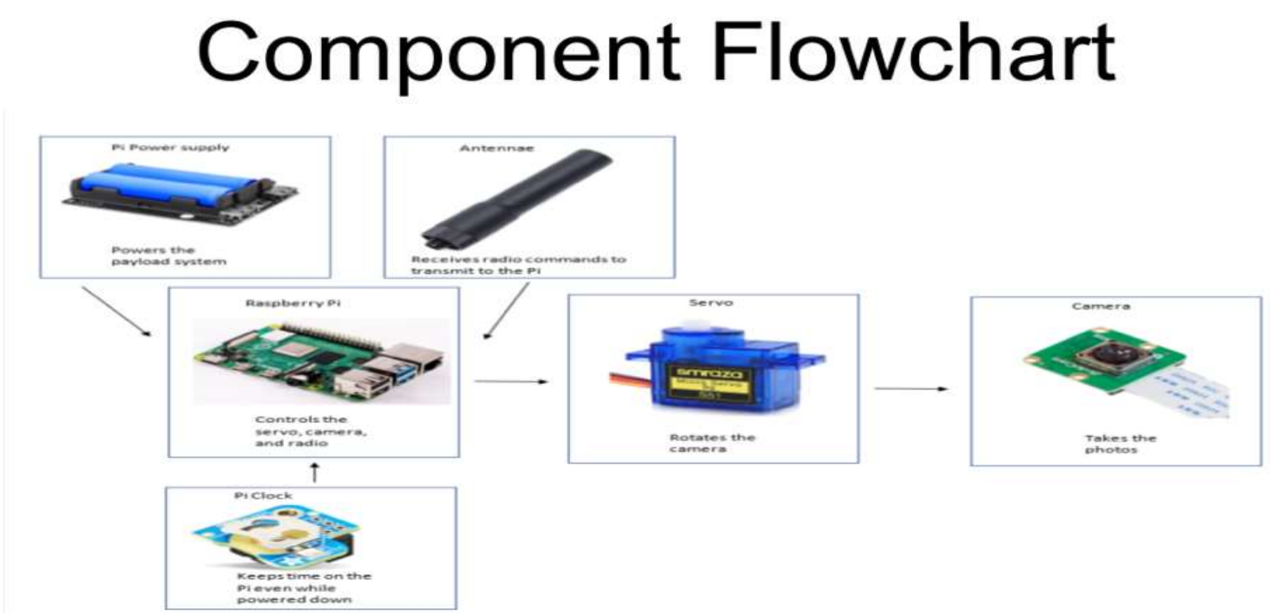
4.4.4.2. PETG Material

PETG was chosen as the material for the electronics sled due to its strength, impact resistance, and ease of manufacturing. By 3D printing the sled, we will ensure optimal placement for each component and be capable of making rapid design changes if needed. We chose the PETG filament over other leading contenders for its reliability in strength, for example, PETG filament's deformation temperature is 73C while still able to maintain a decent durability. This means that the PETG filament can withstand an extreme temperature range without being completely affected by the temperature difference. Another reason for our team to choose the PETG filament is for its efficiency in manufacturing. Our team considered printing the electronics sled out of polycarbonate filament to increase the durability, however the PETG filament was more efficient to print, repair, and highly cost effective for a similar amount of durability compared to the polycarbonate filament.

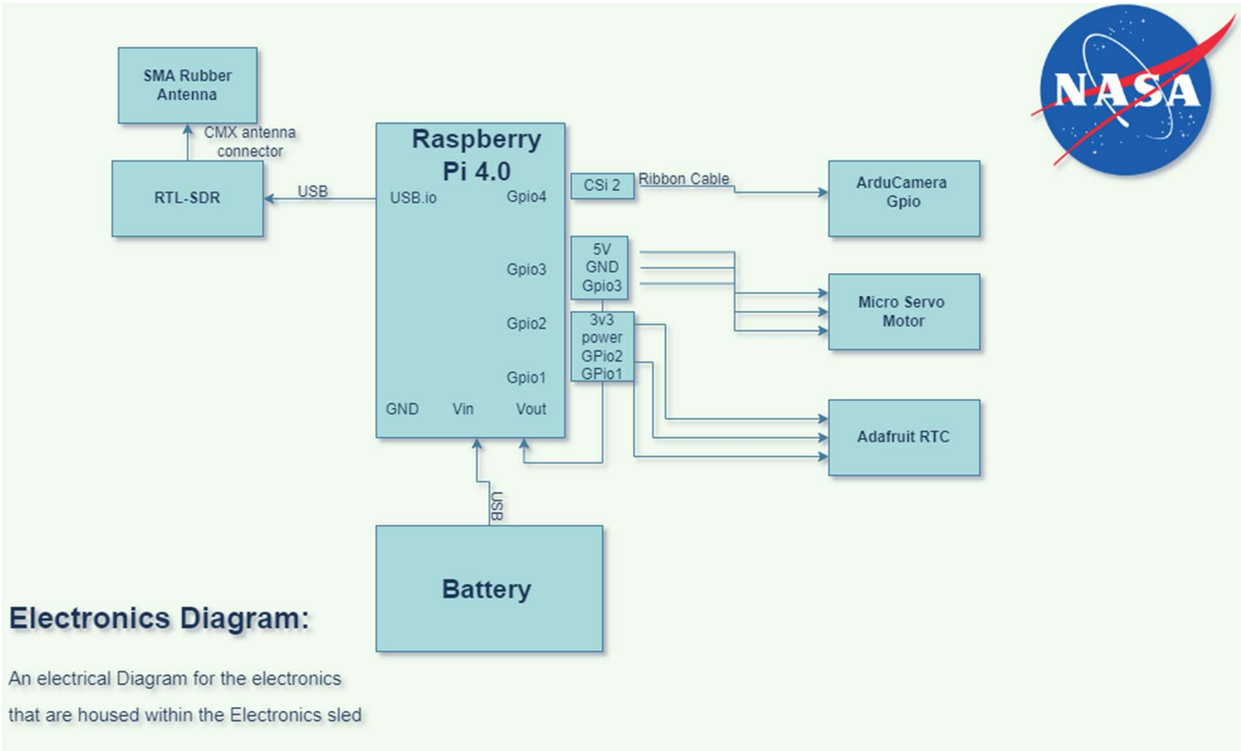
4.4.4.3. Ball Bearings

The electronics sled contains ball bearings which always align the camera to the horizon. Although our team had designed the payload system's outer casing to act similarly to a roll cage, our team had taken into consideration the possibility of high friction between the PETG filament and the Polycarbonate outer casing. With the Ball Bearings embedded into the electronics sled, this will reduce the friction between the two materials so that the 'self-orientation' component is not compromised.

4.4.4.4. Component Flowchart



4.4.4.5. Electronics Diagram



4.4.4.6. Controller

For the microprocessor, we chose the Raspberry Pi 4B, due to it being the most powerful model in the Raspberry Pi lineup, and having 8GB RAM to process the camera photos, add filters, and receive radio signals to translate into servo inputs. We did not select an Arduino for the main processor in the P.I.L.L. due to it not being powerful enough to run the servo, camera, add filters to the camera photos, and receive radio signals all simultaneously.

