University of Central Florida – 2023 – FRR – Report

4000 Central Florida Blvd, Orlando, FL 32816

Knights of Experimental Rocketry

03/06/2023

1 Summary

1.1 Team Summary

Team name: Knights Experimental Rocketry

Mailing Address: MAE/Knights Experimental Rocketry

12760 Pegasus Drive, Room 307

Orlando, FL 32765

Mentor Name: Gary Dahlke

Phone Number: (321) 848-7730

Email Address: rocket1@palmnet.net

NAR Number: #21735

Certification Level: 3

Hours Spend:

Social Media:

Instagram @ucf_rocketry

Twitter: @KnightsRocketry

YouTube: Knights Experimental Rocketry

STEM Engagement Events: 9

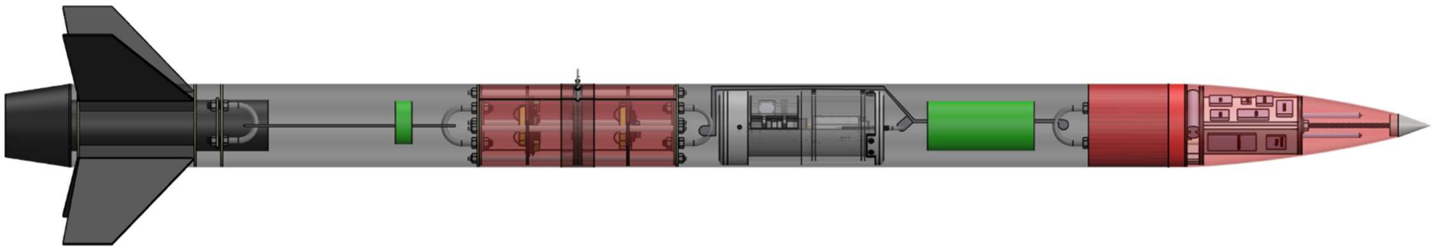
People Reached: Approximately 2000

Types of Events: Workshops, tabling, speeches and volunteering events

1.2 Launch Vehicle Summary

Vehicle Name	Asclepius
Target Altitude	5507’
Motor Selection	Aerotech Rocketry K1000T-P
Vehicle Mass	26.266 lbs
Vehicle Outer Diameter	5.1”
Vehicle Length	87”
Vehicle Independent Sections	4
Vehicle Recovery System	Dual Deployment: Apogee and 600’

Table 1.1: KXR Team Summary



1.2.1 Target Altitude

As discussed in PDR, our target altitude is 5570’. We determined that altitude by using OpenRocket and doing many different simulations for apogee with varying different launch angles and wind speeds and we took the mean. We used the mean because we feel that gives us the best chance of hitting our altitude because the mean can account for varying conditions and gives us some leeway.

1.2.2 Final Motor Choice

For our final motor choice, we decided to go with an Aerotech K1000T. In-depth analysis and justification for this motor choice is provided in section 3.4.3.

Aerotech Rocketry K1000T	
Total Impulse	2511.5 Ns
Max Thrust	376.33 lbs
Burn Time	2.4 s
Propellant	Blue Thunder

Table 1.2: Motor Summary

1.2.3 Size and Mass of Launch Vehicle

Asclepius	
Expected Mass	26.266 lbs
Length	87in
Outer Diameter	5.1in
Rail size	1515 Railing - 144in

Table 1.3: Launch Vehicle Summary

1.2.4 Recovery System

Our recovery team has focused their efforts towards achieving a fast descent time and safe impact velocity. To achieve both the needed requirements and the bonus objectives for the competition, we have chosen a dual deployment mechanism that uses a 1’ drogue parachute and a 7’ main parachute to allow for a faster descent while also safely recovering the rocket. The 1’ drogue will be deployed at apogee with a redundant free-floating charge going off 1 second after apogee and the main parachute will be deployed at 600ft with a redundant free-floating charge going off at 500ft to ensure deployment. The drogue is such a small size for the sole purpose of receiving the extra bonus points on section 3.11. Furthermore, whilst this would suggest larger snatch forces – which is true – the use of four aluminum rods, black oxide steel U-bolts, and locknuts ensure that the recovery system will stay intact and that the snatch force will not shear the bulkheads.

1.3 Payload Summary

Our payload system consists of three main sub-systems, Experiments, Telemetry, and Ground Station. The telemetry and ground station sub-systems are not mission critical but will serve as an important basis for building a foundation for more complex vehicles in subsequent years. The primary payload simulating what is essentially a lunar lander will be handled by the Experiments team whereas, the secondary payload will be dealt with by the telemetry system.

1.3.1 Primary Payload

The Primary payload is a terrain lander that uses self-orientation camera systems to meet NASA student launch's experimental payload criteria. The P.I.L.L also known as the Payload, Integrated, Launch, Log is a 3D printed assembly that is composed of three independent sections. One of the cylindrical sections of the payload contains important electronics that are able to receive and execute commands that are distributed by NASA. The center of the electronics sled contains an experimental liner elevator along with a wide-angle camera that aids in performing the necessary actions that are commanded by NASA. The outer, independent sections are able to spin freely; all parts are integrated via a bearing interface. Due to the weight distribution of the internal electrical components inside of the PILL, the center section is always aligned and leveled parallel to the horizon. The experimental payload is attached directly to the main parachute with a Nylon shock cord, allowing the payload to exit upon main parachute deployment. Once Deployed, the PILL can then receive radio commands and execute all commands, including rotation of the camera 360 degree and surveillance of the area with different filters by using OpenCV and Python.

1.3.2 Secondary Payload

The secondary payload will still be composed of a Run Cam Split HD which will operate entirely separately of our other avionics equipment. The only additional component we will be using from our primary avionics will be the 2200 mAh LiPo battery. Although STEM Engagement requirements are due on FRR submission, we've decided to use our secondary payload for promotional material to allow those who have followed UCF's USLI project to see it at its end.

2 Changes Made Since CDR

Whilst we attempted to avert any changes since CDR, mishaps and complications arise in manufacturing which we must work around. All changes are thus consequentially biproducts of the manufacturing process the severity of which has been purposefully minimized.

2.1 Changes Made to Vehicle Criteria

2.1.1 Vehicle

Few changes have been since CDR. During the manufacturing process, a significant bottleneck was introduced when the autoclave we plan to use for our pre-preg carbon fiber was out of service. And since we did not have a timetable for the autoclave, we chose to wet lay our body tube which change our thickness from .060" to .074".

Another change we made since CDR was the type of mold we use for our nosecone. Original we opt in for a female split mold but change it to a male mold made from PLA. This was due to the complexities that arise when making this female mold out of medium density fiberboards but mainly due to the inner tolerance for our nosecone not being accurate enough.

2.1.2 Recovery

2.1.2.1 Altimeter Choice

Our altimeter choice had changed from the RRC3+ Sport as our main altimeter and the PerfectFlite Stratologger CF as our redundant to the PerfectFlite Stratologger CF as our new main altimeter and the RRC2+ as our redundant. The reason for this change is because the RRC3+ Sport was short-circuited, and the circuit board is fried. With the change in altimeters, there was also a change in deployment of parachutes. Originally, the detonation of our main redundant charge was 1 second after our main primary charge detonated at 600ft. When the switch in altimeters was made, the RRC2+ was not able to be set up a time delay, but only a height delay. Our main deployment is at 600ft with a redundant charge going off at 500ft.

2.1.2.2 Battery Redundancy

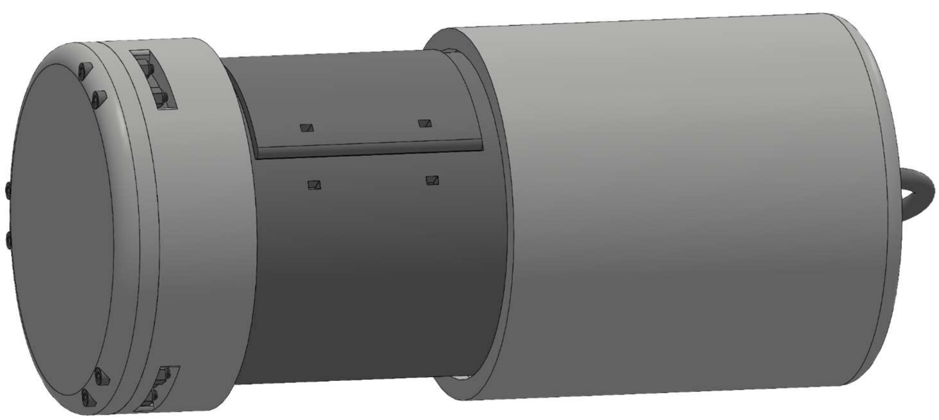
Our Battery choice had changed from using 7.4V LiPo batteries to using 9V alkaline batteries. The reason for this change is because it is easier to wire the altimeters instead of using a current limiting resistor which is needed for the LiPo batteries. In addition to easier wiring, the 9V alkaline batteries are suggested for use with both the Stratologger CF and the RRC2+ which will eliminate possible brownout. 9V alkaline batteries are also much safer than the 7.4V LiPo batteries making our system safer.

2.2 Changes Made to Payload Criteria

2.2.1 Primary Payload

2.2.1.1 Hinge

The PILL's hatch that is used to protect and aid in deployment of the camera system was redesigned by CDR to better accommodate the electronics system. Beforehand, The previous design of the hinge used an overlapping hinge design that incorporated a pin to connect the hatch to the PILL. However, The new design has been simplified to have two simple holes that the hatch will be connected by two 4-inch zip ties. This improvement allows the hatch to extend its range of motion farther upon opening and reduces failure of proper deployment.



2.2.1.2 Resin

Regrettably, the UCF Nanotechnology pavilion was unable to make our resin in time; however, our USLI team, been sponsored by X-Materials, a company known for their ceramics and high-temperature plastics.

X-Materials has a sub-division that experiments with resins and epoxy. Initially, we were looking to utilize their high-temperature resistant resin to mitigate the effects of the black powder charges on the payload. However, after consulting with X-Materials, they suggested using a high-impact resistant epoxy instead. This would help to mitigate the impact forces our payload will endure. This will be provided at no additional cost to our team.

2.2.2 Avionics Bay

2.2.2.1 Sleds

Due to an excess of weight and unexpected dimensional changes through the process of manufacturing our fiberglass nosecone, we opted to change the triple sled avionics bay within the nosecone to double sled design. This will maximize our now limited amount of space while allowing for a still extremely simple design.

2.3 Project Plan Modifications

2.3.1 Funding plans

Our funding plans remain largely unchanged, although we did experience a shortfall in funds due to our Daytona 500 sponsor falling through. However, thanks to the support of our parent club KXR and our collaboration with FSGC, we have received donations that enable us to continue working towards the goals of our project.

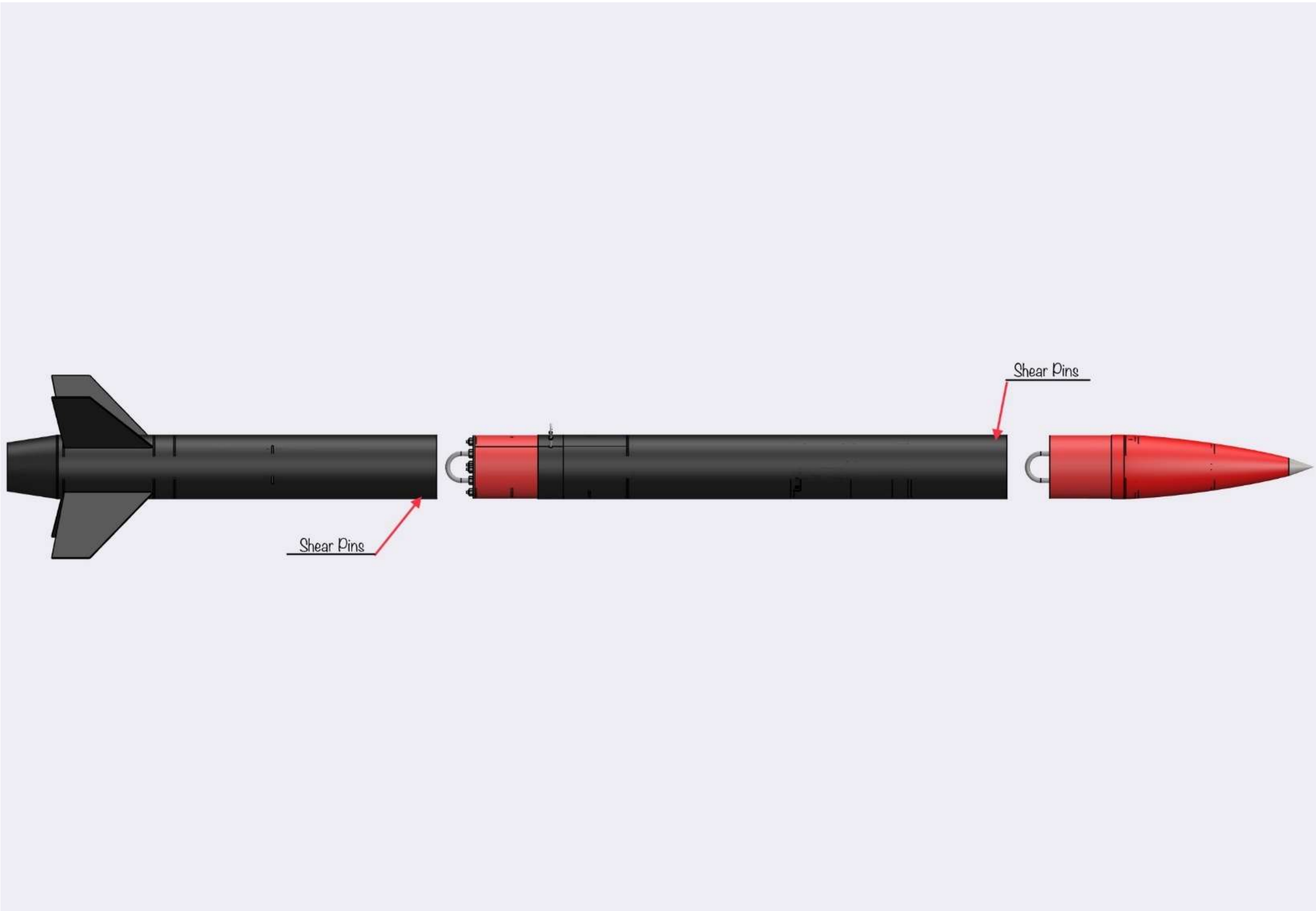
2.3.2 Manufacturing timeline

We initially aimed to conduct our vehicle demonstration flight on February 18th to allow for the completion of FRR, based on the available launch dates at the Palm Bay launch site. However, we missed our launch window and had to postpone the flight until March 3rd. As a result, our payload demonstration flight is now scheduled for March 18th, and we need to ensure that our payload is ready before that date. It's important to adjust our plans according to launch windows to ensure a successful demonstration.

3 Vehicle Criteria

3.1 Design and Construction of Launch Vehicle

3.1.1 Final Locations of Separation



The launch vehicle has two points of separation. The first separation point is located between the lower tube and the coupler. They are held together by three nylon 4-40 shear pins. The second separation point is located between the upper tube and the nose cone shoulder. They are held together by four nylon 4-40 shear pins. All sections after separation are connected by using a kevlar shock cord which are tethered to U-bolts on all connections. There will be two black charges on both sides of the coupler for a total of four charges.

3.1.2 Launch Vehicle Features

3.1.2.1 Structural Elements

3.1.2.1.1 Lower Airframe

Properties of Outline Row 3: Carbon Fiber

	A	B	C
1	Property	Value	Unit
2	Density	1800	kg m^-3
3	Isotropic Elasticity		
4	Derive from	Young's Modulus and Poisson's...	
5	Young's Modulus	2.3E+11	Pa
6	Poisson's Ratio	0.27	
7	Bulk Modulus	1.6667E+11	Pa
8	Shear Modulus	9.0551E+10	Pa
9	Tensile Yield Strength	4.9E+09	Pa

Figure 3.1: Carbon Fiber Properties

Properties of Outline Row 3: G10 Fiberglass

	A	B	C
1	Property	Value	Unit
2	Density	1800	kg m^-3
3	Isotropic Elasticity		
4	Derive from	Young's Modulus and Poisson's...	
5	Young's Modulus	1.8615E+10	Pa
6	Poisson's Ratio	0.12	
7	Bulk Modulus	8.1645E+09	Pa
8	Shear Modulus	8.3103E+09	Pa
9	Tensile Yield Strength	2.62E+08	Pa

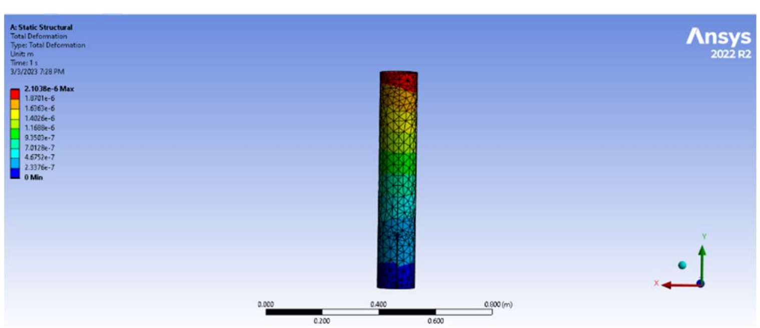
Figure 3.2: G10 Fiberglass Properties

Properties of Outline Row 3: PETG

	A	B	C
1	Property	Value	Unit
2	Density	1270	kg m^-3
3	Isotropic Elasticity		
4	Derive from	Young's Modulus and Poisson's...	
5	Young's Modulus	2.2E+09	Pa
6	Poisson's Ratio	0.25	
7	Bulk Modulus	1.4667E+09	Pa
8	Shear Modulus	8.8E+08	Pa
9	Tensile Yield Strength	5.22E+07	Pa

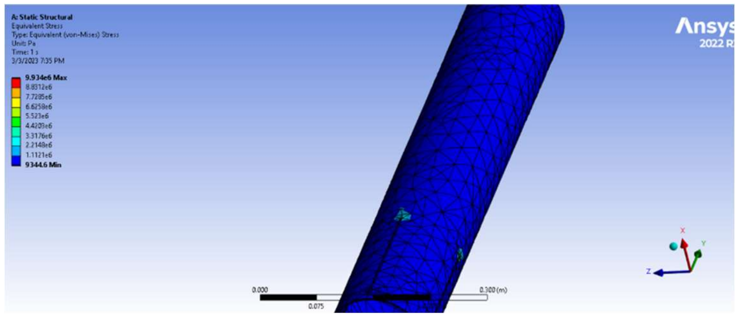
Figure 3.3: PETG Properties

To mimic the force that the lower body frame will undergo, separate FEA's will be conducted in each part where the force will be precisely placed. The first component that the FEA was conducted on was the lower body tube. It will have two forces, one from the motor pushing against the centering rings which would push against the upper face of the fin slot and the force that will be coming from the upper body tube. They will have a value of 500 N and 800 N, respectively.