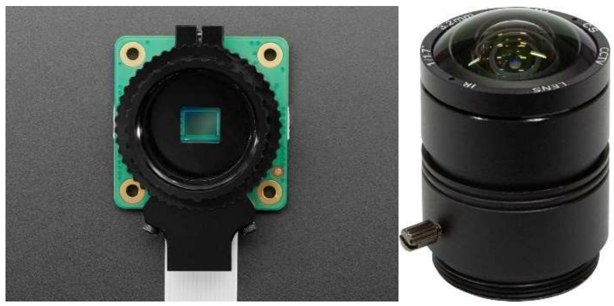
4.4.4.7. Camera

The camera we have chosen is a Raspberry Pi HQ camera coupled with an additional lens modification to achieve NASA's 100-degree FOV requirement. Using a CSi-2 port along with a 2ft ribbon cable extension. The camera is expected to take timestamped photos from commands received from NASA and will save them on an SD card.

Specification	Arducam 64MP
Sensor	IMX477R

Lens	C-mount, CS-mount
Output Format	RAW12/10/8, COMP8
Optical Size	7.9mm Diagonal
Ribbon Cable Length	200mm (We will be using a 2ft ribbon cable extension)
Weight	1.41 ounces

Another option we had was using a USB camera, but we ultimately decided on the RPi HQ camera due to its extensive documentation it has and its compatibility with Raspberry Pi's.



4.4.4.8. Battery

For our battery pack, we chose the MakerHawk Raspberry Pi UPS. We choose this as our solution for our power needs due to its best combination of small size and power output.

4.4.4.9. Rotation Motor

For our rotation motor, we decided to pick the SMRAZA SG90 servo. Compared to other options we found, it had the best average quantity and quality for the 20$ price range and is made of higher quality materials than similarly priced options. The amazon listing for it is also the most detailed, letting us know exactly what we are buying, what the inside looks like, and having high reviews as well. Even though it has a 180-degree rotation angle, we can gear it up to move 360 degrees for our rotation of the camera.

4.4.4.10. Radio

The radio that will be used to receive commands from NASA will be the RTL-SDR Blog Software Defined Radio. The radio can accept up to 1.7 GHz which satisfies NASA's frequency requirement and will be plugged into the Raspberry Pi in order to submit the given commands into the Python code.

Our radio has the following specifications:

Specification	RTL-SDR Blog V3 Radio
Tuner Technology	ADS-B, DAB, Digital
Tuner	R820T2 (500 kHz to 1.7 GHz with up to 3.2 MHz of bandwidth)
Chip	RTL2832 ADS
Oscillator	1PPM TCXO
Connector	SMA F

4.4.4.11. Antenna

The antenna we chose is the mini short walkie talkie antenna. The reason we chose this particular one is because of its frequency as well as it being compatible with our radio.

Specifications	Mini Short Walkie Talkie Antenna
Antenna Type	Radio
Impedance	50 Ohm
Model	ABBREE AR-805S
Connector	SMA F
Band	Dual Band VHF/UHF
Max Power	10 Watts

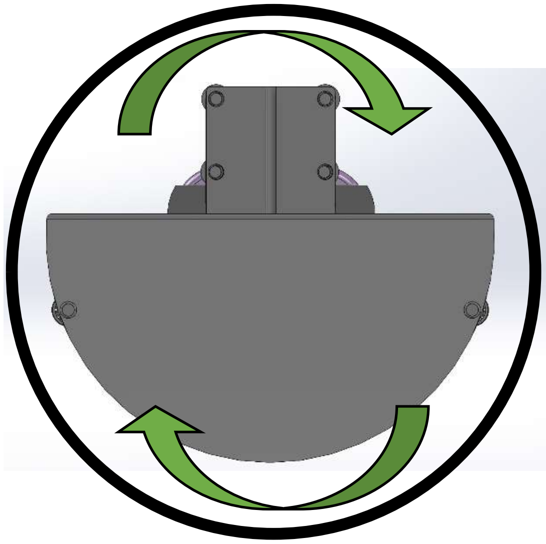
Antenna Length	5 cm/1.96”
Frequency	144/430 MHz
Gain(MAX)	2.15 dBi/3.0 dBi

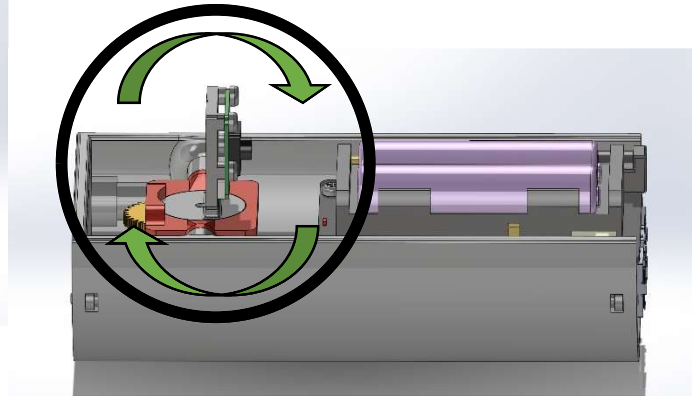
4.4.4.12 Real-time Clock Module

For the payload we decided to add a Real-Time Clock module so the timers on the Pi could work without internet or need to be adjusted once we perfect the timing of the payload deployment. We selected the Adafruit PiRTC DS3231, which can keep time while powered off even through temperature changes, unlike the cheaper option of the PiRTC PCF8523 offered by Adafruit which gains or loses up to 2 seconds per day, in addition to being affected by temperature changes. The Real-Time Clock will allow our system to record accurately timestamped images.

4.4.4.13. Self-Orientation to Horizon

The PILL payload is designed to keep the camera parallel to the horizon regardless of its landing orientation. This is achieved by stabilizing the camera in two axes. The ball-bearings in the sides of the electronics sled allow the sled to roll independently of the outer casing. The electronic components are arranged such that the sled is extremely bottom-heavy, causing it to naturally rest in an upright position due to gravity. This aligns the camera in one axis. Within the sled, the camera is placed between two ball-bearings with a servo underneath, allowing the camera swing perpendicular to the first axis, much like a pendulum. Through a combination of these two stabilization methods, the camera is kept aligned to the horizon.





Axis 1 *Axis 2*

4.4.7. Image Processing

For processing our images, we will be using OpenCV. OpenCV is an open-source library typically used for computer vision, machine learning, and image processing. While languages such as C++ and Java are supported, we will be using Python due to its simplicity and easy to read syntax.

In our Python code, the way OpenCV will read in an image sent from the camera will be through the imread() function. It will be saved to an SD card via the imwrite() method. An accurate timestamp will be overlaid on the image. There will additionally be various functions included such as adding and removing special effects, rotating the image, and changing the image to grayscale. Our code is also expected to turn the camera to a specified angle.

4.4.8. Payload Deployment

The experimental payload will be deployed behind the main parachute via a shock cord secured to the edges of the P.I.L.L. Once on the ground, the Pi will recognize that the rocket had completed its route after launch and receive RF commands from NASA to rotate the servo and have the camera capture panoramic photos of the landscape.

4.4.9. Potential Issues and Mitigation

Potential Issue: The safety and damage inflicted onto the payload system inside the rocket:	Solution A: Inside the main body of the rocket, two centering rings that are made from Plywood will hold the payload system in place. The centering rings will reduce the effects of damage and vibrations caused by factors such as air turbulence and forces enacting upon the rocket.	Solution B: On each end of the domes that the PILL is sealed with, there would be two shock absorbers that are used to keep the PILL stay put inside the Main Body of the rocket. Furthermore, the PILL would be wrapped up inside a fire blanket to reduce the vibrations caused by air turbulence and reduce the soot

		produced from the black powder charge damage the polycarbonate outer casing.
Potential Issue: Tension from shock chord enacted onto the Payload system:	Solution A: The shock cord would be cut and knotted onto two eyehooks. The eyehooks will be attached to the shock absorptions mechanism that is attached to each dome on the PILL. Inside the outer casing of the pill, a threaded rod would absorb the shock from the tug that the parachute deployment would cause.	Solution B: Two eyehooks would be placed in line with the top of the camera and perpendicular to the outer casing of the payload system. The shock cord would be threaded through the two eyehooks and when the main parachute is deployed, the PILL would be pulled out along with it.
Potential Issue: The rough terrain of the launch site:	Solution A: The payload system will keep the domes, however, the servo used for the Adrucam would contain a second servo. The usage of the second servo would enable the camera to turn parallel to the horizon by using an IMU with a Gyroscope mechanism.	Solution B: The payload system would still contain the polycarbonate cylinder and would have flat edges instead of the dome. However, the edges would be rounded out by sanding down the harsh edges to be rounder.

5. Safety

Safety is integral to the success of the rocket; it requires the collaboration of everyone participating. It is important for everyone to be able to understand and acknowledge the hazards behind the project. The teams understand that hazards may come up throughout the entire process and not everything can be accounted for, for us to mitigate the risks as much as possible this section was created to condense the information for all members to read and understand before we begin the production process; with this we can reduce the risks to the personnel and project and increase the likelihood of success.

5.1. Hazard Analysis Methods

We are going to use two criteria to determine the magnitude of the hazards and events; we are going to check the likelihood and severity of the hazards and determine it by assigning values accordingly.

5.1.1. Likelihood of event

Description	**Percent Chance**

Frequent - 5	100% - 80%
Likely - 4	80% - 60%
Occasional - 3	60% - 40%
Rarely - 2	40% - 20%
Improbable –1	20% - 0%

Table 5.1

5.1.2. Severity of event

Description	**Level of Risk**
Fatal - A	High Risk
Critical - B	High Risk
Moderate - C	Medium Risk
Minimal - D	Low Risk

Table 5.2

5.1.3. Risk analysis

	Fatal - A	**Critical - B**	**Moderate - C**	**Minimal - D**
Frequent - 5	5A	5B	5C	5D
Likely - 4	4A	4B	4C	4D
Occasional - 3	3A	3B	3C	3D
Rarely - 2	2A	2B	2C	2D
Unprobable - 1	1A	1B	1C	1D

Table 5.3

5.2. Personnel Hazard

Hazard	Description	Risk Rating	Mitigations	Verification
Handling black powder	If the black powder explodes while transferring it to the charges, then injuries such as burns may occur	1B	We will prevent this by securely storing black powder away from anything that could cause a spark or fire. The safety officer will have to check off the area before any black powder is moved	All black powder will be handled by our NAR (National Association of Rocketry) certified mentor
Epoxy gets on skin	Epoxy has direct contact with a team member's skin while working on the construction of the rocket, which could result in chronic contact dermatitis, a rash that is not life threatening or contagious, but is extremely uncomfortable	3D	All team members using epoxy will be required to wear disposable latex gloves, long sleeve shirts, pants, and will be required to complete a safety quiz	Team members will have to check with the Safety Officer that they are wearing the correct safety equipment before using epoxy
A team member inhales epoxy fumes	When epoxy fumes are inhaled due to working with the	2C	To prevent team members from inhaling epoxy fumes, all	Before using epoxy, team members will have to show the Safety Officer

	epoxy, it can cause irritation in your nose, throat, and lungs. Continuous exposure to these fumes can end in asthma and sensitization		members who use epoxy will wear a mask while using it in a well-ventilated setting	that they are wearing masks
Super glue (CA) gets on skin	If super glue gets onto a team member's skin due to working with super glue, it could cause irritation. It could also cause skin to be removed with glue if not removed properly	5D	If gloves, protective eyewear, and long clothes are worn, then the risk of super glue getting on skin is extremely low. If this does occur, the person with the super glue on their skin will immediately wash that part of their skin thoroughly with hot water and soap	Team members will have to show that they are wearing proper safety equipment before they start working with super glue.
Motor fumes	Exposure to motor fumes while working with the motor can cause headaches, dizziness, nausea, and fatigue. Exposure to these toxic fumes over an	3C	We will prevent inhaling toxic motor fumes by only working with the motor outside in a well-ventilated space	The Safety Officer will check the wind direction and advise attendees where to spectate from

	extended period could lead to death			
Paint fumes are inhaled	While painting the rocket, team members may inhale the fumes from the paint. This can cause short term issues like headaches, dizziness, runny nose, and itchy eyes. Some more serious problems that could stem from this could be nervous system and organ damage	4C	This can be mostly prevented by painting outside so fumes are not trapped. This can also be prevented by wearing a mask.	All team members that are painting will have to show the Safety Officer that they are wearing masks
The drill press bit catches on material being drilled and twists it, launching the material or part of the broken bit	Material thrown from drill press due to being caught on the drill bit may cause severe injury through impalement, laceration, or otherwise high-speed impact of penetration with/of the skin. This will cause potentially severe loss of blood.	2C	We will prevent this by requiring any team member that is using the drill press to watch safety markings and to keep hands and loose articles of clothing or hair out of the drill area. Material being drilled will be clamped securely using vises and clamps, and members will be	Team members will be required to always wear safety glasses and secure the material being drilled. Using the correct type of drill bit and drilling speed for the material and size of hole.