As shown above, the maximum deformation that the lower body will have will be at the upper part of the lower body tube. This is because the force from the upper body tube and the force that the motor exerts from below will meet at this area. The deformation has a max value of 2.1 x 10^-6m and the least value will be

2.3x10^-7m. This is relatively low compared to the size of the lower body tube therefore its chosen material and design is justified.

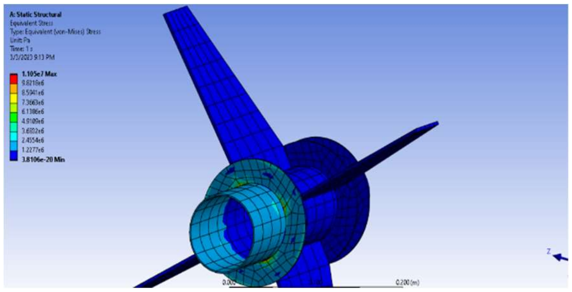


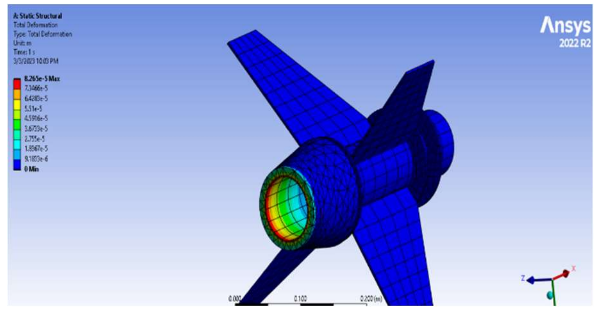
Additionally, the maximum stress will be concentrated on the upper face of the fin slots. This is expected due to cracks and edges being the concentration for stresses. However, the deformation around this area is very low with an approximate value of 2.33 x 10^-7m so it will not raise any problems during its use.

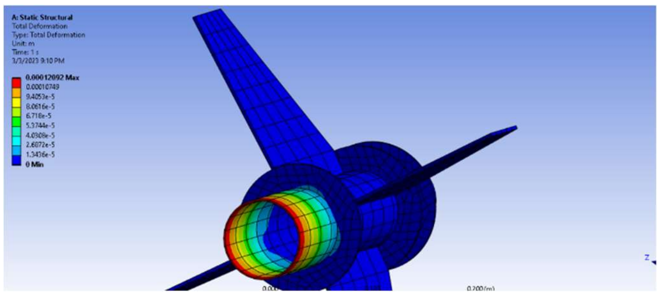
3.1.2.1.2 Motor Mount Assembly

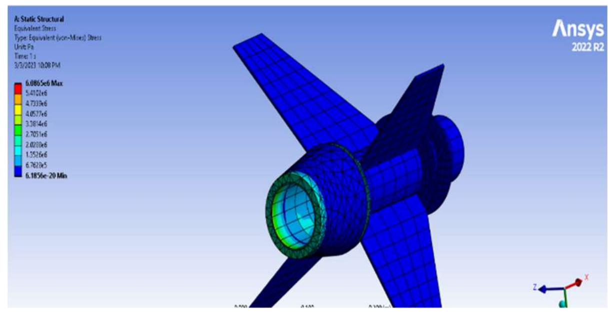
The centering rings will also experience an immense amount of force because it's connected to the motor mount. It is a key factor for the stability of the fins and for holding the motor tube in place. This means that with the generated thrust of the motor, the centering rings will most likely absorb some of the force. When FEA was conducted, there were three total areas of interests for force placement. The first placement was at the top of the lower body tube where it experiences the force from the upper body tube. The second placement was at the fins where it encounters pressure from the air. Lastly, the force from the motor will be placed at the bottom of the motor mount. As shown from the FEA, the maximum stress will be on the contact area between the first centering ring and the motor mount. It will experience a maximum stress of 1MPa but its deformation will have a value of approximately 2.69 x 10^-7m. It can be observed that while it does take most of the force from the thrust generated by the motor, it performs very well due its relatively low deformation. This is ideal in this situation because it is made out of the strongest materials in the lower airframe (G10 Fiberglass) and prevents any stress concentration in other weaker parts.

On the other hand, the motor mount is made out of PETG, which has a lower value for its tensile strength. It can be seen in the FEA that the motor mount will deform more with a value of .00012m compared to the centering rings deformation of 2.69 x 10^-7m. Even if the motor mount deforms more than the centering rings, there is no doubt that its deformation is still relatively small and the design for the motor mount assembly is succesful. Lastly, the tailcone will be connected to the motor retainer and the motor mount and because of this, some of the stress will be shared to the tailcone. Even if this was the case, it was observed that it will attain a maximum deformation of 8.26 x 10^-5m and a maximum stress value of 6 MPa. Its material PETG is able to withstand up to 52.2 MPa so 6 MPa is within the safe values for stress. Its deformation is also relatively small so the tailcone was a safe addition to the rocket.



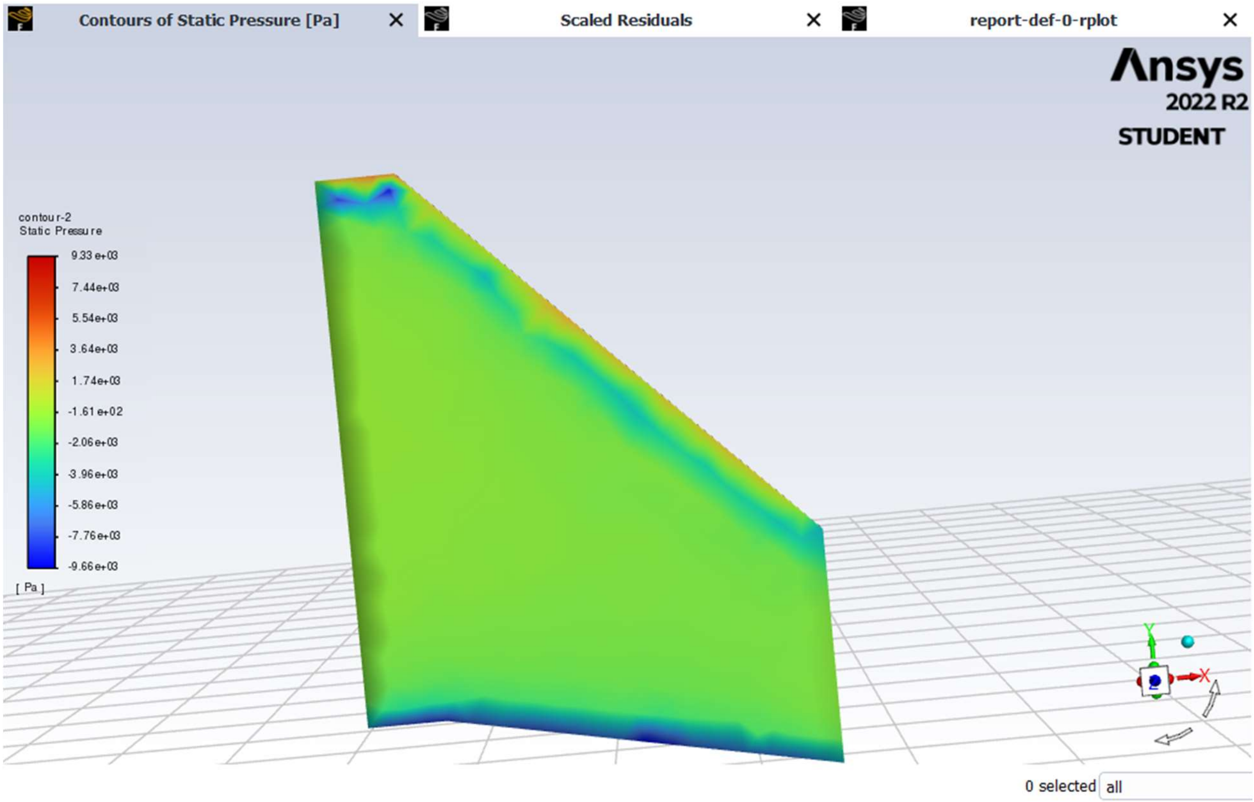






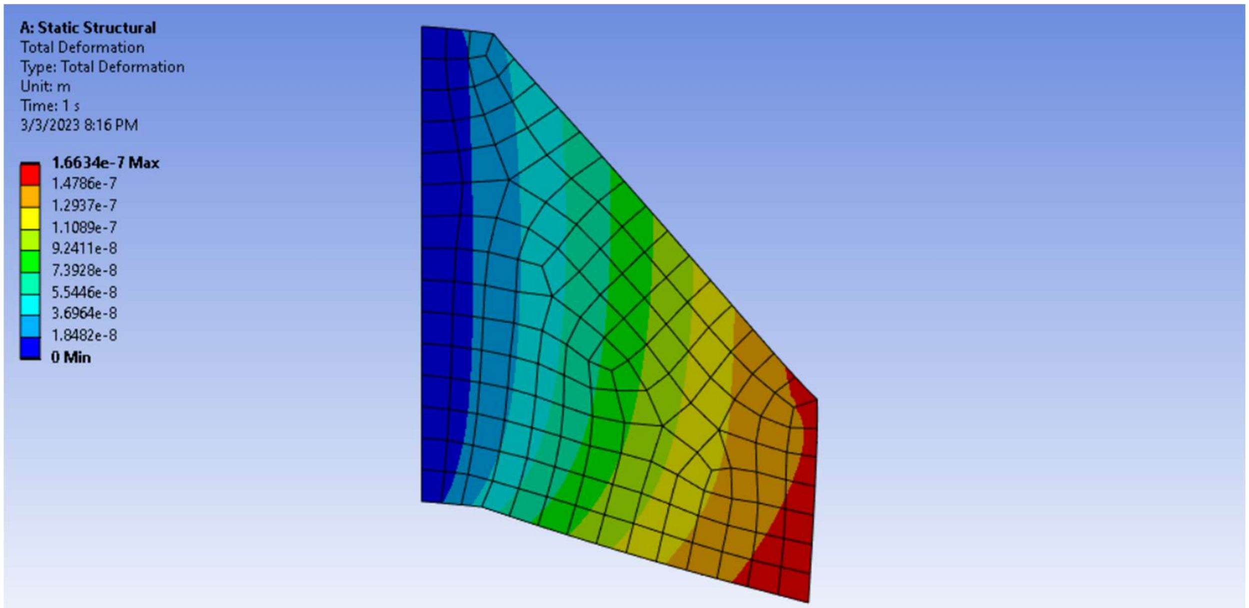
3.1.2.1.3 Fins

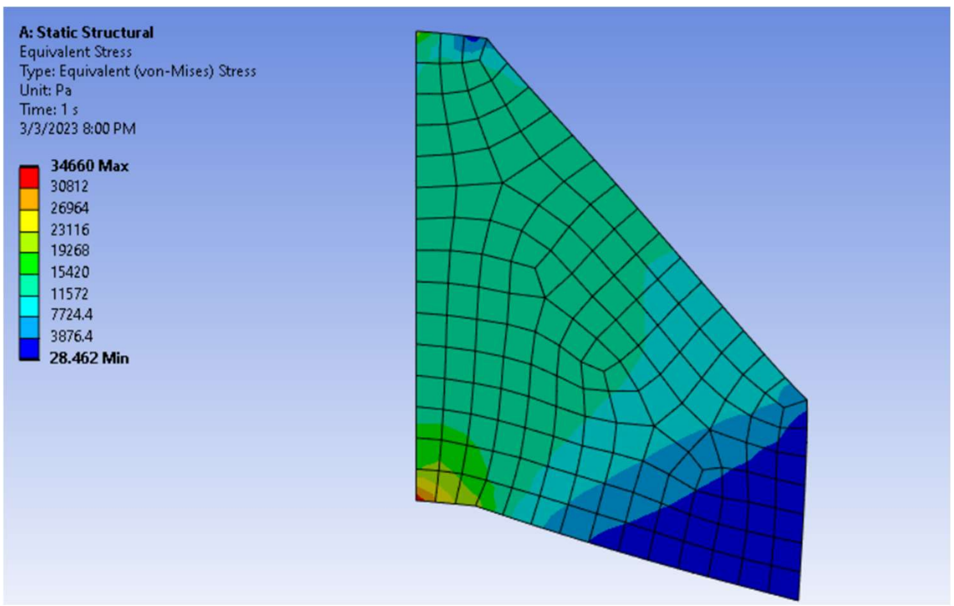
The fins will be one of the most vulnerable parts of the airframe, so it needs to be durable from intense forces either from landing or from the air. To be able to see the amount of force that the fins will be undergoing throughout its flight, CFD was performed on the fins where it was exposed to the flow of air with an approximate speed of 214 m/s. The value of the velocity of air was taken from OpenRocket. According to the CFD, it was shown the upper section of the fins will be exposed to a maximum pressure value of 9330 Pa, while the majority of it will be exposed to lesser pressure.



Taking the maximum pressure value into Ansys, it showed that the fins will have a maximum deformation of 1.66 x 10^-7 m. This deformation will occur at the farthest section of the fins from the body as shown in the figure below. This is because it will be the easiest area to move due to its distance from the lower body tube. However, this is still a safe value for the deformation of the fins and this FEA ensured that the fins will be safe throughout the flight, even at its maximum velocity encounter.

It was also observed that the maximum stress will occur on the fins at the area that was farthest from the point of contact from air. This is the lower area of the fins that is connected to the lower body tube which will experience a maximum 34,660 Pa. This is still within the safe ranges of pressure that the fins can take, especially because it is made from G10 Fiberglass that measures a tensile strength of approximately 262 MPa.





3.1.2.1.4 Bulkheads

As expected, most of the stress will be located in the center of the bulkhead, where it holds the maximum stress value of 4733 psi. Since the material of the bulkhead is made from G10 Fiberglass with a measured shear strength value of 19,000 psi, the maximum stress is still within safe values. This can be further seen in the maximum deformation of the bulkhead, with a maximum value of 0.008 inches. This is a low deformation so the bulkhead will be safe from breaking due to the snatch force generated by the parachute.

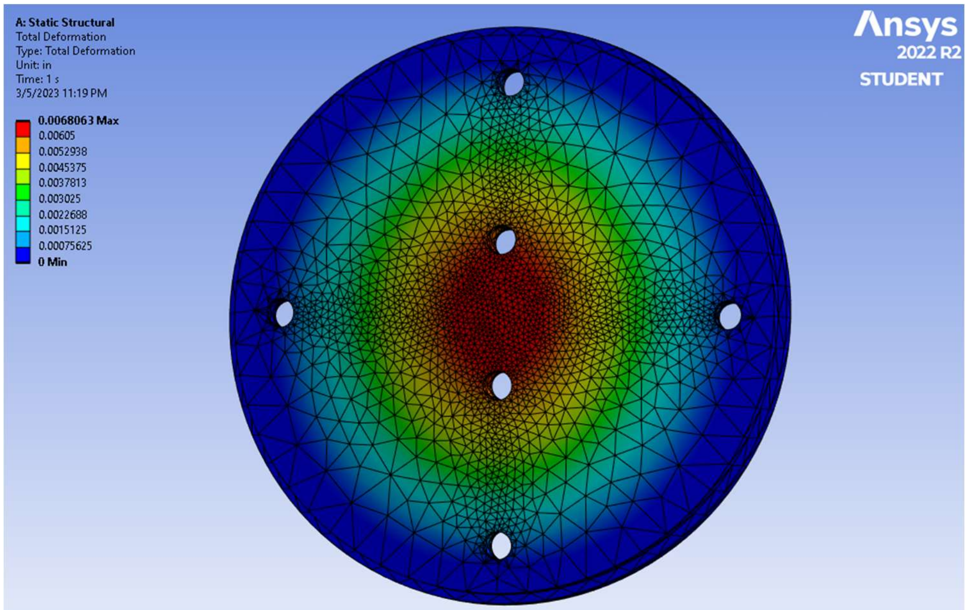


Figure 3.13: Total Deformation on Bulkhead

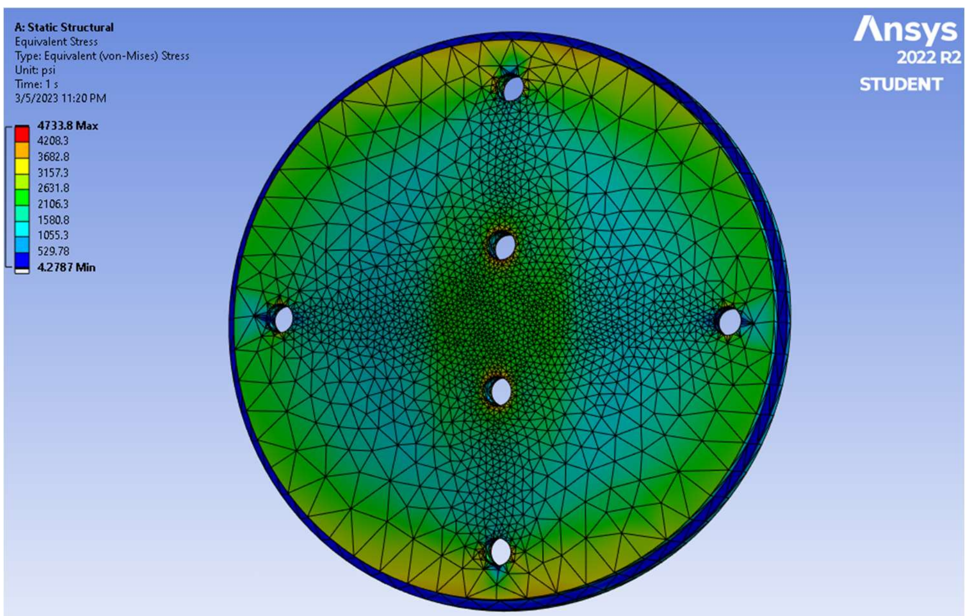


Figure 3.14: Equivalent Stress on Bulkhead

3.1.3 Flight Reliability Confidence

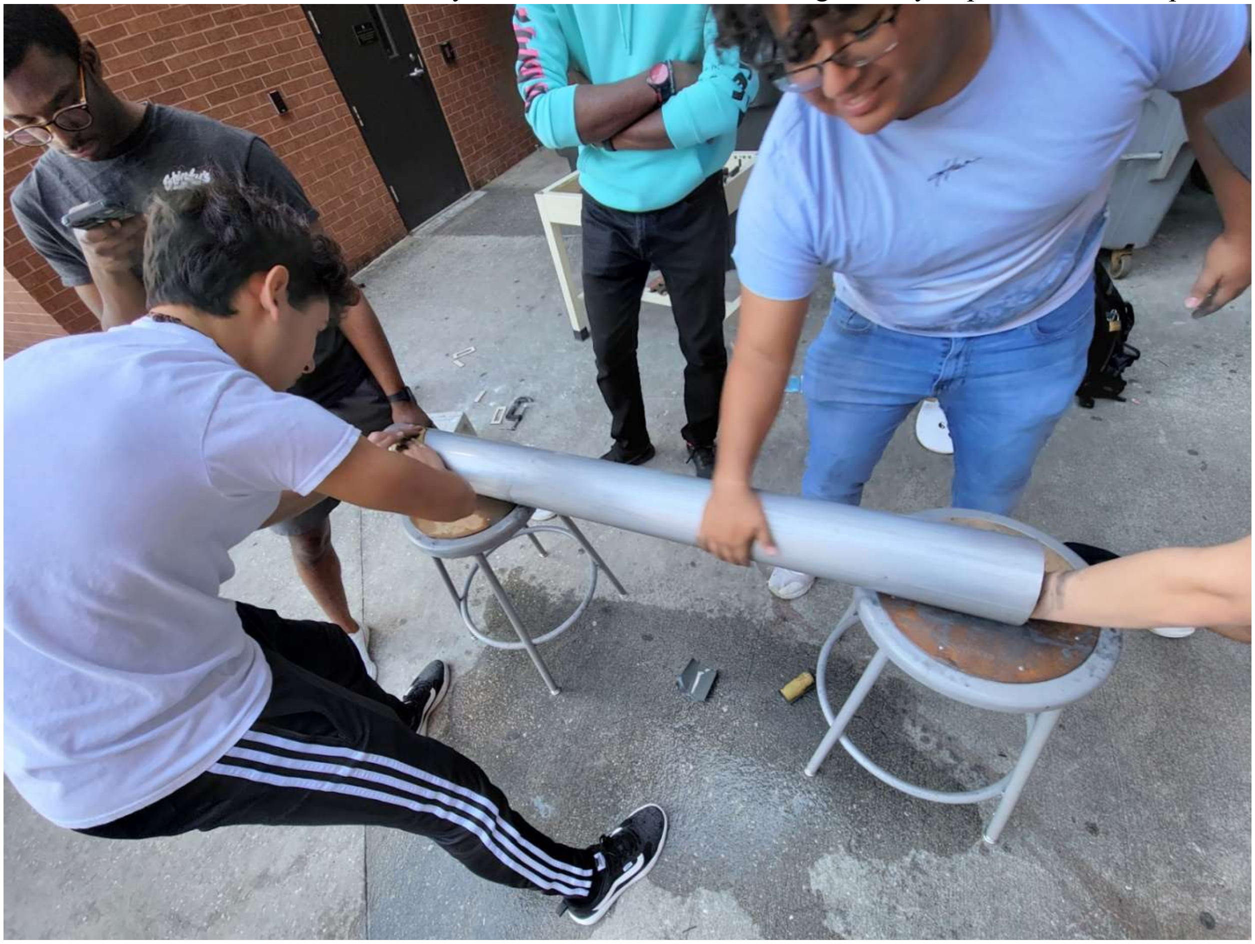
We have high confidence in the success of our rocket due to using familiar manufacturing techniques. We built off of past success with other projects we have done in the past. We have done several ANSYS simulations to prove our rocket's design and ensure it will withstand the forces experience during flight. Building off the experience of our mentor we are able to say we have confidence in our design.

3.1.4 Documentation of Construction Process

The following section shows the methodology of our manufacturing process. This section specifically refers to our body manufacturing. The process is shown under the assumption that all materials of components being manufactured were already in stock.

1. Mandrel prep

Wet sand the mandrel, a five-inch radius metal tube, while gradually increasing grit from 120 grit to 1500 until smooth. Apply Bondo putty in large scratches that could result in an uneven surface on the mandrel's body. After Bondo has fully cured, dry sand Bondo with 220 grit sandpaper until the surface is flush with the rest of the body. Wet sand in a similar fashion as stated before to even out any scratches from Bondo sanding and any imperfections from previous sanding.



2. Measuring unidirectional fiber sheets

Verify the diameters and tube lengths of the rocket from engineering drawings, and calculate the width of the body component surface area. Verify direction of the fibers on unidirectional sheets are in the correct direction, so they are running the length of the tube. Ensure measurement marks on fiber sheets are correct lengths and are perfectly straight lines, tape over drawn measurement lines on the side that will not be cut. Cut the carbon fiber sheet with a slight overhang towards the tape if possible, with caution to not cut the tape to reduce the chance of fraying.

3. Measure carbon fiber sleeves

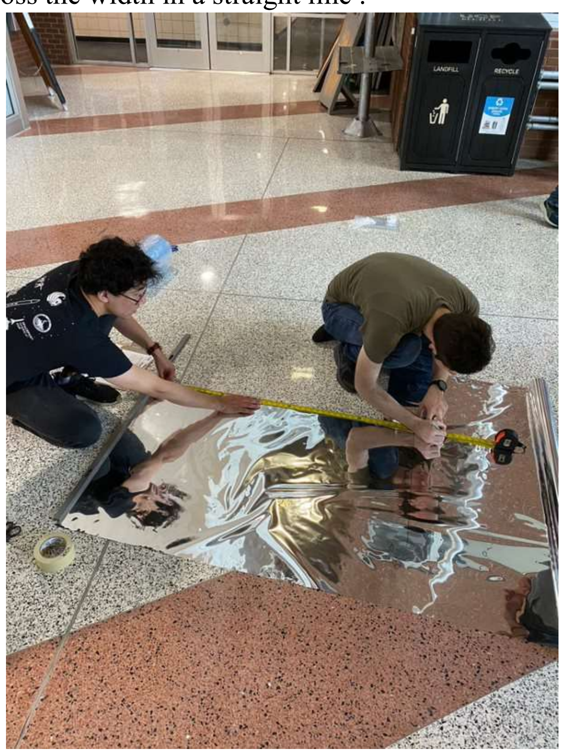
Stand the mandrel up vertically, and slowly expand the diameter of the carbon fiber sleeve to allow it to slide over the mandrel. When it is to its desired length on the mandrel, apply light pressure to lengthen the sleeve to constrict it to the diameter of the mandrel. Mark where to cut based on the length of the tube that is to be cut, and cut with a slight overhang.

4. Measure fiberglass sheets and sleeves

Trace around a template measured to half of the surface area of the nosecone, and cut on the outside of the perimeter. Measure the sleeve length in a similar process to the carbon fiber sleeves.

5. Measure and cut mylar sheets and heat-shrink sleeves

In a similar fashion to how the carbon fiber sheets were cut; measure, trace, and cut the mylar sheets. Measure the heat shrink to the same length, and cut across the width in a straight line .



6. Wetlay tubes

Apply and buff Brasso onto the surface of the mandrel. Apply liquid car wax evenly across the surface of the mandrel and wait for it to harden. Follow this with dry car wax on the surface. Wrap mylar over the car wax, ensuring the mylar is smooth with no creases or bumps. Seal the seam of the mylar with packaging tape. Apply three layers of frekote with a shop cloth, two vertically and one radially. Brush epoxy resin as an initial layer of the wet laying process. Expand a sleeve over the epoxy and smooth out to cover the desired length ensuring the fibers do not bend in their direction. Brush epoxy over the sleeve, and wrap a sheet over the epoxy. Ensure epoxy is spread between the layers of the sleeve and sheet seam and the seam of the sheet itself. Brush more epoxy over the sheet, slide the last sleeve over epoxy identically like before, and brush epoxy over the sleeve. Slide on a heat-shrink sleeve once the final epoxy pot is fully depleted, and apply heat from a heat gun to the heat-shrink to apply pressure to carbon and prevent it from drying out.

7. nosecone mold prep

Wet sand the mold in a similar fashion to the mandrel to ensure a smooth surface. Cover the mold with clear plastic packing tape.

8. Wetlay nosecone

Apply frekote onto the tape in a similar manner to the mandrel, and brush epoxy resin as an initial layer across the nosecone mold. Apply sheets and epoxy continuously until four total layers have been laid. Then lay two fiberglass sleeves, one of a smaller diameter to account for the tip of the nosecone, over the sheets and paint on more epoxy. Slide on a heat-shrink sleeve once the final epoxy pot is fully depleted, and apply heat from a heat gun to the heat-shrink to apply pressure to carbon and prevent it from drying out.

9. Remove the composites from their molds

Remove all heat-shrink from the composites after at least 18 hours have elapsed from the heat-shrink compression. Apply heat from a heat gun to either melt the car wax or deform the nosecone mold, depending on which composite is being worked on. Once the car wax is melted, fill the mandrel with dry ice to rapidly chill, shrink the mandrel, and pull the carbon off smoothly. Once the nosecone mold is deformed enough to slide the fiberglass off, remove the nosecone from the mold.

10. Measuring and cutting tubes, couplers, and switch band

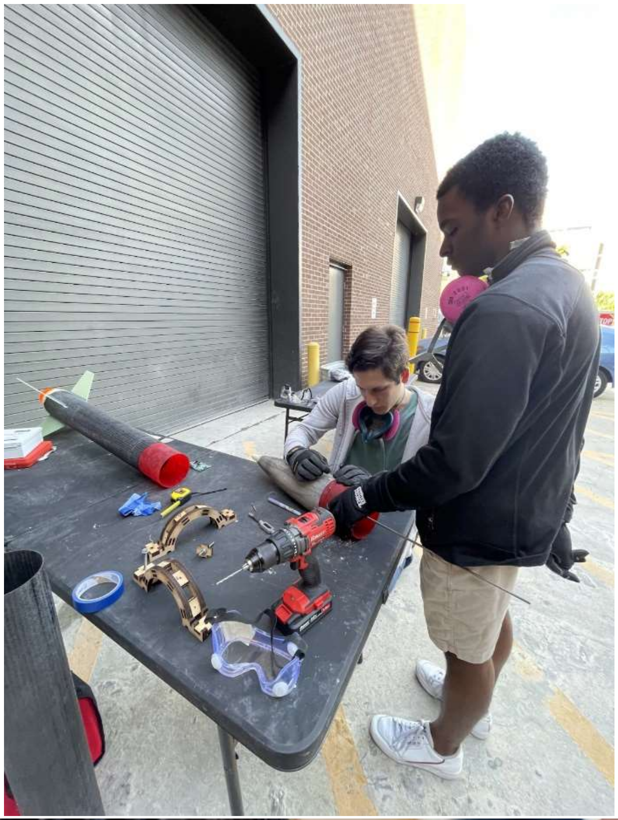
Make safety cuts on the outer edges of the tubes to remove all large sharp edges. Measure tubes and couplers to their intended size on the length of the tube, and mark around the circumference of the measurement. Cut on the outer end of the measurement mark to ensure the correct sizing and enough space for post-processing.

11. sanding tubes, couplers, and nosecone

Sand down all rough edges and surface areas of all components until they can comfortably dry fit together with enough friction to keep it in place but not too much not to allow components to be able to rotate between each other. The surfaces of all components should be smooth to the touch and pose no risk of injury while being handled.

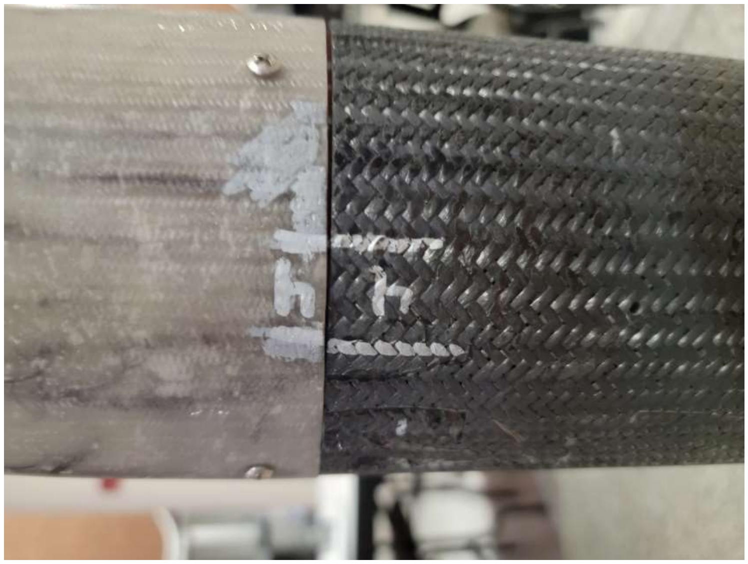
12. Measuring, drilling, and tapping holes

Measure how far from the edge of the tube where a hole will need to be, and draw a dotted circumference across the surface of the tube. Line this circumference with painter's tape, and secure a drilling jig where alignment holes will be aligned with the tape. After all holes have been drilled, tap with its appropriate size tap. Immediately after tapping a hole, ensure a bolt or pin is inserted to ensure proper alignment while tapping all subsequent holes.

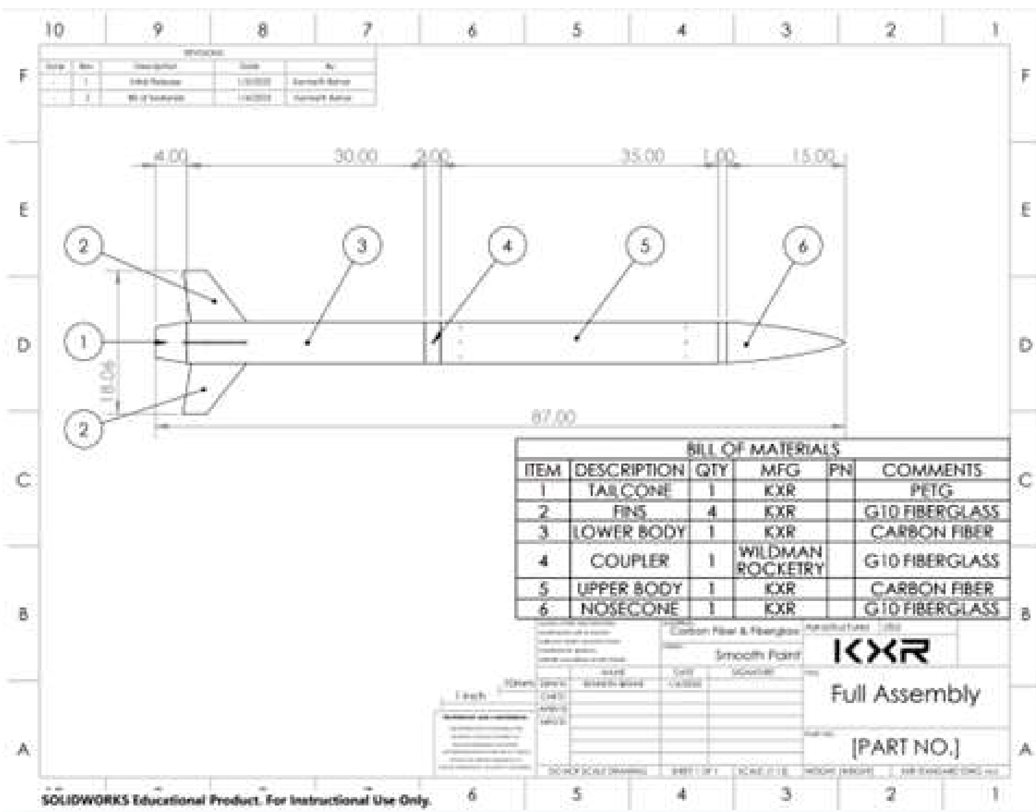


13. drawing witness marks

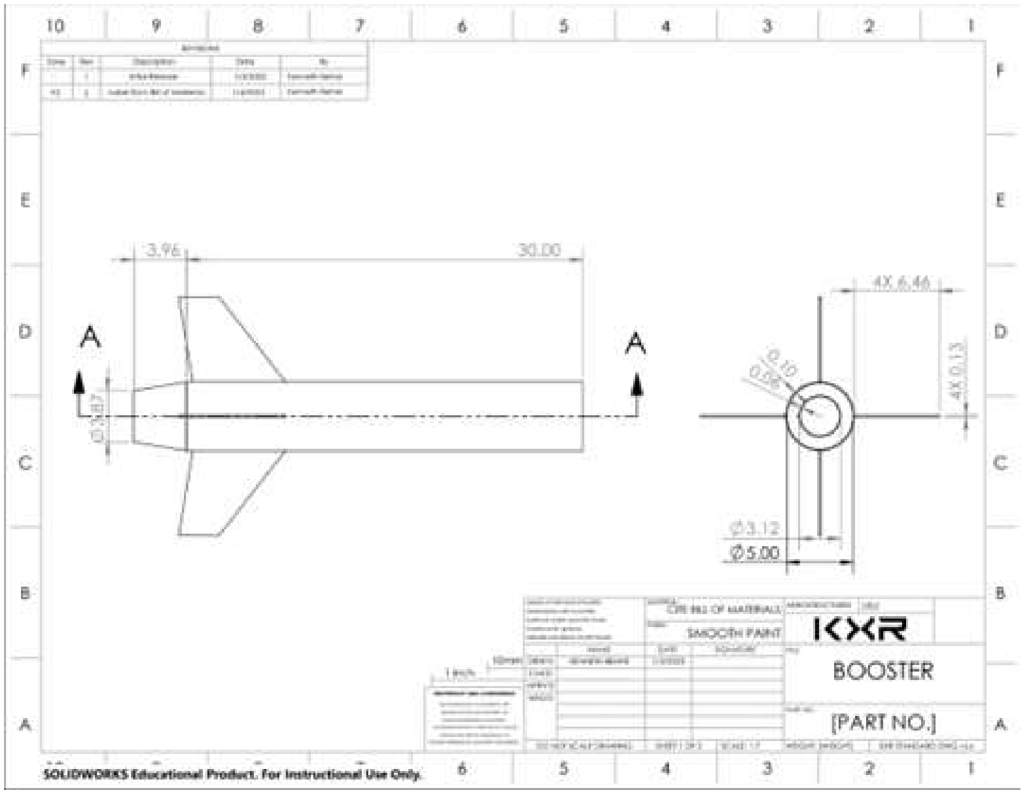
After all holes have been filled with shear pins and steel bolts, draw and label multiple witness marks to ensure proper reassembly later.