			required to wear safety glasses.	
CNC machines dust gets in operator's or spectator's eyes, nose, or mouth	Dust coming out of the machine could get in someone's eyes and cause irritation. A launched broken bit could impale a bystander and cause blood loss.	1D	This will be prevented by having a plexiglass cover in between the opening of the machine and the team members. Protective eyewear, and restrained clothing will be worn, and hair and loose articles will be secured to minimize the chance of a problematic incident. A dust collector will also be in place.	The Safety Officer or authorized mentor will be present whenever the CNC machine is being used. They will make sure that everyone is following the right procedures.
While using the electric drill a team member is pinched by the drill, or is impaled by the drill	A team member is pinched or impaled by the electric drill while constructing the rocket. This could cause a range of injuries including slight irritation to blood loss	2C	This will be prevented by using caution and making sure the item being drilled is secured in place to prevent movement which could lead to injury. This can also be prevented by using the appropriate but for the material.	All team members who are using electric drills will have to confirm with the Safety Officer or trained mentor that the item being drilled is being done so with the appropriate bit and that it is properly secured
A team member is impaled by a driver	A team member impales themself or others while using a	2C	Team members will ensure that the item is properly secured using clamps or vices	Before working with drivers team members will have to show the Safety

	driver. This may result in blood loss.		whenever using a driver	Officer that the item is properly secured
Unstable flight	If unstable flight occurs due to the fin material being too thin, or the center of gravity being below the center of pressure, this can cause the rocket to wobble in the air, and can affect the rocket's flight path making it unpredictable and dangerous	2D	This can be prevented by putting the center of gravity above the center of pressure. This stabilizes the rocket and prevents any wobbling from changing the course of the rocket.	During the construction of the rocket the Safety Officer will have to double check the center of gravity and the center of pressure
CATO (Catastrophe at Take Off) is a term that is used for when there is a catastrophic rocket engine failure.	If Catastrophic Rocket Engine Failure occurs due to a malfunction during flight, the rocket could be destroyed. Falling debris could be a hazard for people on the ground	1B	This can be prevented by having everyone stand as far away from the rocket as possible during the launch.	If this occurs the Safety Officer will make sure that the while team follows all safety procedures
Failure to deploy parachutes	The parachute fails to deploy during the launch. This could result in the destruction of the	2B	To prevent this, we will make sure that the parachute is inserted properly, and the cord is in a position where it	Everyone on the team will be properly instructed by our experienced high-powered rocketry mentor on how to properly pack a

	rocket, and if anyone is hit by falling debris, then it could be crippling or fatal		will not get caught on anything. In case this happens, everyone in the immediate area will move as far as they can to lower the risk of obtaining injuries from the impact of the rocket	parachute and the Safety Officer will double-check the process on all launch occasions
Fiberglass fumes are inhaled by a team member	A team member inhales toxic fumes produced while cutting or sanding fiberglass. These fumes can cause slight irritation in your lungs	2C	This can be easily prevented by wearing a mask	The Safety Officer will make sure that all team members that are working with fiberglass are wearing masks
Fiberglass shards cut skin	A team member is cut by a shard produced when cutting or sanding this fiberglass. This could result in blood loss or punctured skin	1D	We will require all members working with fiberglass to always wear gloves	Team members who are working with fiberglass will have to check in with the Safety Officer to make sure that they are wearing gloves
Carbon Fiber fumes are inhaled by a team member	A team member inhales toxic fumes produced while cutting or sanding carbon fiber. These fumes can cause	2C		The Safety Officer will make sure that all team members that are working with carbon fiber are wearing masks

	slight irritation in your lungs			
Carbon Fiber shards cut skin	A team member is cut by a shard produced when cutting or sanding this carbon fiber. This could result in blood loss or punctured skin	1D	We will require all members working with carbon fiber to always wear gloves	Team members who are working with carbon fiber will have to check in with the Safety Officer to make sure that they are wearing gloves

5.3. Vehicle Failure Modes and Effects Analysis

Hazards	**Description**	**Risk Rating**	**Mitigations**	**Verifications**
Airframe Failure	Buckling or shear of the rocket ripping it apart and causing debris. Could cause loss of vehicle.	1A	Ensure all measurements, manufacturing methods and material simulations are accurate and done in a proper fashion.	Manufacturing leads are to inspect every simulation and CAD design, as well as monitor all manufacturing and materials.
Ignition Failure	Issues with the continuity on the launch pad. Nothing Catastrophic.	2D	Make sure to check the continuity before loading the pad.	Ensure this is listed on the flight day checklist.
Instability	Occurs when the stability margin is <1.00. The rocket and have a dangerous flight path creating a hazard. This would lead to possible loss of vehicle.	2A	All the models and simulations must be updated when changes are made, every single material must be accounted for when manufacturing.	The center of gravity must be determined and physically marked right after completion of the rocket.

Altimeter Failure	Connection loss or programming issues, flight path can become dangerous, this would lead to possible loss of vehicle.	3A	Testing of altimeter and its settings before launch	Ensure this is listed on the flight day checklist
Bulkheads Tear	Cavity or tearing of the bulkhead exposing delicate components of rocket, leading to the charges damaging the components.	2A	Proper manufacturing and use of measurements.	Reassuring all measurements are correct prior to any manufacturing and checking the integrity before flight day.
Motor Retention	Forces exerted by the motor cause it to break off weak and poorly made retainers, causing damage and possible complete loss of the vehicle.	3B	Proper design and manufacturing methods used to prevent any weak points.	During manufacturing the leads must inspect and determine if it is usable before launch day
Charge damage	Excess charges used to cause physical damage to bulkheads, couplers, parachutes, payloads, and avionics. This could lead to a total loss of the vehicle	3A	Proper calculations of charges needed to not use any excess and cause damage within the rocket.	Measurement of the charges must be made precisely before loading on launch day and when charging careful handling must be made.
Inaccurate Calculations	Forces calculated improperly could lead to the production of too thin tubes. This could lead to weak spots for failure.	3A	Make sure the correct measurements are utilized to ensure the tubes result in the proper thickness	Reassuring all measurements are correct prior to any manufacturing.
Nose cone failure	Nose cone halves are not properly bounded which leads to the failure of the nose cone	2B	Proper technique is carried out when integrating the nose cone with the rest of the rocket	Ensure that during the manufacturing process, that the nose cone is properly attached

Fin failure	Fins are not properly bonded to the rocket which could lead to the failure of the flight.	3A	Proper technique is carried out when bonding the fins with the rest of the rocket	Ensure that during the manufacturing process, that the nose cone is properly attached
Failure to retrieve flight data	Connection loss or programming issues could lead to the team not being able to retrieve the flight data	3C	Testing of the system used to retrieve flight data prior to launch	Make sure that it is on the flight day checklist

5.4 Environmental Concern Analysis

Hazards	**Description**	**Risk Ratings**	**Mitigations**	**Verifications**
Landscape	If there are power lines, trees, brush, forests, or any obstructions that may affect the success of the rocket is a hazard to the vehicle, and it may result in total loss	2A	The angle of launch will be away from all obstructions and try to aim for the landing to be away from those obsturctions as well.	When putting the vehicle on the pad we must ensure the angle and the direction are verified by the safety officer.
Humidity	The weather may influence the electrical components of the rocket, even if the rocket isn't directly exposed to rain, it may still have an effect. Could result in loss of the rocket, if components are destroyed.	2A	All handling of the rocket must be in adequate weather conditions, even during launch day the rocket should only be pulled out of the transport vehicle if the conditions are correct.	The team will verify the weather to be sure of the conditions.
Winds	High wind may cause the rocket to veer of course and head towards obstructions and people.	4B	The windspeed will be determined the day of the launch.	Verification of the speeds must occur right before the rocket is scheduled to be on the pad.