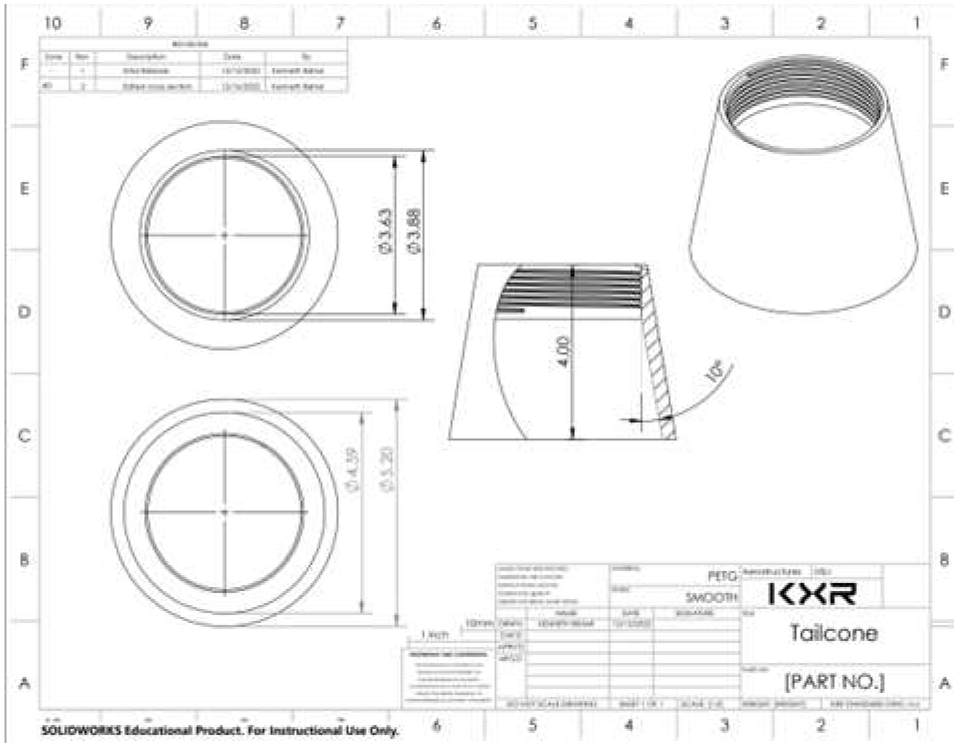
3.1.5 As-built Schematics



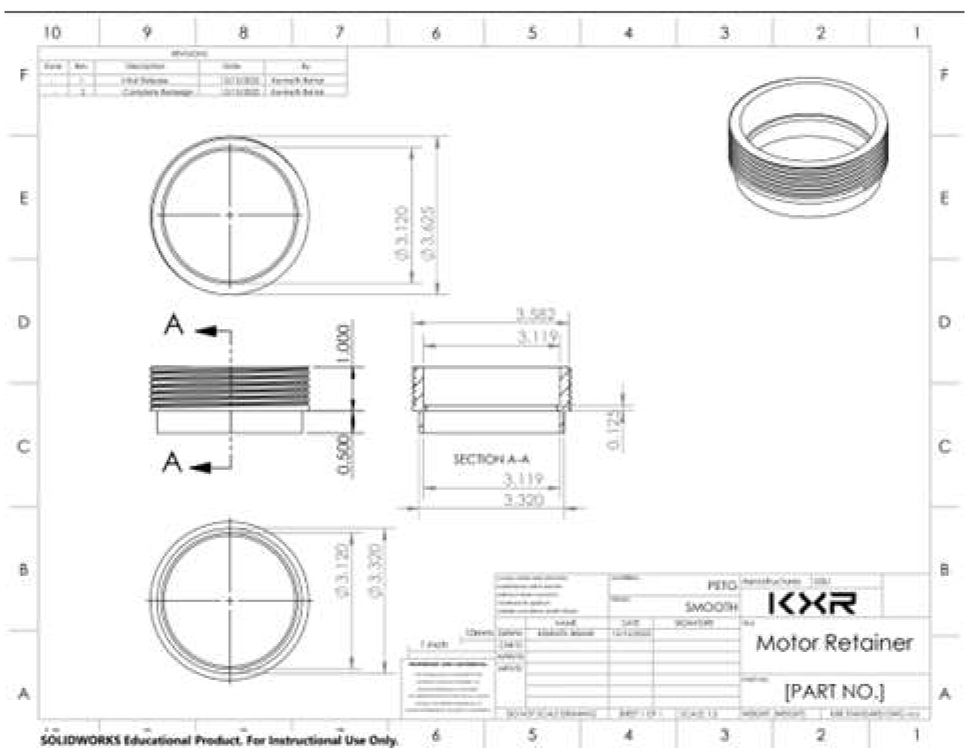
The full assembly depicted above is made primarily of carbon fiber and G10 fiberglass. It consists of three main sections: the lower body, upper body, and nosecone. A G10 fiberglass coupler connects the lower and upper body. The lower body features mounts for four fiberglass fins and a 3D printed PETG tailcone. The diagram only illustrates the external parts and their measurements.



The booster or lower airframe is comprised of the lower body tube, fins, and tailcone. The tailcone connects with the motor retainer to secure the motor in place. To stabilize the motor tube, three G10 fiberglass centering rings are used. The four fins are inserted into spaces between the first two centering rings, while the third centering ring is positioned slightly higher up the tube. The fin slots are arranged in a quadrangular pattern around the tube.



The 3D printed PETG tailcone can be attached or detached from the lower body tube using bolts. Its end is threaded to enable it to connect to the motor retainer.



The motor retainer, also 3D printed from PETG, is screwed into the tailcone and features a threaded end to attach to the tailcone. The motor will fit against the lip, which is visible at the center of the cross-section view, when attached to the motor retainer.

3.1.6 Difference between Constructed Rocket and Earlier Models

Some differences between the constructed rocket and initial models are that we had to make to the change from pre-preg carbon to wet-laying carbon fiber. We had to make the change because the necessary equipment required to work with pre-preg was broken when we wanted to use it. Another design chance we incorporated was doing tip to tip on our fins in order to ensure that they would surive any hard landings.

3.2 Recovery Subsystem

3.2.1 As-Built and As-Tested Recovery System

3.2.1.1 Structural Elements

3.2.1.1.1 Coupler

The coupler connects the upper and lower body tubes of the rocket and houses the avionics bay. The coupler is made of fiber glass with an outer diameter of 5 in, an inner diameter of 4.82 in, and a length of 12 in. The bulkheads on the top and bottom of the coupler are made out of G10 fiber glass. The Bulkhead has U-bolts "Black-Oxide Steel U-Bolt 1/4""-20 Thread Size, 1"" ID" that connect the coupler to the shock cord. It contains 18 of holes, 7 on each bulkhead, four ¼ in holes for the threaded rods to be secured with nuts, two 3/8in holes for the insertion of the U-bolt, and one 5/32in hole for wiring. Around the coupler in the area where the switch band will be, one 1/4in for the pin, and three 3/16in, 220 degrees apart, pressure holes.

3.2.1.1.2 Switch Band

The switch band is made of carbon fiber, it has an outer diameter of 5.1in, Inner diameter of 5in, and length of 0.88in. It has a 1/4in hole for the pin, and three 3/16in, 220 degrees apart, pressure holes. It’s secured onto the coupler by friction fit and epoxy.

3.2.1.1.3 Bulkheads

Because of the availability of fiberglass within our inventory, we decided to use fiberglass for the bulkheads of the coupler. This will be cheaper than buying another material such as carbon fiber or plywood. Although fiberglass has less tensile strength than carbon fiber, we thought that the decrease in costs is better than the increase in unnecessary tensile strength. The bulkhead will have a diameter of 5 inches and 4.815 inches for its shoulder along with a thickness of .125 inches for both. Since the body tubes’ inner diameter is 5 inches and we chose to have 0% tolerance, we made the bulkheads diameter to be 5 inches. The diameter of 5 inches for the bulkhead is also optimal because it is large enough to fit components within the coupler and it is also small enough to prevent the spread of stress points. Based on the structural analysis from Ansys, the shear stress from the snatch force will be concentrated in the middle. To calculate our snatch force load. At 150 ft/s the maximum snatch force loads the bulkhead will experience is 4500 N. To reduce this, we decided to use a U-bolt with a mounting plate instead of an Eyebolt with a nut and a washer, in order to distribute the force over a shear area of 1 square inch of the plate.

3.2.1.1.4 Switch Holder

The limit switches are mounted onto a PETG plate with m2.5 screws and nuts to secure them in place. There's a secondary PETG plate above the switches with a hole to prevent compression from the plate onto the screws. The PETG plates have a 1/4 the hole for the recovery pin to disarm the system. When the recovery system has all elements and is inserted in the system, the recovery pin is then pulled which arms the system.

3.2.1.1.5 Altimeter Sleds

We chose not to use sleds for the recovery design because we thought that it would be unnecessary to use both the sled and plates. We can utilize the same space by using only the plates. It was also discussed that due to the length of the coupler, the bending forces will be greater within the coupler and the sled will be more prone to these bending forces compared to just using the plates which will have exponentially fewer bending forces acting on it. We want the forces to be distributed along the rods within the coupler and not the sleds or the plate, thus its removal. Also, it was discussed that different altimeters must be in a certain orientation to give the most accurate data. However, the RRC2+ and Stratologger do not require any specific orientation.

Each electronics plate is made for a specific altimeter which has the dimensions of the outline of each respective altimeter as well as the hole placement for each altimeter. For each hole in the altimeter, the plates have been made to have heat set threaded inserts holes to securely fasten the electronics in place. The plate also includes an outline for a battery as well as holes for zip ties to secure the battery in place.

3.2.1.1.6 Attachment Hardware and Heat Shielding

The parachute will have a 3/8-inch-thick quick link attached to the end of it and this will be used to attach the shock cord to the bulkhead. The bulkheads will have a U-bolt so that the forces can be divided between the two bases of the U-bolt instead of an I-bolt where the force will be concentrated in one area. U-bolts will also be using a mounting plate to further distribute the force. A fire-retardant blanket, specifically named Nomex Blanket, will be attached on the shock cord a few feet away from the parachute to avoid any possible tangling and also to protect the parachute from burning due to the black powder charges.

3.2.1.2 Electrical Elements

3.2.1.2.1 Primary and Redundant Altimeters and Batteries

The Primary altimeter will be the PerfectFlite StratoLoggerCF which will be connected to a 9V Alkaline battery. The StratoLoggerCF was chosen due to its high capabilities and small size. Furthermore, the StratoLoggerCF has a low power draw of 1.5ma and has the ability to provide altitude, temperature, battery voltage, and more flight data. This allows us to compare our flight data with telemetries flight computer. The StratoLoggerCF also has a small form factor coming in at two inches in length, 0.84 inches in width, and 0.5 inches in height with a weight of 0.38 ounces.

The redundant altimeter being used is the RRC2+ which will also be wired to a 9v Alkaline battery, which it is optimized for. The RRC2+ was chosen due to its simplicity and capability to report our peak altitude. The dimensions of the RRC2 are 2.28 inches in length and 0.925 inches in width. Additionally, the RRC2+ is lightweight coming in at about 0.323 ounces. Furthermore, the RRC2+ is a cheap option costing about $50. To add on, the RRC2+ has an output current of 5 amps which is compatible with the battery we are utilizing.

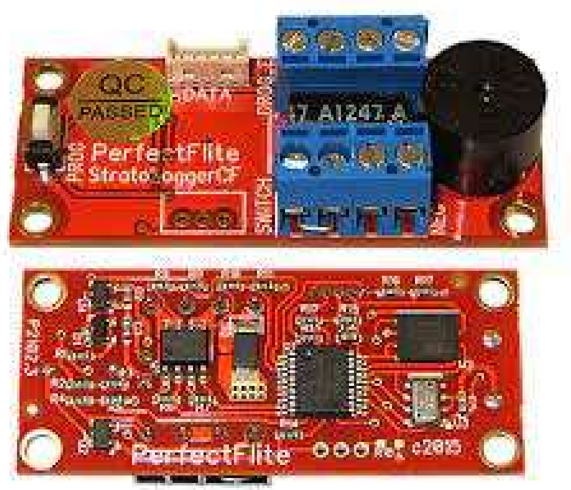


Figure 3.15: PerfectFlite StratoLoggerCF

Figure 3.16: MissileWorks RRC2+

3.2.1.2.2 Switches

The electronics bay will house two limit switches for each altimeter in the pin module. Two adjacent plates will be placed making up the pin module. These plates will have a gap of 0.25 inches for the arming pin to go into. The limit switches will be "sandwiched" between the two with the removable pin holding them down. When the pin is released, the switches activate and send a signal to the altimeters. This arming mechanism is designed to meet the requirements for section 3.6. of the handbook, force exerted on the pin by the switch also ensures that removing the pin would require clear intention and prevent any safety concerns. As for the specific limit switches, we will be using the SS-5GL2. These will have a unit weight of 0.056 ounces and dimensions of 0.787in*0.394in*0.236in.

Figure 3.17: Limit Switch

3.2.1.2.3 Wires

The limit switches are connected to the altimeters via simple wires. The limit switches come pre-wired for direct connection to the altimeters switch terminals for quick attachment. Simple wires are used to connect the altimeters to the terminal blocks and are run along a series of holes strategically placed throughout the assembly to reach the terminal blocks on both bulkheads.

3.2.1.2.3.1 Exterior Terminal Blocks

Primary and a redundant terminal block on each bulkhead, for a total of four terminals. The altimeter wire goes through the 5/32in hole in the bulkhead to the terminal. The terminal blocks connect the wires from our altimeters to the wire of the ejection charges.

3.2.1.3 Redundancy

Redundancy is achieved in the recovery system through two separate altimeters with entirely independent circuits. Each circuit includes an altimeter, either the Stratologger CF or RRC2+, connected to a 9V alkaline battery and a limit switch. Each altimeter is then wired to the terminal blocks on the front and aft bulkheads for their respective main and drogue charges.

3.2.1.4 As-Built Parachute Sizes and Descent Rates

3.2.1.4.1 Parachutes

Our drogue chute was chosen to be a 1 ft diameter Rocketman's Parabolic Nylon Parachute. This chute was chosen based on its ability to provide enough drag to slow the rocket down to a safe speed for main chute deployment, while not causing the rocket to touch down after 80 seconds. Our main chute was decided upon by our ideal ground hit velocity, which was found to be approximately 21.3 ft/s. By doing multiple simulations in OpenRocket we were able to determine that a 7 ft. Diameter Rocketman's Parabolic Nylon Parachute was the best option to use as a main chute to reach our target ground hit velocity. We did encounter an issue in our choice of chutes; the OpenRocket simulations that were ran calculated the velocity at main chute deployment to be 143 ft/s which is too fast to be considered safe. We were able to determine that this velocity was calculated as a result of OpenRocket's limitations in that it does not take into account the tumbling of the rocket during descent. This means that our expected velocity at main chute deployment will be much less than what is shown in the OpenRocket simulations. Our choice of drogue and main chutes are able to achieve a descent time of approximately 72.38 seconds which we deem to be ideal. This descent time will mitigate the drift of the rocket while also ensuring an appropriate descent speed.

3.2.1.4.2 Descent Rate Table

Descent Under	Descent Velocity (ft/s)

Drogue	143
Main	21.3

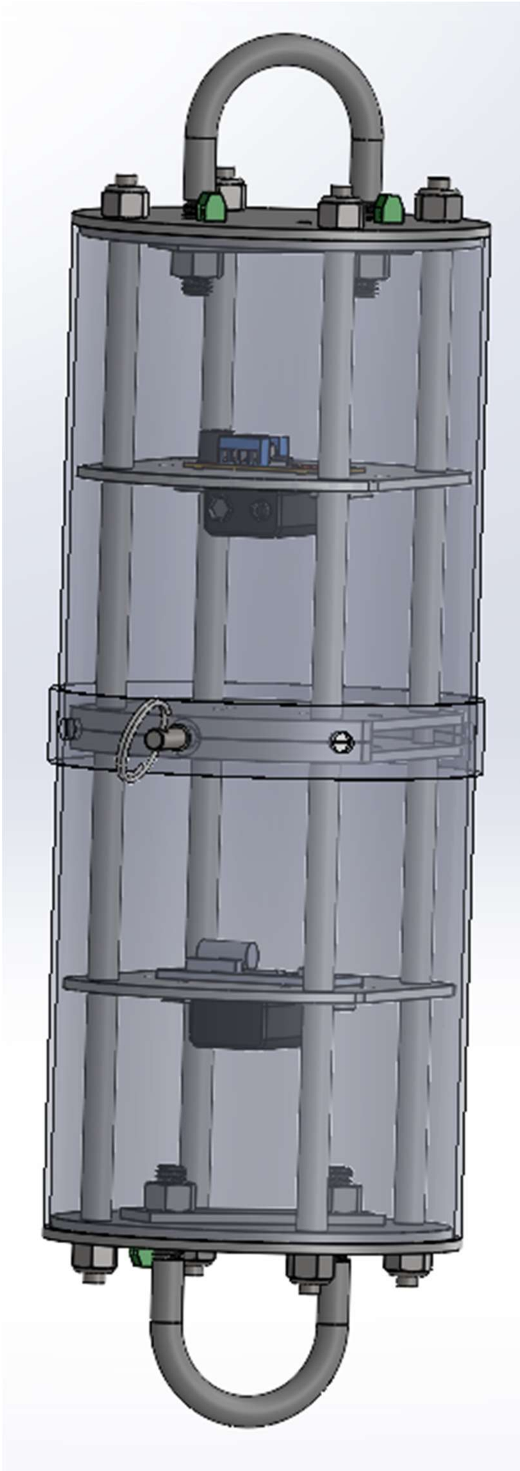
Table 3.1: OpenRocket Descent Rates

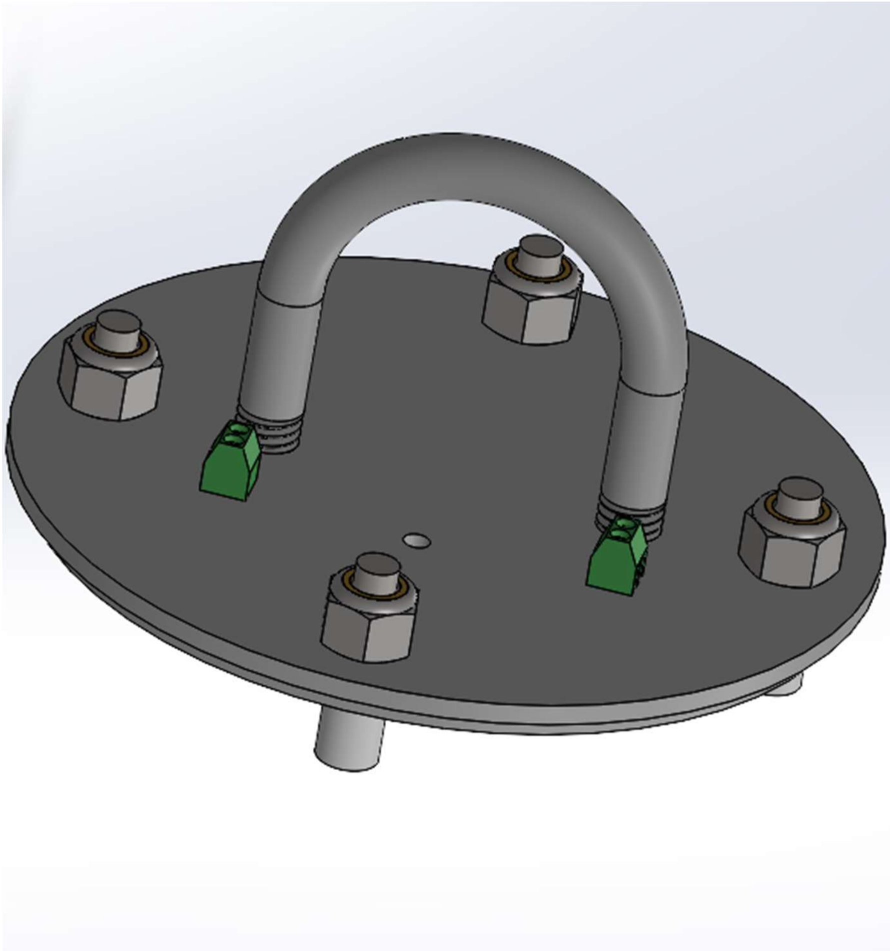
3.2.1.5 Ejection Charges and Sizing

Our ejection charges are free floating black powder charges prepared in the tip of a glove with an eMatch preinserted. The glove tip is filled with black powder and wrapped in electrical tape as a seal. Each charge is then wired to its corresponding terminal located on the nearest bulkhead of the coupler. We have a primary and redundant charge for each parachute. The main charge terminals are located on the upper bulkhead (nose cone side), with both primary and redundant terminals labeled for ease of assembly. The drogue charge terminals are located on the lower bulkhead (motor tube side), also with primary and redundant labeled. FFFFg Black powder was chosen due to its simplicity and reliability. E-matches are easy to wire and are already well integrated with our altimeters, making a combustible powder. Black powder being the most common to use and the most used previously by our group. Our main charge is 4.5 grams while the drogue is 3.5 grams. The redundant charges will be increased by one gram to insure separation.

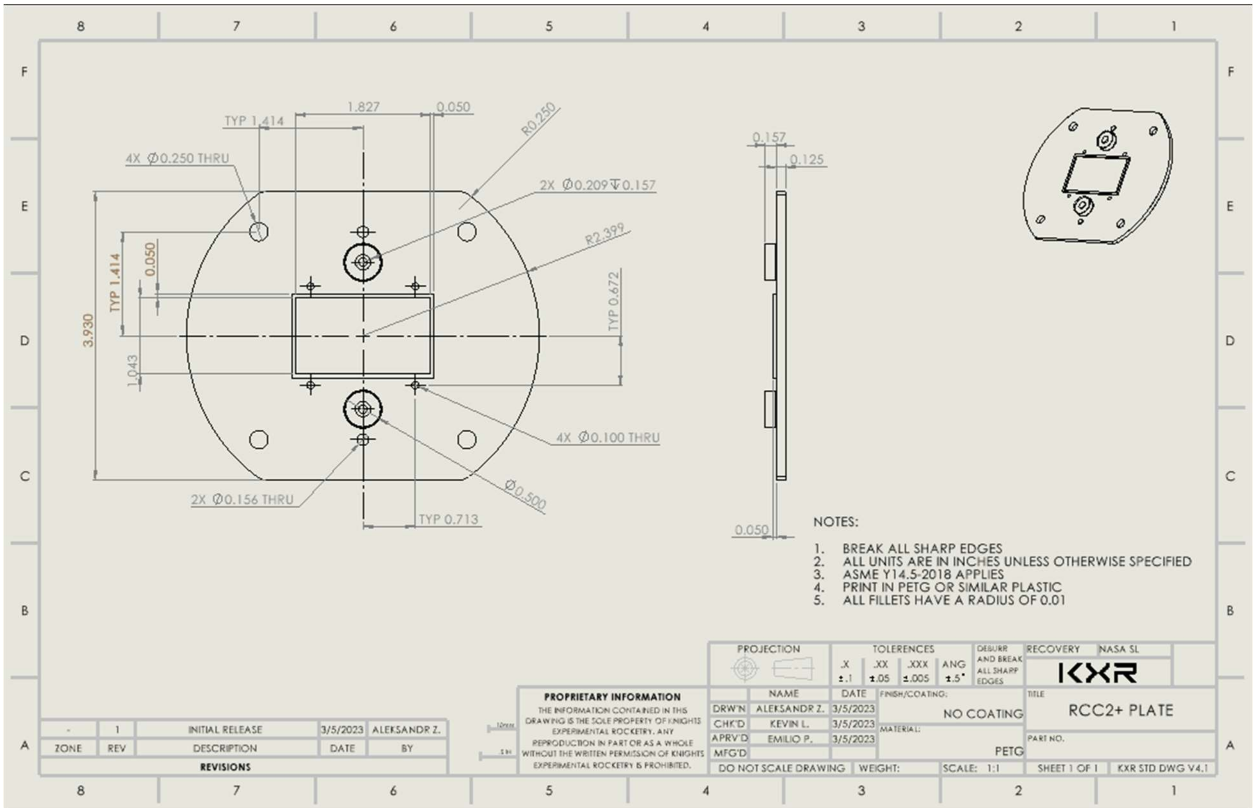
3.2.1.6 Drawings and Schematics of Structural and Electrical Assembly

3.2.1.6.1 Electronics Bay Assembly and Sub-Assemblies (CAD)





3.2.1.6.2 Custom-Designed and 3D Printed Parts (Dimensional Drawings)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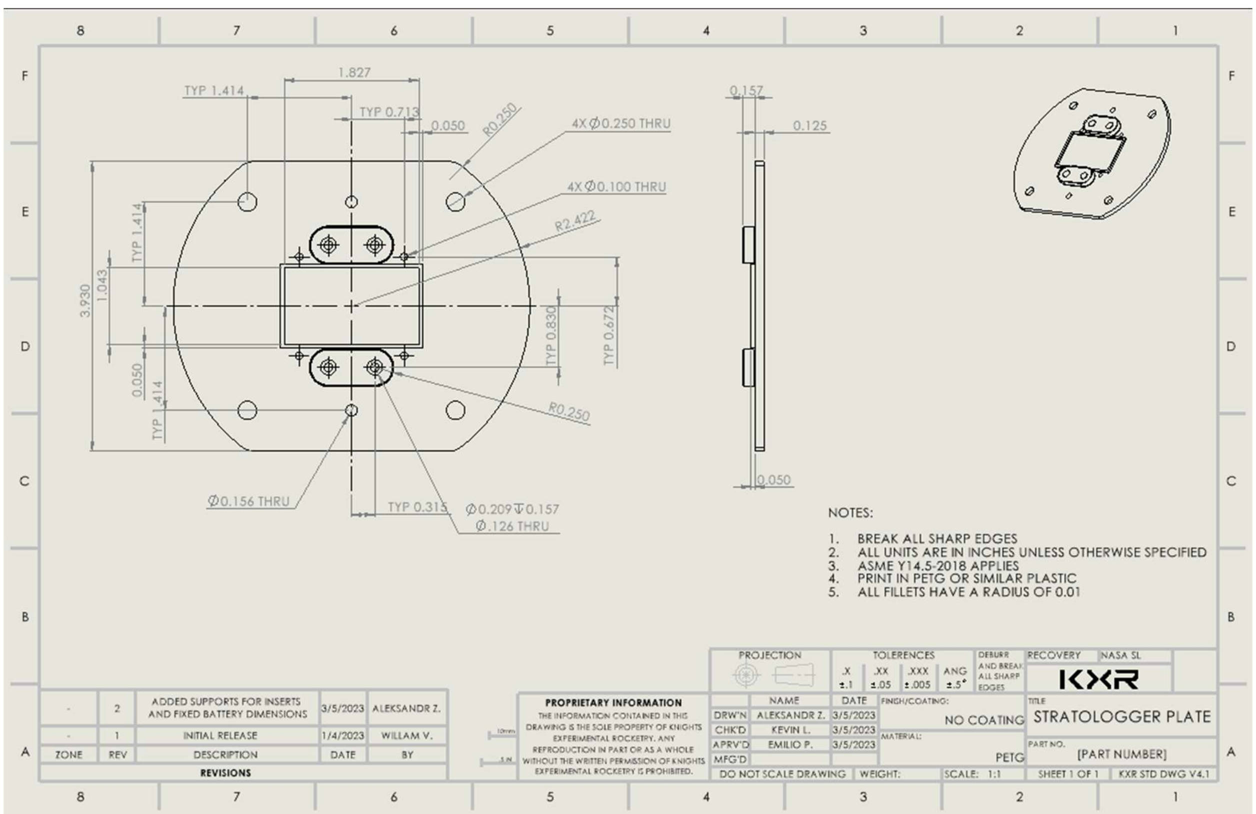
0.050
R0.250
4X ⌀0.250 THRU
2X ⌀0.209 ↧ 0.157
R2.399
TYP 1.414
0.050
3.930
TYP 0.672
1.043
4X ⌀0.100 THRU
2X ⌀0.156 THRU
⌀0.500
TYP 0.713
0.157
0.125
0.050
NOTES:
1. BREAK ALL SHARP EDGES
2. ALL UNITS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
3. ASME Y14.5-2018 APPLIES
4. PRINT IN PETG OR SIMILAR PLASTIC
5. ALL FILLETS HAVE A RADIUS OF 0.01
PROJECTION
TOLERENCES
.X ±.1
.XX ±.05
.XXX ±.005
ANG ±.5°
DEBURR AND BREAK ALL SHARP EDGES
RECOVERY
NASA SL
KXR
PROPRIETARY INFORMATION
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF KNIGHTS EXPERIMENTAL ROCKETRY. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF KNIGHTS EXPERIMENTAL ROCKETRY IS PROHIBITED.
NAME
DATE
DRW'N ALEKSANDR Z. 3/5/2023
CHK'D KEVIN L. 3/5/2023
APRV'D EMILIO P. 3/5/2023
MFG'D
FINISH/COATING: NO COATING
MATERIAL: PETG
TITLE RCC2+ PLATE
PART NO.
- 1 INITIAL RELEASE 3/5/2023 ALEKSANDR Z.
ZONE REV DESCRIPTION DATE BY
REVISIONS
DO NOT SCALE DRAWING
WEIGHT:
SCALE: 1:1
SHEET 1 OF 1
KXR STD DWG V4.1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4X ⌀0.100 THRU
R2.422
3.930
1.043
TYP 1.414
0.050
TYP 1.414
TYP 0.830
TYP 0.672
R0.250
⌀0.156 THRU
TYP 0.315
⌀0.209 ↧ 0.157
⌀.126 THRU
0.157
0.125
0.050
NOTES:
1. BREAK ALL SHARP EDGES
2. ALL UNITS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
3. ASME Y14.5-2018 APPLIES
4. PRINT IN PETG OR SIMILAR PLASTIC
5. ALL FILLETS HAVE A RADIUS OF 0.01
PROJECTION
TOLERENCES
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DEBURR AND BREAK ALL SHARP EDGES
RECOVERY
NASA SL
KXR
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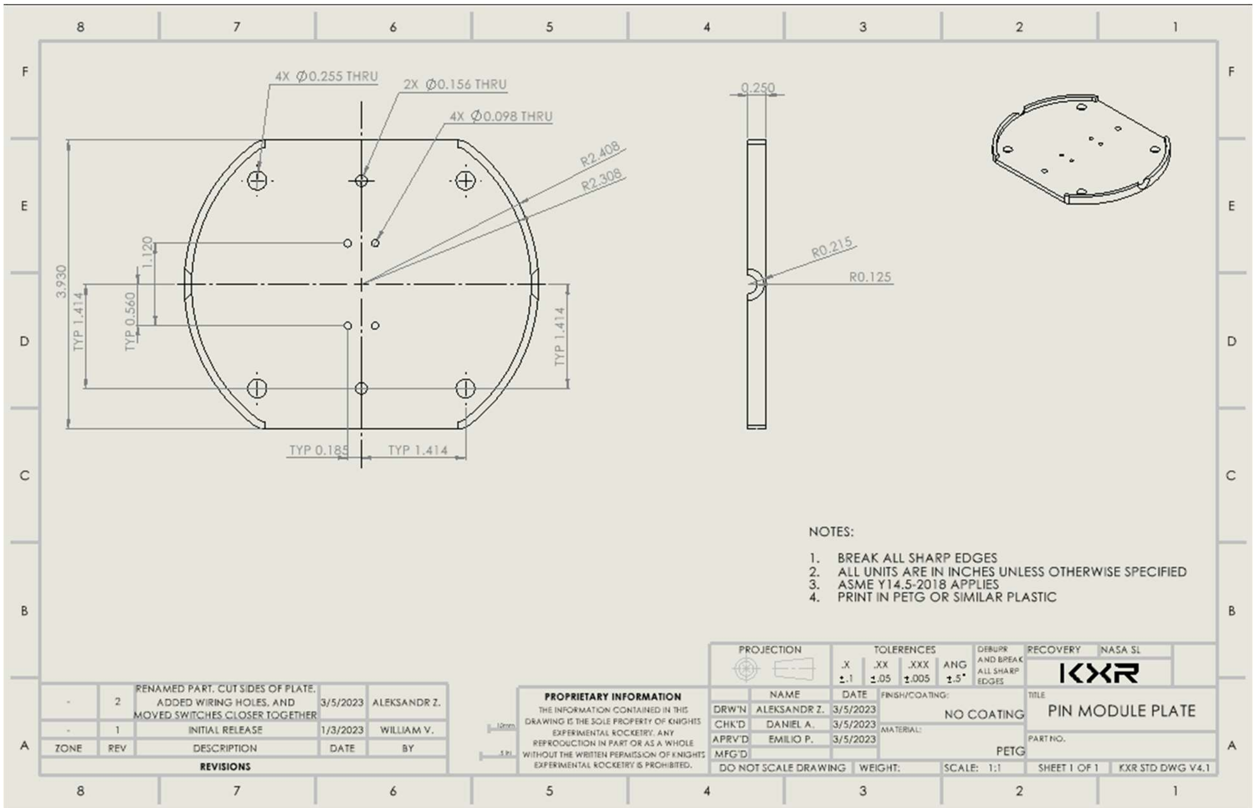
NAME
DATE
DRW'N ALEKSANDR Z. 3/5/2023
CHK'D KEVIN L. 3/5/2023
APRV'D EMILIO P. 3/5/2023
MFG'D
FINISH/COATING: NO COATING
MATERIAL: PETG
TITLE STRATOLOGGER PLATE
PART NO. [PART NUMBER]
- 2 ADDED SUPPORTS FOR INSERTS AND FIXED BATTERY DIMENSIONS 3/5/2023 ALEKSANDR Z.
- 1 INITIAL RELEASE 1/4/2023 WILLAM V.
ZONE REV DESCRIPTION DATE BY
REVISIONS
DO NOT SCALE DRAWING
WEIGHT:
SCALE: 1:1
SHEET 1 OF 1
KXR STD DWG V4.1


4X ⌀0.255 THRU
2X ⌀0.156 THRU
4X ⌀0.098 THRU
R2.408
R2.308
0.250
R0.215
R0.125
3.930
1.120
TYP 1.414
TYP 0.560
TYP 1.414
TYP 0.185
TYP 1.414
NOTES:
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2. ALL UNITS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
3. ASME Y14.5-2018 APPLIES
4. PRINT IN PETG OR SIMILAR PLASTIC
PROJECTION
TOLERENCES
.X ±.1
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.XXX ±.005
ANG ±.5°
DEBURR AND BREAK ALL SHARP EDGES
RECOVERY
NASA SL
KXR
- 2 RENAMED PART, CUT SIDES OF PLATE, ADDED WIRING HOLES, AND MOVED SWITCHES CLOSER TOGETHER 3/5/2023 ALEKSANDR Z.
- 1 INITIAL RELEASE 1/3/2023 WILLIAM V.
ZONE REV DESCRIPTION DATE BY
REVISIONS
PROPRIETARY INFORMATION
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NAME DATE
DRW'N ALEKSANDR Z. 3/5/2023
CHK'D DANIEL A. 3/5/2023
APPRV'D EMILIO P. 3/5/2023
MFG'D
FINISH/COATING: NO COATING
MATERIAL: PETG
TITLE PIN MODULE PLATE
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WEIGHT:
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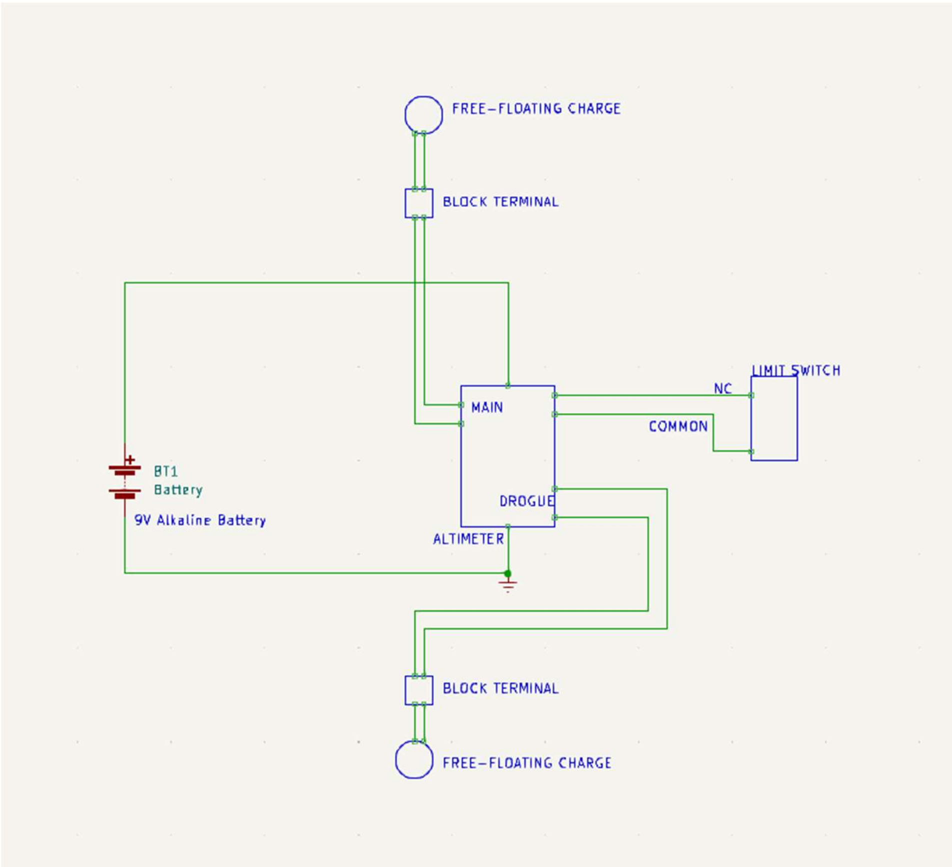
SHEET 1 OF 1
KXR STD DWG V4.1