Fire	The combustion from the rocket may cause a fire in the area depending on if there is vegitation under the pad.	3C	The vegetation near the launch pad should be layed down, if possible, it’s important to get it out of the way.	The area must be cleared by the safety officer to make sure there is no risk of fire.

5.5 Project risk analysis

Hazard	**Description**	**Risk Ratings**	**Mitigations**	**Verifications**
Insufficient budgeting	If the team underbudgets the project, we might not have enough funding and we won't be able to complete the vehicle.	3A	The team should do extensive research and present the budget to the University, as well as outsource funding,	Leads must have everyone contribute to this.
Parts	Failure to receive any parts due to long shipping times and mishandling inventory.	3A	The teams should be aware of how long certain components take to ship or if there are any shortages in whatever we need.	Leads need to collaborate with each other and all personnel to ensure success.
Testing	If there are failures during testing or difficulties finding areas to test, then the project won't be able to be complete.	5A	Making sure any subscale or testing of the actual rocket is well done, and the rocket is well made, we want to prevent any damage or anything that may delay the process or prevent us from participating at SL.	All the teams need to work together to make sure that all the components are going to integrate together so the chances of success are high.
Tools failure	If tools fail there may be a delay in the construction process, and it may affect the success of the rocket.	3A	The team should find an alternate source in case this does occure so the delay isn’t as long.	Leads should search for outside resources in case of any issues.
Transit damage	During transit there might be instances where the rocket takes damage due to terrain or recklessness.	2C	The team should always carry backup material incase anything occurs, best way to mitigate is the assurance of the asset, keeping it safe	Before leaving the University, the rocket must be inspected in the transportation.

			and providing some type of protection.	
Personnel Issues	If personnel fail to attend meetings and construction dates, then the project may be delayed, or we would miss deadlines and be excluded from the projects.	3A	Everyone participating should be truthful about their commitment and say how many hours they can contribute to the project	The leads should take surveys about their teams and figure out who has sufficient time to put into the project.

6. Project Plan

6.1. Mission Success Requirements

Requirement	Payloads	Vehicle	Recovery	Systems	Verification Plan	Verification Action
1.1				X	Only we will do all the work	The executive board of the club will ensure all aspects of design, manufacturing, and analysis are overseen
1.2				X	We will keep track of our project plan in an excel spreadsheet	The Systems Lead Manager will be responsible for meeting with Project System Leads to update necessary items
1.3				X	We will submit everyone that is attending Launch week activities by CDR	The Systems Lead Manager will be responsible for ensuring that the roster list for attending students is complete by CDR
1.5				X	We will be posting constant updates on our Instagram	The Knights Experimental Rocketry Executive board oversees all social media and will communicate with the Systems Lead Manager
1.6				X	We will email all documents by the deadline	The Systems Lead Manager will be responsible for collecting all documents necessary from each subsystem and emailing them to the appropriate location
1.7				X	We will complete all satisfactorily requirements on time	The Systems Lead Manager will be responsible for establishing hard deadlines for subsystems to follow in order to satisfy requirements
1.8				X	We will have all documents in PDF format	The Systems Lead Manager will communicate that all

						documentation must be in PDF format
1.9				X	We will have a table of contents and subsections	The Systems Lead Manager will format the PDF such that we have a table of contents
1.10				X	We will have page numbers on every page	The Systems Lead Manager will format the PDR such that we label every page
1.11				X	We will use a computer for video teleconferences	The Systems Lead Manager will be responsible for ensuring that there is a computer available for video teleconference
1.12	X	X	X	X	We will only use launch pads provided by Student Launch's launch services provider	NASA Ground crew will communicate to us which pad to use and where to go on launch day
1.13					We will have a mentor	
1.14				X	We will use an excel spreadsheet to document how long we have worked on each section	The Systems Lead Manager will be responsible for communicating to the other subsystem leads ensuring that they are recording there hours
2.1	X				We will deliver the payload to an apogee of 5000 feet	The Vehicle Design Manager wll ensure that payload reaches 5000 feet
2.2	X			X	We will declare our finial altitude goal by PDR	The Systems Lead Manager will ensure that the Vehicle Design lead has verified the apogee recorded through Openrocket
2.3	X	X	X	X	We will build a recoverable and reusable rocket	The Vehicle Design, Payload, and Systems Manager will establish procedure to test and validate that the rocke tis recoverable and reusable
2.4	X				We will only have a maximum of four independent sections. We will also have 2 airframe diameters in length on each coupler/airframe shoulders	The Vehicle Design Manager will work with the subsystem throughout

2.5	X	X	X	X	We will be able to prepare the rocket for launch within 2 hours	The Systems Lead Manager will organize the other 2 subsystems to work effectively and efficiently on launch day
2.6	X	X	X	X	We will be able to remain in launch-ready configuration on the pad for a minimum of 2 hours	The Systems Lead Manager will organize the other 2 subsystems to work effectively and efficiently on launch day
2.7		X			We will be able to launch the vehicle using a 12-volt direct	The Vehicle Design team will validate and test through static fires that the rocket can launch with the given ignition system
2.8	X	X			We will not use any external circuitry or ground support equipment	The Payloads Manager will verify that all electronics can work independently of ground support systems
2.9		X			We will use only commercially available ematches or igniters	The Vehicle Design manager will ensure that the only igniter mechanism purchased is ematches. This will be communicated to the Systems Lead Manager
2.10		X			We will only use a commercial motor	The Vehicle Design manager is responsible for selecting and focusing design iniatives on a commerical off the shelf motor
2.11		X			We will only use a single motor	The Vehicle Design manager is responsible for ensuring all guidelines are met as given by NASA
2.12		X			We will use a maximum of L-class motor	The Vehicle Design manager will be observant of the NASA guidelines and also the motor selected such that it falls within required rules
2.13		X			We will not be using a pressure vessels	The Vehicle Design manager will ensure that no pressure vessels are considered or purchased throughout the design and manufacturing process
2.14		X			We will have a minimum static stability margin of 2 at point of rail exit	The Vehicle Design team will validate and justify with Open Rocket that the stability has a minimum of 2 at point of rail exit