3.2.1.6.3 Wiring Diagram



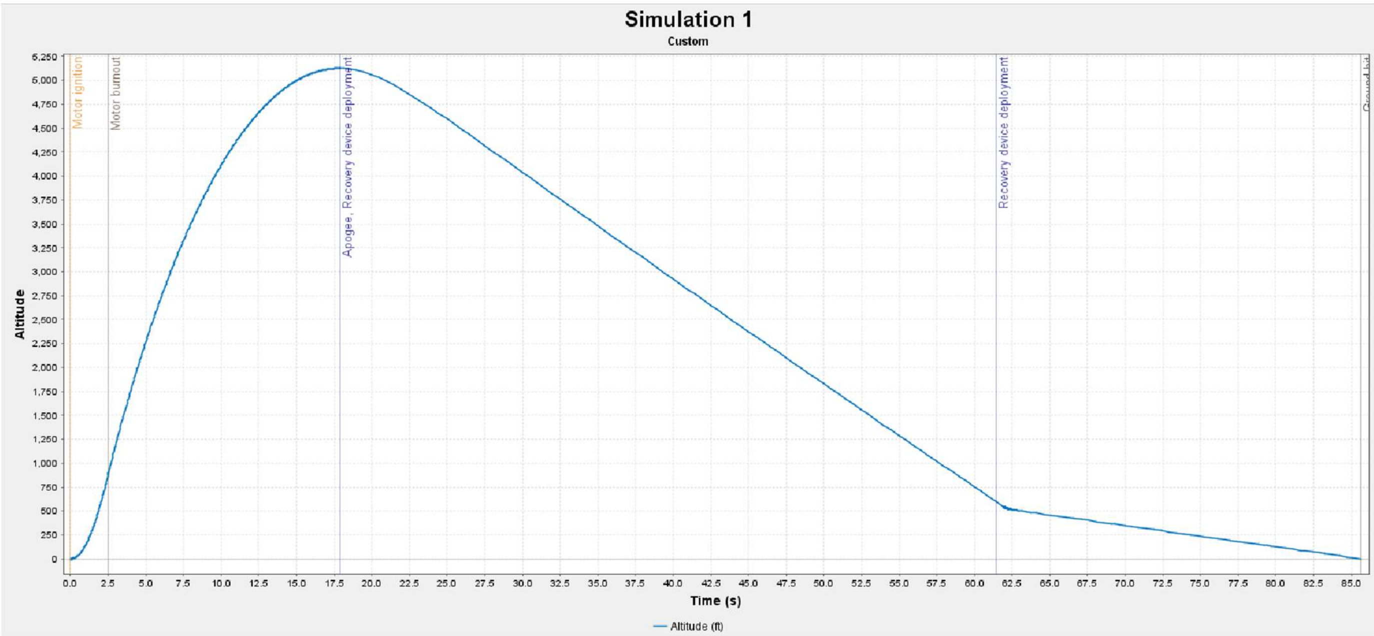
3.2.2 Sensitivity of the Recovery System

While it is possible for our recovery altimeters and e-matches to be negatively affected by certain electromagnetic fields from other devices within the rocket, the separation of the telemetry devices ensures that this will not be an issue. The only electronic components in the coupler are those that are directly responsible for parachute deployment. This means that our altimeters are well protected from the other electronics by the several insulators in the upper body tube. These insulators include the fiberglass bulkheads, the main parachute, and the PILL. We have also ensured that the altimeters will be sufficiently shielded from physical harm as well. By giving each component of the recovery system its own plate within the coupler, we have ensured that no component vibrations will be able to damage one another, and even under severe movement of the main body, the electronics should not experience much force.

3.3 Mission Performance Predictions

3.3.1 Flight Profile Simulations

3.3.1.1 Altitude Prediction with Simulated Vehicle Data



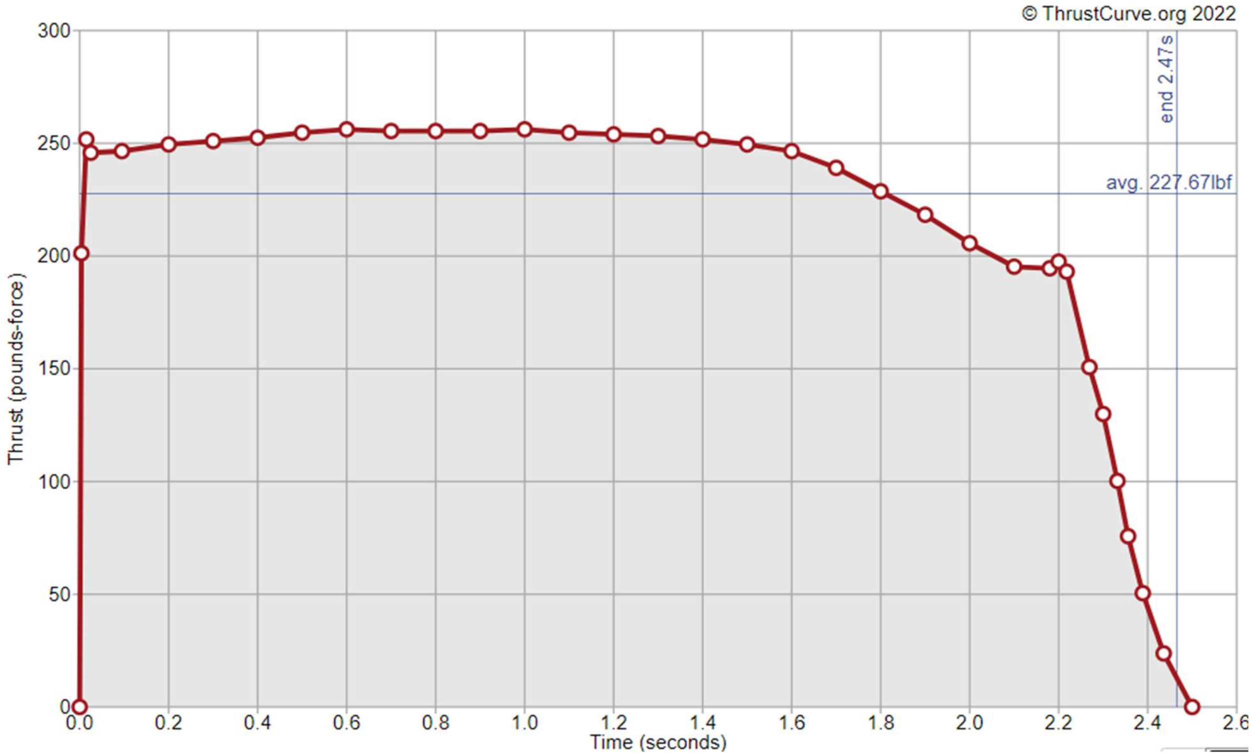
With our updated weight we are reaching a max altitude of 5125 feet. The simulation was done with an angle of three degrees with a wind speed of ten miles per hour. We are significantly lower than our original target of 5507 feet due to the change in the manufacturing process of our carbon fiber tubes.

3.3.1.2 Component Weights

Component	Weight (lbm)
Nose Cone	3.5
Upper Tube (with parachute)	2.7
Payload	5.1
Coupler	2.3
Lower Tube	5.9
Motor	6.6
Total	26.3

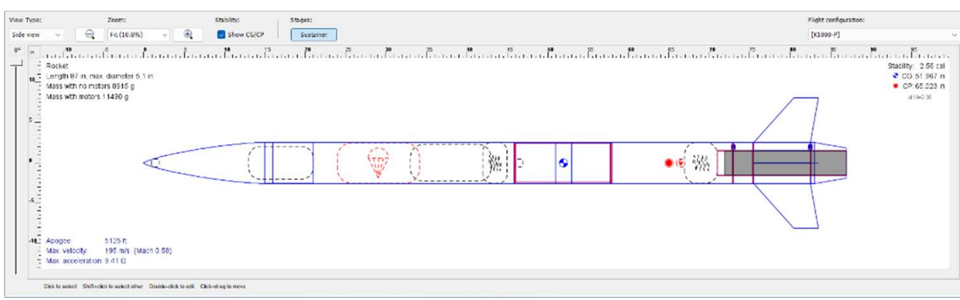
3.3.1.3 Simulated Motor Thrust Curve

Aerotech K1000T	
Total Impulse	2511.5 Ns
Burn Time	2.4 s
Max Thrust	376.33 lbf
Propellant	Blue Thunder



3.3.2 Stability Margin and Center of Pressure/Center of Gravity Relationship and Locations

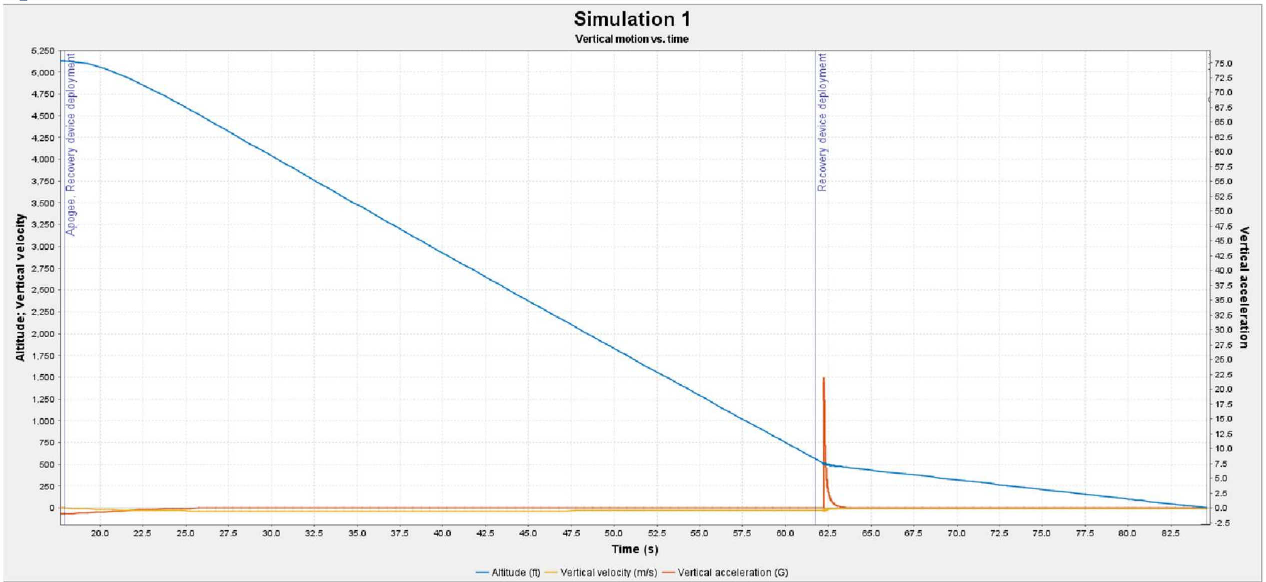
The launch vehicle is now updated with the current Center of Gravity and Center of Pressure after the manufacturing phase. The new CG from the tip of the nose cone is 51.967 inches, and the new CP from the tip of the nose is 65.023 inches. Our new stability is 2.56cal off the launch rail.



3.3.3 Kinetic Energy of Each Section

Kinetic Energy Under Drogue			
Section 1: 620.122 ft-lbf		Section 2: 2672.31 ft-lbf	
Kinetic Energy Upon Landing			
Section 1: 25.58 ft-lbf	Section 2: 40.85 ft-lbf	Section 3: 24.59 ft-lbf	Section 4: 15.84 ft-lbf

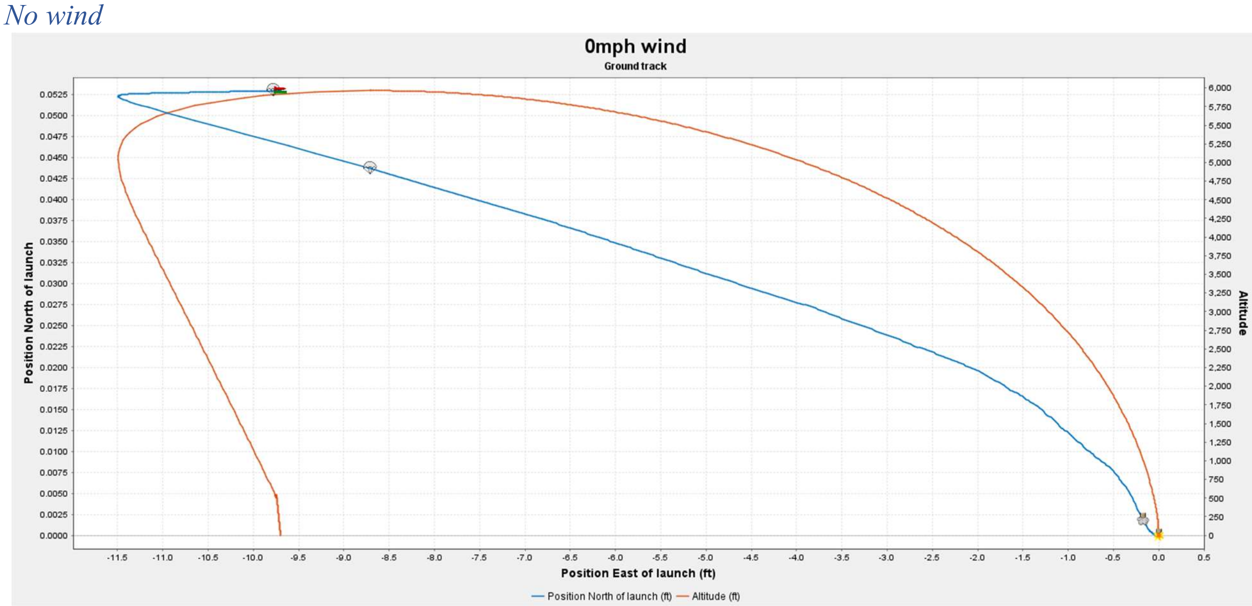
3.3.4 Expected Descent Time for Rocket and Untethered Sections



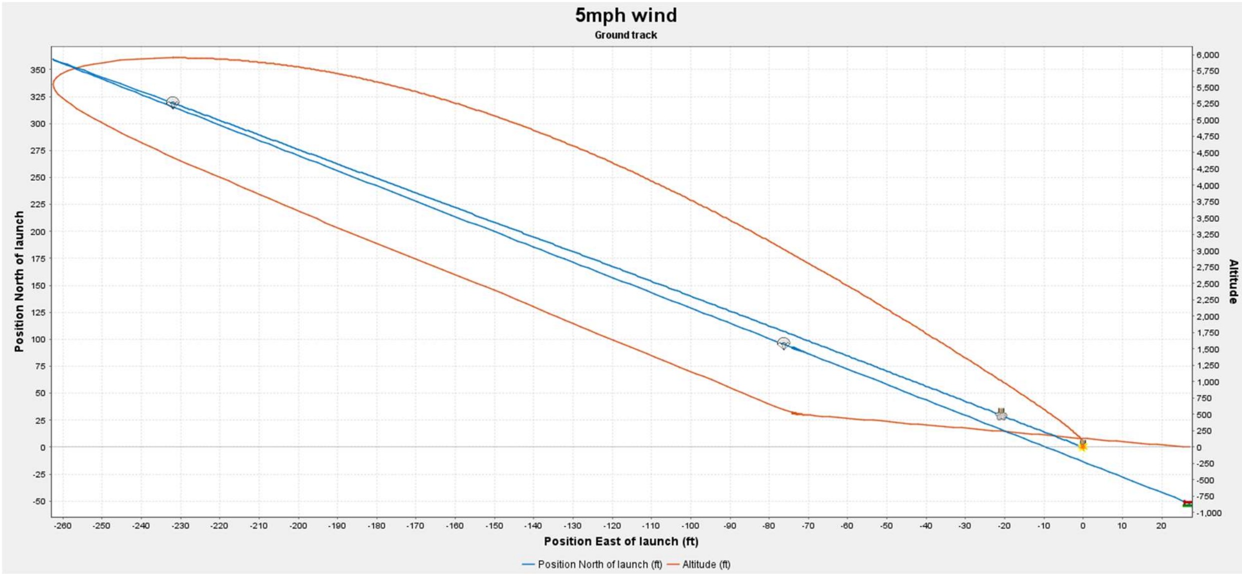
OpenRocket predicts an 66.66 seconds descent time from apogee to landing, which is under the maximum requirement of 90s.

3.3.5 Drift for Each Independent Section

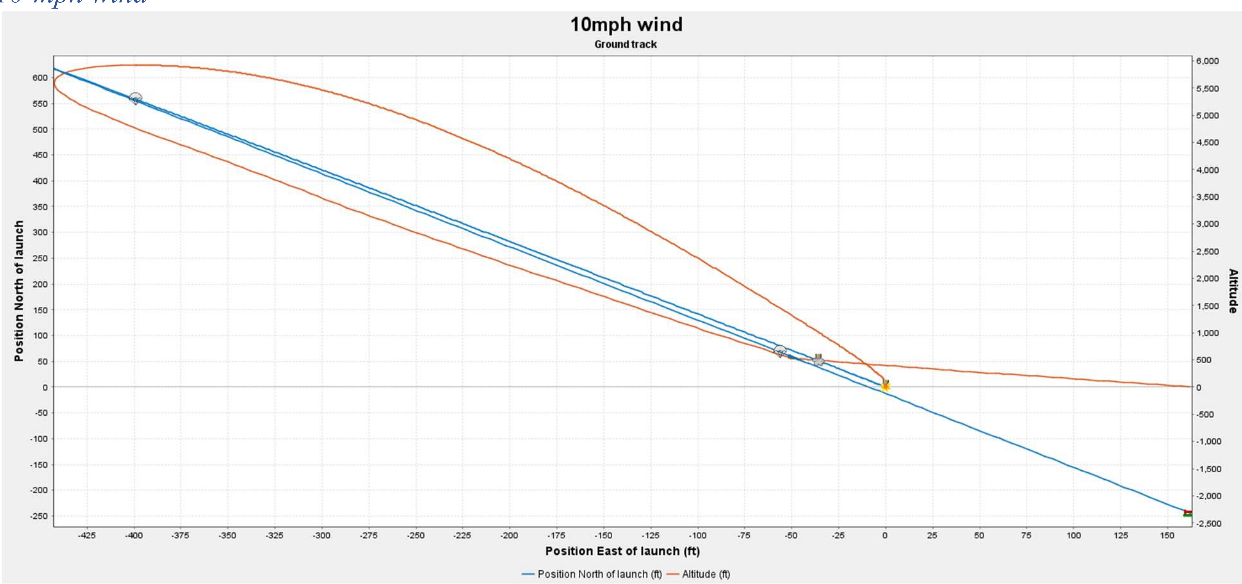
3.3.5.1 No wind



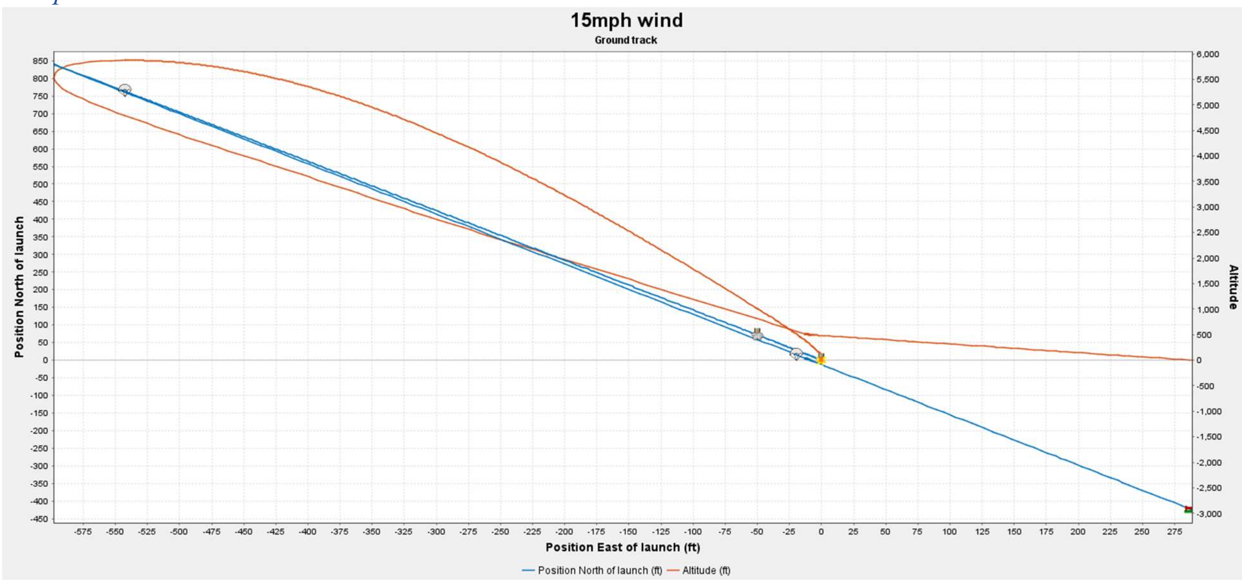
3.3.5.2 5-mph wind



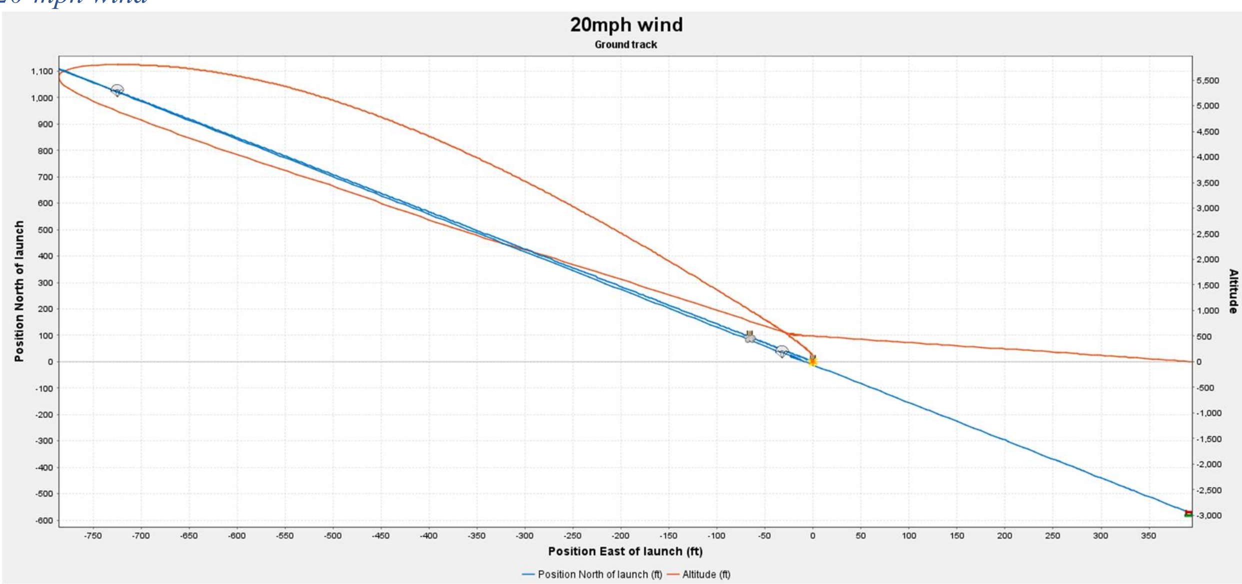
3.3.5.3 10-mph wind



3.3.5.4 15-mph wind



3.3.5.5 20-mph wind



4 Payload

4.1 Payload Criteria

In order to consider our Payload successful, we must meet the requirements outlined in the NASA Student Launch Handbook. Our payload must land safely upon impact with the ground and self-orient itself parallel to the horizon; promptly, the camera must be able to rotate about the z-axis.

Our Payload system will achieve this using a polycarbonate rolling cage that is split into two larger sections and one smaller section that are lined with ball bearings in between each section. The camera will spin using a 3:2:1 geared Servo system and will be pushed out of the polycarbonate outer casing rolling cage through a linear elevator. Certain specifics regarding hardware must be met: FOV, accepting RAFCO, etc.

Additional self-imposed requirements must also be met to consider the payload system successful. This includes live telemetry, flight renders, video recording, and more.

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
Telemetry	Self-imposed	Flight Video Recorded	Incomplete
Telemetry/GS	Self-imposed	Live Telemetry	Incomplete

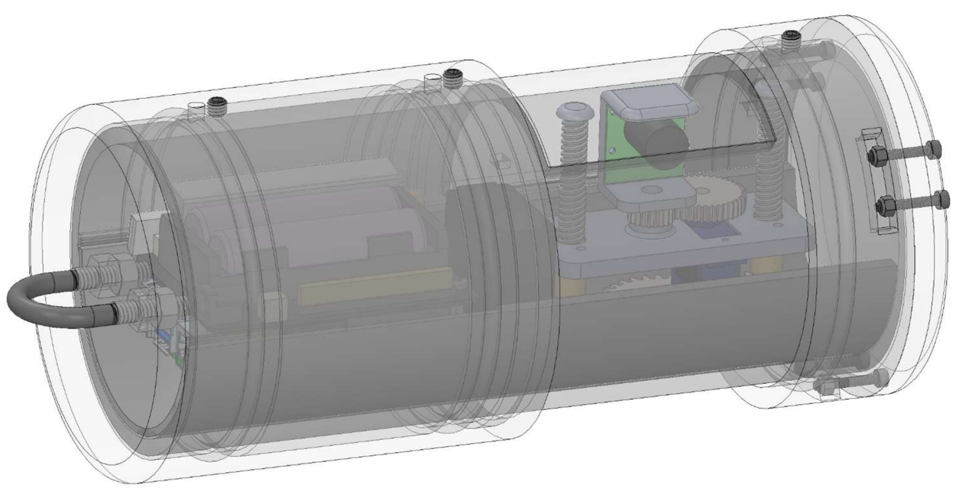
This list is not tentative, but only indicative of the goals we deemed most important as a measure of our own success. A more tentative general list can be found in section 6 Project Plan.

4.2 Payload Integrated Launch Log System

The PILL (Payload, Integrated, Launch, Log) is the primary experimental payload that is being used to meet NASA student laucnh's experimental payload criteria. The PILL is a 3D printed assembly that is composed of three independent sections that use momentum and self-orientation to prop the terrestrial lander upright. The Inner sled contains a linear elevator and other electrical components that are used to deploy a wide-angle camera and survey the area while executing tasks that are broadcasted by NASA via RAFCO commands.

4.2.1 System Overview

The PILL currently consists of a primary outer section and inner primary section. The outer section of the PILL has two independent rotating sections, the Primary end cap and Secondary end cap. The end caps are held together via metal ball bearings that aid in decreasing the friction coefficient between the outer casing and inner casing. The inner section consists of the hatch mechanism that keeps the electronics and linear screw camera system protected and the electronic sled. Within the electronic sled, all electrical components have been carefully arranged to maintain a constant center of gravity aimed towards the ground so the payload can orient parallel to the horizon. The interior of the PILL also contains a radio antenna that will forward the radio signals to our Raspberry Pi 4b, and initialize our mechanism to raise the camera outside of the casing and to rotate it 360 degrees. The Raspberry Pi will receive signals from NASA, rotate the servo, and capture images. The Raspberry Pi then will be able to apply standard and custom filters and all images captured will be saved onto a microSD card.



4.2.2 Current Design and Changes Made

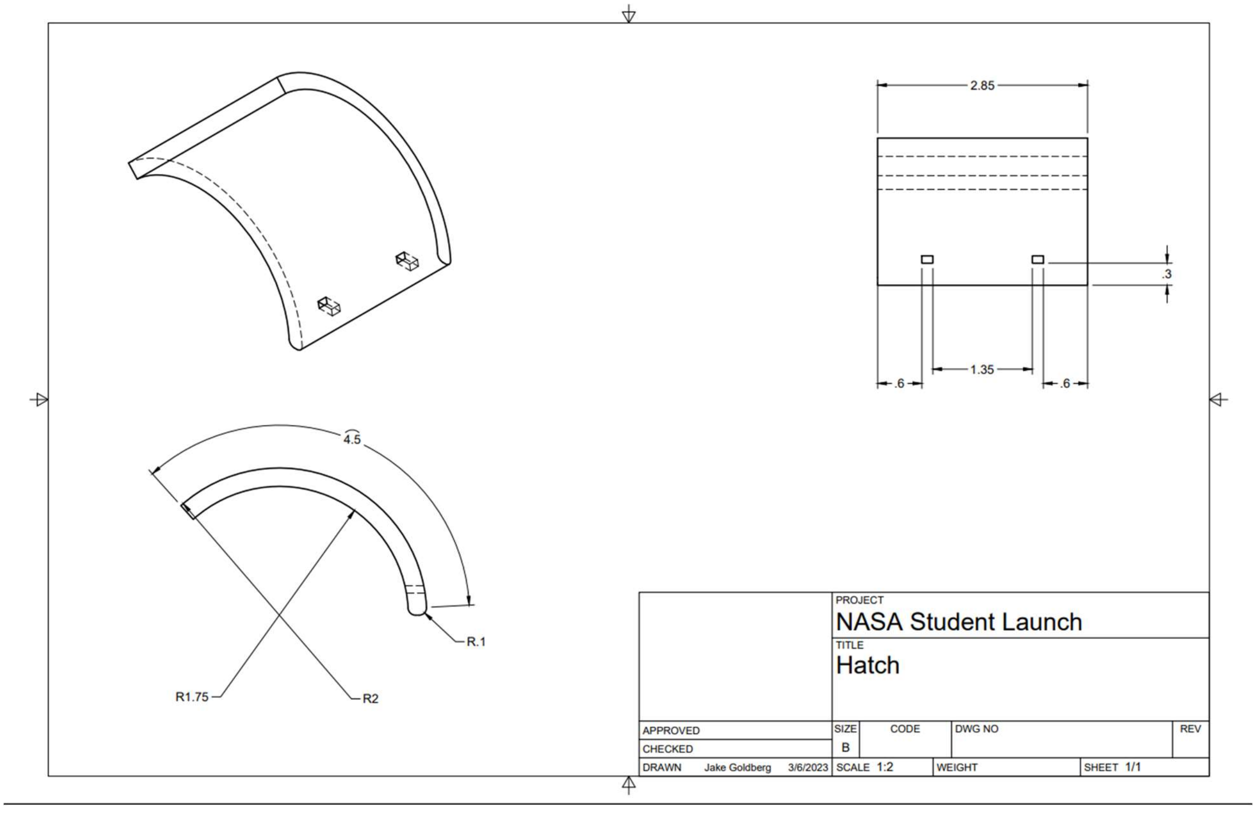
The hatch mechanism has been refined since CDR. Whereas the previous version utilized an overlapping hinge design with a pin, the new version has been simplified to use two sets of holes connected by 4-inch zip ties. This improvement allows the hatch to open farther and reduces failure points.

The primary end cap and large outer section have been combined into a single part. Previously, the removable end cap allowed access to the electronics sled. However, due to structural concerns regarding the force on the attached U-bolt during deployment, the entire outside cylindrical section is now a single part. The removable end cap has been relocated to the other end of the PILL, where it will experience far less strain.

The attachment mechanism for the removable end cap has been redesigned to use 20mm M3 bolts and nylon lock nuts. The previous design utilized heat inserts, which were not deemed structurally sound and interfered with the bearing mechanism. Both outer sections of the PILL have been hollowed out on the inside to reduce friction in the bearing interface. The internal diameter is now 0.15 inches greater at all points except where the bearing grooves make contact.

4.2.2.1 Hinge

The hinge mechanism will be very similar to our previous hatch mechanism. The component and cutout will rest on the outside of the inner tube to allow for a sealable opening for the camera to penetrate once the program is initialized. The mechanism we implemented into the hinge to open it, will be simply a set of zip ties to allow for a very loose hinge preventing any binding.

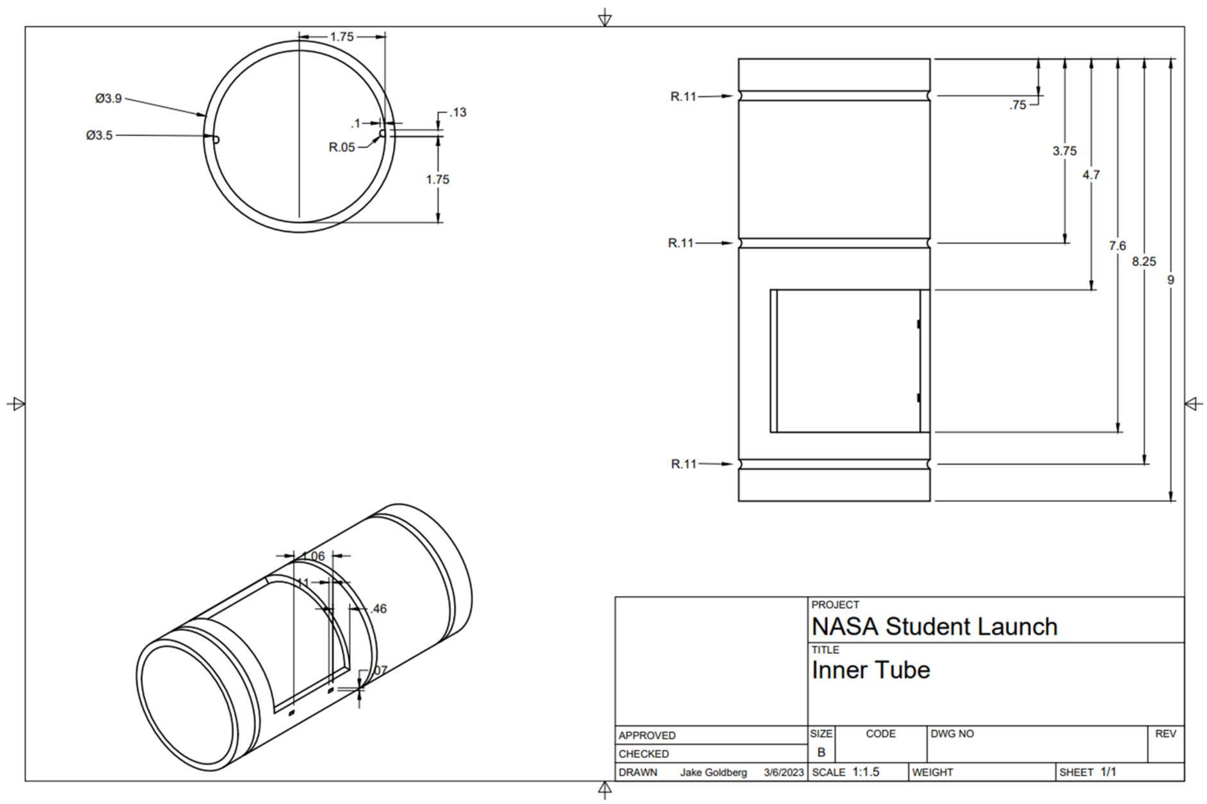


4.2.2.2 Self-Orientation

Our PILL boasts the ability to self-orientate upon ground hit. This is achieved through a combination of design elements, including an outer casing that rolls along the ground, an inner casing that contains all the electronic components, and bearings that reduce friction for a smooth rolling motion. The casings are separated by a small distance, which allows the PILL to move with ease. The inner casing is equipped with strategically placed weights at the bottom, which ensures that it will rotate and settle at the bottom of the PILL once it comes to a stop. The PILL's hatch for the camera is positioned upwards, providing optimal visibility, and ensuring that the camera captures clear and unobscured footage.