2.15		X			We will have a minimum thrust to weight ratio of 5:1	The Vehicle Design team will determine and validate with Open Rocket that the thrust to weight ratio is 5:1
2.16					We will not be using any external structural protuberance	The Vehicle Design Manager is responsible for ensuring that there is no structural protuberance from the airframe of the rocket
2.17					We will have at least 52 fps at rail exit	The Vehicle Design team will verify and validate with Open Rocket that the exit rail velocity is 52 feet per second
2.18	X	X	X	X	We will launch a subscale model prior to CDR. The subscale will resemble and perform similarly to the full-scale model. We will have an altimeter that will record the model's apogee altitude. We will have altimeter graphs or high-quality video and pictures of the as landed configuration	The Systems Lead Manager will be responsible for coordinating with the other leads and subsystems the manufacturing process, timeline, and procedures for subscale launch
2.19					We will launch a full-scale rocket launch in the same configuration we would be launching in as if it was actually launch day for competition	The Systems Lead Manager will be responsible for coodinating with the other leads and subsystems the updated manufacuturing process, timeline, and procudres for full-scale launch
2.20					We will complete an FRR Addendum if required to re-fly or completing a payload demonstration flight	The Systems Lead Manager will be responsible for communicating with the other subsystems to obtain specific infomration in order to complete the FRR
2.21					We will have our team name and launch day contact information in or on the rocket airframe in	The Systems Lead Manager will communicate effectively with NASA all of our information and with the Vehicle Design Manager to

					a place of easy of access	have the information on the Airframe
2.22	X		X		We will mark and protect all lithium polymer batteries	The Payloads Manager will require that all batteries be protected and marked
2.23		X			We will not utilize forward firing motor, motors that expel titanium sponges, a hybrid motor, cluster motor, friction fitting for motors, exceed Mach 1 at any point during flight, 10% of the total unballasted weight of the rocket as it would sit on the pad, transmissions will not exceed 250mW of power, transmissions will not create excessive interference, and no metal	The Vehicle Design Manager will ensure that all motor designs fall within specifications outlined by NASA
3.1			X		We will use a dual deployment recovery system	Recovery team will ensure use of a dual deployment recovery system.
3.2			X		We will perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full-scale vehicles	Recovery lead will ensure proper recovery events prior to launches with successful ground ejection tests.
3.3		X			We will have a maximum kinetic energy of 75 ft-lbf at landing	Vehicle Design team will ensure vehicle design will be exerting a maximum kinetic energy of 75 ft-lbf at landing.
3.4			X		We will use redundant commercially barometric altimeters	Payloads team will ensure use of redudant barometric altimeters.

3.5			X		Each altimeter will have a dedicated power supply	Payloads team will ensure all altimeters will be battery-powered individually.
3.6			X		Each altimeter will be armed by a dedicated mechanical arming switch	Payloads team will ensure altimeters are armed manually.
3.7			X		Each arming switch will be capable of being locked in the ON position	Payloads team will ensure arming switch will be turned on and locked in.
3.8			X		All recovery systems will be separate from payload electrical circuits	The Recovery Subsystem Lead will ensure that all electronics will be independent of experiements and telemetry electronics
3.9		X			We will be using removable shear pins	Vehicle Design team will ensure use of removable shear bolts during stage separation.
3.10		X			We will land with in a 2,500 feet radius of the launch pads	Vehicle Design team will ensure the launch radius is 2500 feet.
3.11	X		X		We will have a descent time of less than 90 seconds	We will ensure that descent time will be in accordance of our simulations from Open Rocket
3.12	X				We will have a GPS in all sections of the rocket that won't be tethered together	The Payloads Recovery team will ensure GPS will be in all nontethered portions of the rocket.
3.13	X				The recovery system electronics will not be adversely affected by any other on-board electronic devices	The Recovery subsystem lead will work with Experiements and Telemetry to ensure no advserse affects to on board electronics.
4.1	X				We will design a payload that upon landing autonomously receives RF commands and performing a series of tasks with an on-board camera system	The Payloads Experiments subsystem will be in charge of our Payload Integrated Launch Log (PILL).

4.2	X				We will have camera system capable of swiveling 360 degree to take images of the entire surrounding area of the launch vehicle. We will be able to accept RF sequence and perform a set of actions in order.	The Experiments Subsytem will have a telemetry capable payload containing a camera capable of 360 degree motion.
4.3			X		We will only use black powder for in-flight recovery.	The Systems Lead Manager will be responsible for ensuring that the the use of black powder will be used for recovery systems.
5.1				X	We will use a launch and safety checklist	The Systems Lead Manager will be responsible for ensuring use of a launch and safety checklist.
5.2		X			We will identity a student safety officer	We will host an interview process to select a saftey officer that is qualified and will ensure that our team reamins safe durin manufacturing
5.3	X	X	X	X	The student safety officer will be responsible for design of vehicle and payload, construction of vehicle and payload components, assembly of vehicle and payload, ground testing of vehicle and payload, subscale launch test, full-scale launch test, competition launch, recovery activities, STEM Engagement Activities	Our safety officer will outline procedures and ensure all actions of design and manufacturing will be in accordance with safety standards.
5.4	X	X	X	X	We will abide by the rules and guidance of the local rocketry club's RSO	We will follow all rules and regulations set by Knights Experimental Rocketry.

5.5	X	X	X	X	We will abide by all rules set forth by the FAA	We will make sure everything is done in accordance with all set rules.
6.1				X	We will not show up to NASA Launch Complex without permission. We will complete and pass and LRR conducted during Launch Week.	We will ensure we have permission for launch and have all prequities completed before launch.
6.2	X	X	X	X	We will launch at a NAR or TRA sanctioned and insured club launch if we do not end up launching at the NASA Launch Complex	Launch team will drive to our HPR L1 workshop launch site in Palm Bay if we are unable to travel to Huntsville.
6.3	X				The PILL will be a clear strucutre capable of landing normal to the ground	Payoads team will design exterior of the PILL with a clear polycarbonate capable of centering with respect to the ground..
6.3.1	X				The PILL will enclose a microcontroller, motor, batteries, and camera that are able to withstand impacts from landing and aerodynamic forces	Experiments subsystem will ensure PILL is capable of withstanding descent and impact conditions.
6.3.2	X	X			The PILL will be able to recieve long range radio command from NASA to instruct the devices on board	Experiments subsytem will ensure Pill is capable of telemetry and Vehicle Design team will ensure upper body tube is radiotransparant.
6.3.3	X				The PILL will be able to survive a landing impact velocity of 21 feet per second	Payloads subsystem will ensure PILL is capable of impact of 21 feet per second without failure.
6.3.4	X				The PILL structural design will be justified and validated through decision matrix	The Experiements subsystem will utilize decision matrix methodology and comparison and contrast methods to determine structural design choices

					methodology and iterative design

6.2. Budget

- Aerostructures Budget
    - SUM: $2,022.97

Status	ccour	Subsystem	Recieved	rchase	Item Label	Component Description	Details	Quantity	Price Each	Total Cost	Vendor
			no	no	Nylon 8 ft Chute Main	120" Nylon Chute Main (20% discount)		1	$70.50	$ 75.44	Rocketman
			no	no	Kelvar	1,200lb Kelvar Shock Cord 30'		1	$35.50	$ 37.99	Rocketman
			no	no	Kelvar	1,200lb Kelvar Shock COrd 25'		1	$28.50	$ 30.50	Rocketman
			no	no	Drogue Chutes	2Ft. Standard Parachute with 20% discount		1	$28.50	$ 30.50	Rocketman
			no	no	Plywood	1/4"x4'x8' Hardwood PureBond Plywood		1	$44.68	$ 47.81	Home Depot
			no	no	Fillet Epoxy	Thixo Fast Cure 2:1 Epoxy Adhesive - One 185 ml Cartridge & 2 Mixing Tips Code: TBTotalXyla		1	$26.09	$ 27.92	TotalBoat
			no	no	Flame Retardant Blankets	USA Fabric Store Neon Yellow 7 OZ. Nomex Aramid Canvas Twill Fabric 62 inch W Soft Flame Retardant FR		1	$8.95	$ 9.58	Amazon
			no	no	Nylon 4-40 Shear Bolts	Nylon Pan Head Screws Phillips, 4-40 Thread, 5/16" Long pack of 100		1	$8.48	$ 9.07	McMaster
			no	no	Alloy Steel 1/4-28 Fasteners	Passivated 18-8 Stainless Steel Pan Head Phillips Screw 1/4"-28 Thread Size, 5/16" Long		1	$9.24	$ 9.89	McMaster
			no	no	U-Blot	Black-Oxide Steel U-Bolt with Mounting Plate, 1/2"-13 Thread Size, 3" ID		4	$5.82	$ 24.91	McMaster
			no	no	Lock Nuts	High-Strength Steel Nylon-Insert Locknut, Grade 8, 1/4"-20 Thread Size		1	$4.49	$ 4.80	McMaster
			no	no	Quick Links	Oval Shaped Threaded Connecting Link Type 316 Stainless Steel, 1/4" Thickness, 9/32" Opening, Not for Lifting		4	$2.78	$ 11.90	McMaster
			no	no	U-Bolt Nuts (50 ct.)	High-Strength Steel Nylon-Insert Locknut, Grade 8, 1/2"-13 Thread Size		1	$4.76	$ 5.09	McMaster
			no	no	Popsicle Sticks	100 pack of popsicle sticks Jumbo		1	$6.95	$ 7.44	Amazon
			no	No	Rover Shock Cord	5' tubular nylon shock cord		1	$8.50	$ 9.10	Rocketman
			no	No	Team 3 Nylon 9 ft Chute Main	108" Nylon Chute Main (20% discount)		1	$60.40	$ 64.63	Rocketman
			no	no	Nose Cone PLA Filament	1 kg (2.2 lbs) white filament spool		2	$22.59	$ 48.34	Amazon
			no	no	Sandpaper	120-3000 grit sandpaper for sanding composite		2	$7.99	$ 17.10	Amazon
			no	no	Microfiber Cloth	14x14 Micorfiber Cloth blue 24 pack		1	$10.98	$ 11.75	Amazon
			no	no	Frekote Mold Release	Frekote 700-NC Mold Release	ıund Shipping an extr	2	$30.67	$ 65.63	Composite Envisions
			no	no	Fiberglass Plates	G-10 FR4 .125" x 12"' x 24"	24 shipping	2	$29.30	$ 62.70	ePlastics
			no	no	Threaded Rod	1/4 by 36in		3	$8.32	$ 26.71	Home Depot
			no	no	Paper Towel	Shop Towels 6 pack		1	$10.98	$ 11.75	Home Depot
			no	no	Nylon 2-56 Shear Bolts	2-56 length: 5/16" nylon shear bolts 100 pack		1	$8.48	$ 9.07	McMaster
			no	no	U-Bolt Washers (100 ct.)	Black-Oxide 18-8 Stainless Steel Washer for 3/8" Screw Size		1	$14.39	$ 15.40	McMaster
			no	no	Aluminum Mandrel Extrude	5.000 x 0.125 ALUMINUM 6061 ROUND TUBE 50" long		1	$103.87	$ 111.14	Metal Supermarkets
			no	no	Aluminum Coupler Mandrel	5.000 x 0.25 ALUMINUM 6061 ROUND TUBE 24" long		1	$128.77	$ 137.78	Metal Supermarkets
			no	no	Nose Cone Tip	T6511 2.000" ALUMINUM 6061 ROUND BAR 5" long		1	$30.94	$ 33.11	Metal Supermarkets
			no	no	Dry Ice	Publix Dry Ice	Per feet	40	$1.89	$ 80.89	Publix
			no	no	Orbital Sander	5in. Orbital Sander w/ Dust Bag	ot purchase from wal	1	$26.88	$ 28.76	Walmart
			no	no	Orbital Sand Paper	Gator 5-inch 8-Hole Red Resin Aluminum Oxide Multi-Surface Hook and Loop Sanding Discs, 60-Grit, 5-Pack, 3725-30		2	$3.68	$ 7.88	Walmart
			no	no	Red Cups	Solo Disposable Plastic Cups, Red, 18oz, 50 count		3	$4.12	$ 13.23	Walmart
			no	no	MDF Boards	1/4 in. x 2 ft. x 4 ft. Medium Density Fiberboard		4	$12.49	$ 53.46	Home Depot
			no	no	Uni Directional CFF Pre preg	711 KSI HIGH TENSILE STRENGTH FIBER ▪ 36 MSI STANDARD MODULUS CARBON FIBER ▪ 250F EPOXY RESIN ▪ 0.006" THICK	Per linear yard	28	$41.39	$ 1,240.04	Rockwest Composites
			no	no	Fiberglass Sheets	E-Glass - Style 7500, 9.4 Oz (319 GSM) Total Weight - 50" Wide X 0.012" Thick	Per linear yard	2	$38.79	$ 83.01	Rockwest Composites
			no	no	Reciept Paper	Pen + Gear 2 1/4"x50' Thermal Paper Rolls ,12 Rolls		1	$11.92	$ 12.75	Walmart

- Payloads Budget
    - SUM: $1,909.65

Project: NASA Student Launch 2023 System: Payloads											
Account	Subsystem	For Safety?	Recieved	Purchase	Item Label	Component Description	QTY	Price Each	Shipping	Total	Vendor
	Experiments	No	no	no	Raspberry Pi 4B	CanaKit Raspberry Pi 4 EXTREME Kit (8GB) PI4-2GB-EXT128EW-C8-BLK	1	$184.95		$ 197.90	CanaKit
	Experiments	No	no	no	Servo	Smraza 10 Pcs SG90 9G Micro Servo Metal Geared Motor Kit	1	$19.99		$ 21.39	Amazon
	Experiments	No	no	no	Battery Pack	MakerHawk Raspberry Pi UPS Power Supply Uninterruptible UPS HAT	1	$30.99		$ 33.16	Amazon
	Experiments	No	no	no	Batteries	4X Energizer E92 Batteries	1	$6.39		$ 6.84	Amazon
	Experiments	No	no	no	120 degree lens	Arducam 120 degree ultra wide angle lens	1	$34.99		$ 37.44	Amazon
	Experiments	No	no	no	Camera Module	Raspberry Pi High Quality HQ Camera - 12MP	1	$50.00		$ 53.50	Adafruit
	Experiments	No	no	no	Radio SDR Dongle	RTL-SDR Blog R820T2 RTL2832U 1PPM TCXO SMA Software Defined Radio	1	$29.95		$ 32.05	Amazon
	Experiments	No	no	no	Antenna	Mini Short Walkie Talkie Antenna AR-805S SMA-Female Dual Band High Gain Long Range Antenna	1	$7.99		$ 8.55	Amazon
	Experiments	No	no	no	Poly dome 4 inch	4.3 Inch Outdoor Waterproof Polycarbonate PC Clear Ball Cover	2	$17.99		$ 38.50	Amazon
	Experiments	No	no	no	Poly tube 4 inch OD	Impact-Resistant Polycarbonate Round Tube 1/4" Wall Thickness, 4" OD, 3-1/2" ID	1	$51.65		$ 55.27	McMaster-Car
	All	No	no	no	PETG Filament	eSUN 3D 1.75mm Solid Silver PETG 3D Printer Filament 1KG	4	$23.99		$ 102.68	Amazon
	Experiments	No	no	no	Ribbon cable extension	Arducam for Raspberry Pi Camera Ribbon Flex Extension Cable Set	1	$9.99		$ 10.69	Amazon
	Experiments	No	no	no	Usb extender	URWOOW 2 Pack SuperSpeed USB 3.0 Angle Male to Female Extension Cable	1	$6.80		$ 7.28	Amazon
	Experiments	No	no	no	Rubber Isolators	uxcell M3 Thread Male Female Rubber Mounts,Vibration Isolators	8	$6.99		$ 59.83	Amazon
	Experiments	No	no	no	RTC Module	Adafruit PiRTC - Precise DS3231 Real Time Clock for Raspberry Pi	1	$14.95		$ 16.00	Adafruit
	Experiments	No	no	no	Dupont Wires	ELEGOO 120pcs Multicolored Dupont Wire 40pin Male to Female, 40pin Male to Male, 40pin Female to Female	1	$6.98		$ 7.47	Amazon
	Experiments	No	no	no	Assorted Screws	Guard4U 480Pcs #2-56#4-40#6-32 UNC Stainless Steel Button Head Hex Socket Cap Bolts Screws Nuts Assortment Kit	1	$21.99		$ 23.53	Amazon
	Experiments	No	no	no	M3	1215pcs M3 Hex Socket Head Cap Screws Bolts Nuts Assortment Kit	1	$22.99		$ 24.60	Amazon
	Experiments	No	no	no	Ball Bearings	Stainless Steel Ball Bearing Open, Trade Number R144	12	$5.30		$ 68.05	McMaster-Car
	Recovery	No	no	no	Rhino 300mah LIPO	Rhino 300mAh 2S 50C LiPo Battery Pack w/XT30	2	$5.79		$ 12.39	HobbyKing
	Recovery	No	no	no	RRC3 "SPORT"	RRC3 "SPORT" DUAL DEPLOYMENT ALTIMETER	1	$96.50		$ 103.26	Apogee
	Recovery	No	no	no	StratoLoggerCF Altimeter	StratoLoggerCF Altimeter	1	$69.95		$ 74.85	Perfectflite
	Recovery	No	no	no	SS-5GL2 Limit Switch	SS-5GL2 Limit Switch	2	$1.63		$ 3.49	Sager
	Recovery	No	no	no	Zipties	200 Zipties	1	$5.99		$ 6.41	Amazon
	Recovery	No	no	no	Wires	Silicone red/black wires. 10 ft	2	$6.48		$ 13.87	Amazon
	Telemetry	No	no	no	Featherweight GPS	Featherweight GPS Tracker (upd)	1	$365.00		$ 390.55	erWeight Altin
	Telemetry	No	no	no	Arduino Nano	Small complete board based on the ATPmega328P released in 2008.	1	$23.09		$ 24.71	OKdo
	Telemetry	No	no	no	MPU 6050	3 axis gyroscope and 3 axis acceleramotor	1	$6.29		$ 6.73	Amazon
	Telemetry	No	no	no	BMP 280	Barometric pressure sensor	1	$9.50		$ 10.17	Ebay
	Telemetry	No	no	no	SD Card	proprietary non-volatile flash memory card	1	$9.28		$ 9.93	Amazon
	Telemetry	No	no	no	PCB	Printed Circuit Board	1	$8.00		$ 8.56	JLCPCB
	Telemetry	No	no	no	Battery	Alkaine Battery, 9 volts.	1	$8.82		$ 9.44	Amazon
	Telemetry	No	no	no	Camera Module	Camera for Rocket	1	$25.99		$ 27.81	Amazon
	Telemetry	no	no	no	Adafruit GPS	Adafruit Ultimate GPS	1	$29.95		$ 32.05	Adafruit
	All	no	no	no	Metal Rods	1/4 in. x 36 in. Plain Steel Hot Rolled Square Rod	1	$7.47		$ 7.99	Home Depot
	All	No	no	no	Standoffs and M3 Bolts	M3, M3.5 Bolts with Brass Standoffs	1	$12.88		$ 13.78	Amazon
	All	No	no	no	Metric Screws / Bolts	Metric and SAE Bolts / Nuts Pack	1	$40.99		$ 43.86	Amazon
	Recovery	No	no	no	Locknuts	High-Strength Steel Nylon-Insert Locknut, Grade 8, 1/4"-20 Thread Size	1	$4.49		$ 4.80	Mcmaster-Car
	Recovery	No	no	no	Shaft Collars	Set Screw Shaft Collar for 1/4" Diameter, Black-Oxide 1215 Carbon Steel	32	$1.55		$ 53.07	McMaster-Car
	Recovery	No	no	no	U bolts	Black-Oxide Steel U-Bolt, 1/4"-20 Thread Size, 3/4" ID, 1-1/4" Height (pack of 5)	1	$3.27		$ 3.50	McMaster-Car
	Recovery	No	no	no	Threaded Shafts	13" 52100 Alloy Steel Threaded Linear Motion Shaft	4	$56.95		$ 243.75	McMaster-Car

6.2.2 Funding Plan

NASA SL

Expected Costs	
Vehicle Design	$2,477.04
Payload	$1,787.08
Propulsion	$1,020.95
General	$288.92
Total Rocket	$5.284

Funding Source	
FSGC Grant	$3,300
SG FAO Bill	$3,000.00
SG CRT Allocation	$2,500.00
Student Travel Fees	$4,500.00
Total	$13,300.00

Rocket with 25% buffer	$6,605
Travel	$6,009.05
Travel with 25 % Buffer	$7,511.31
Total	$19,389

KXR is one of three primary rocketry registered student organizations affiliated with the University of Central Florida. AIAA and SEDS are the other two clubs. KXR is an affiliate partnership between both AIAA and SEDS, together with KXR they provide resources, students, and financial support to ensure the success of all our projects. This support is established by the payment of club dues. If a student pays dues to either AIAA or SEDS, they can participate in KXR projects. Florida Space Grant Consortium have graciously provided us in the past and now with a liquid grant that allows us to fund projects like these. Furthermore, the Student Government Association provides means for student organizations to obtain funding through a request and approval process. Clubs may fill out funding requests which then get sent to a hearing where the request will be granted or denied. Another outlet for funding is the Mechanical and Aerospace department here at UCF. They also operate on a request approval basis depending on the project, impact on UCF students, and credibility of the club.

6.3. Project Gannt Chart