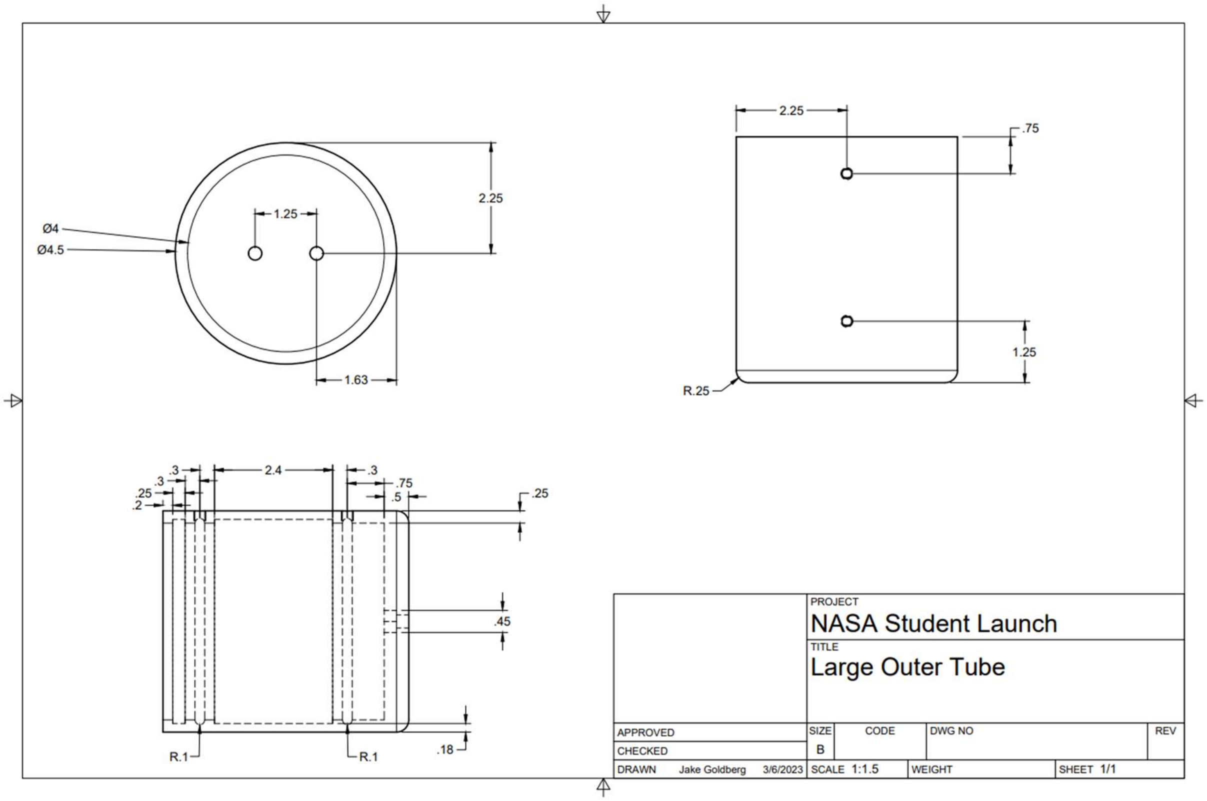
4.2.2.3 Inner Sled

The inner sled will contain all the electronics and the linear actuator mechanism. The sled is easily removable to support the maintenance of the electronics/geartrain inside. It will utilize a keyway to keep itself in alignment with the inner tube. It will be manufactured by using a 3D printer with Poly Lactic Acid (PLA)



4.2.2.4 Outer Casing

The outer casing of the PILL is a 3D printed casing that is printed using an opaque white Polycarbonate filament. We chose polycarbonate over other materials to manufacture the case because of its high heat resistance, durability, and ability to receive RAFCO commands. The electronics sled will also be 3D printed out of PETG filament, a highly durable and cost effective material. Once printed, the polycarbonate casing will be covered in a clear resin that will increase the durability of the polycarbonate.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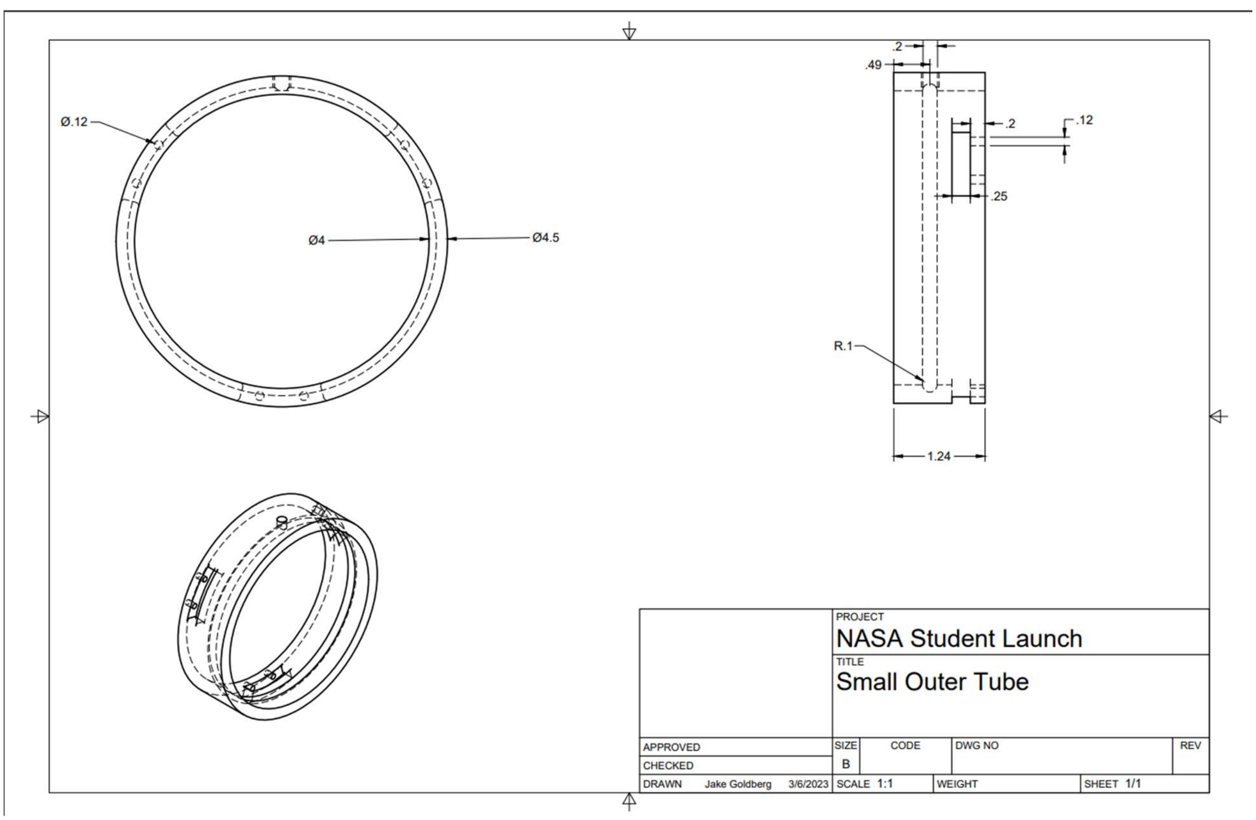
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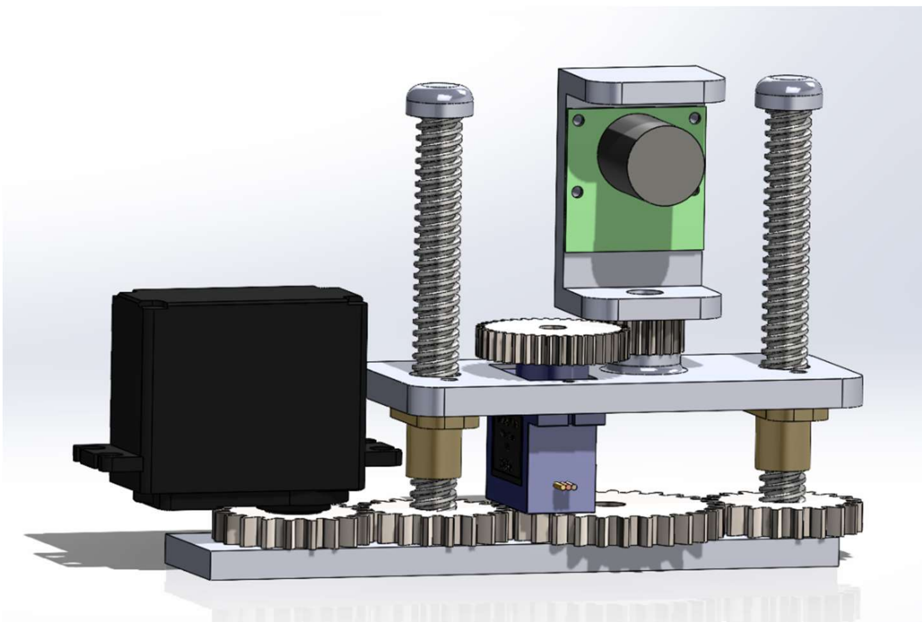
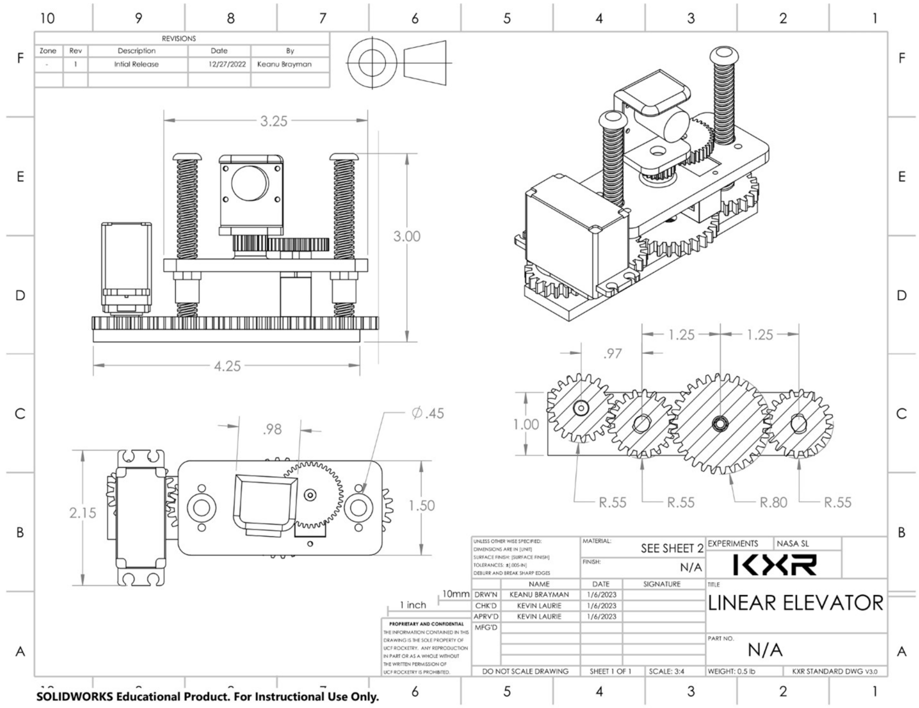
APPROVED
CHECKED
DRAWN Jake Goldberg 3/6/2023
SIZE B
CODE
DWG NO
REV
SCALE 1:1
WEIGHT
SHEET 1/1

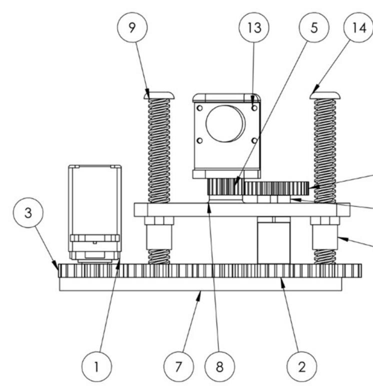
4.2.2.5 Linear Elevator

The Linear Elevator uses a lead screw mechanism to elevate the wide angle camera outside of the PILL through a hatch. The camera is mounted on a small platform, with a lead screw and a support rail running vertically on either side. The lead screw is geared to a continuous servo, moving the entire platform up and down. Some advantages to this design are precision, more control, and increased camera height to camera. The added Lead screws provide extra stability and the overall design is more space efficient within the PILL. A limitation to this design is that this design limits orientation about the y-axis, however, the terrain and small form factor means that it is unlikely that the PILL will not be parallel to the y-axis whilst still being able to maintain the ability to orient about the x-axis and z-axis.





PART NUMBER	ITEM NO.	DESCRIPTION	QTY.
FEETECH FS5109M METAL GEAR SERVO OUTER VOLUME	1	ROTATIONAL SERVO	1
INCH - SPUR GEAR 20DP 30T 14.5PA .2FW --- S30N3.0H2.0L0.25N	2	PETG Gear	1
INCH - SPUR GEAR 20DP 20T 14.5PA .2FW --- S20N3.0H2.0L0.25N	3	PETG Gear	3
INCH - SPUR GEAR 40DP 40T 14.5PA .2FW --- S40N3.0H2.0L0.1875N	4	PETG Gear	1
INCH - SPUR GEAR 40DP 20T 14.5PA .25FW --- S20N3.0H2.0L0.25N	5	PETG Gear	1
MICRO TOWER 9G V2.STEP	6	Continuous Servo	1
BASE PLATE	7	Bottom Alignment Plate	1
LIFT PLATE	8	Elevating Lead Screw Plate	1
97783A170	9	FAST-TRAVEL ULTRA-PRECISION LEAD SCREW	2
57155K346	10	STAINLESS STEEL BALL BEARING	2
QWORK T8 LEAD SCREW NUT	11	Lead Screw Nut	2
SMRAZA CAMERA MODULE	12	Camera	1
CAMERA_MOUNT	13	Camera Mount	1
LEAD SCREW CAP	14	Lead Screw Cap	2



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4.2.2.6 Exterior Resin

We have scheduled a formal meeting with a representative from X-Materials who is in charge of their resin division. During this meeting, they will evaluate our payload and determine an appropriate application method that can work within our quarter-inch clearance requirement. X-Materials creates their resins using a universal testing machine that can withstand an extremely high impact force. This suggests that their resins are likely to have high impact resistance, which is essential for our purposes as our payload will be subjected to high impact velocities.

4.3 Testing

4.3.1 PILL Ejection Test

Person(s) on project:

Date of test:

Test Objective: Observe and analyze the performance of the experimental payload when deployed from upper body tube during main parachute event.

Testing Variable: Payload, Black Powder Charge

Success Criteria: the payload is able to successfully eject from upper body tube upon detachment of the nosecone. The payload is fully enact upon ejection from the upper body tube and successfully mitigated the force of the shock cord when deployed.

Why it is Necessary: This test is necessary because it aids in the integration of the payload with the airframe of the rocket. This means that our team is able to understand how the payload behaves when being deployed in a controlled environment before flight. Furthermore, This test is necessary because the results from the test gives insight on what modifications and concerns need to be addressed and improved for a full-scale flight.

Methodology:

1. Troubleshoot all software and linear actuator before attaching to main parachute
2. Attach Nylon shock cord onto payload by U-bolt and make sure U-bolt is secured.
3. Attach nylon shock cord onto main parachute and use quick-links to secure attachment
4. Place payload behind main parachute within the upper body tube.
5. Proceed with safety measures for ground test and observations.
6. Assess effects on payload once given permission
    a. If payload is not damaged physically and software performance is normal, then proceed with quantifying results.

Impact of Results: Impact of results will give our team an understanding of integration processes with airframe and payload and effects that are inflicted onto payload. With the test results, our team is able to mitigate the negative effects on the payload by changing the integration methods of the payload upon ejection.

Results, Conclusions, and Lessons Learned:

4.3.2 Dry Lubricant Seepage Test

Person(s) on project:

Date of test:

Test Objective: To test the application of dry lubricant to prevent seepage onto other components during flight

Testing Variable: Amount of dry lubricant added / Application Method

Success Criteria: No seepage of dry lubricant anywhere outside of the two outer housings

Why it is Necessary: To prevent dry lubricant from contaminating other sensitive components in the rocket body. If lubricant were to seep out of the PILL, we could see some other internal failures as a result.

Methodology:

1. Choose an application method
2. Weigh out an appropriate amount of lubricant
3. Apply dry lubricant to the bearing surfaces and tube surfaces
4. Roll the outer tubes for 3 minutes
5. Observe the lubricant seepage (YES or NO)
6. Return to step 2 until no seepage is observed

Impact of Results: The correct amount of lubricant will prevent the other components from receiving drainage and can prevent failures during flight/ejection

Results, Conclusions, and Lessons Learned:

4.3.3 Hinge Seal Test

Person(s) on project:

Date of test:

Test Objective: To test the quality of the hinge seal

Testing Variable: Material of seal

Success Criteria: No debris let into the inner tube during test procedure and the seal can be broken easily with the linear actuator

Why it is Necessary: To test the seals ability to prevent foreign debris entering the inner tube which can cause a variety of problems. Debris can jam the geartrain, cloud the lens of the camera, and increase the bearing friction leading to a failed launch.

Methodology:

1.Seal the pill using different sealing techniques/materials

2.Blow dirt at the seal directly

3.Open and inspect debris contamination within the pill

Impact of Results: Depending on which seal lets the least amount of debris in, while maintaining an easy ejection, we will utilize the best seal in our final design

Results, Conclusions, and Lessons Learned:

4.3.4 PILL Drop Test

4.3.4.1 Impact and Casing

Person(s) on project:

Date of test:

Test Objective: Observe the impact and forces on payload and asses the overall affects when dropped from a high altitude.

Testing Variable: Payload, altitude, acceleration, and force.

Success Criteria: Payload is fully functional upon impact with the ground. Outer casing is intact and fully functional, being able to self-orient upon impact.

Why it is Necessary: This is necessary because this demonstrates if the payload is able to remain intact while under high impact forces.

Methodology:

1. Prepare payload by attaching payload to main parachute and mass simulant indicative of the rockets weight minus the payload
2. Drop main parachute and payload off parking garage in a controlled safety zone.
3. Observe impact and observe effects of payload from impact force.

Impact of Results: The impact of the results gathered from this experiment would be the understanding of the materials being used and their effects from being under high stress. Furthermore, the results aids our team by understanding what forces our payload would undergo and how to properly mitigate effects.

Results, Conclusions, and Lessons Learned:

4.3.4.2 Electronics

Person(s) on project: Nic P., Chloe G.

Date of test: TBD

Test Objective: Observe the impact and forces on payload and asses the overall affects when dropped from a high altitude.

Testing Variable: Payload, altitude, acceleration, and force.

Success Criteria: Payload is fully functional upon impact with the ground. Outer casing is intact and fully functional, being able to self-orient upon impact.

Why it is Necessary: This is necessary because this demonstrates if the payload is able to remain intact while under high impact forces.

Methodology:

1. Prepare payload by attaching payload to main parachute and mass simulant indicative of the rockets weight minus the payload
2. Drop main parachute and payload off parking garage in a controlled safety zone.
3. Observe impact and observe effects of payload from impact force.

Impact of Results: The impact of the results gathered from this experiment would be the understanding of the materials being used and their effects from being under high stress. Furthermore, the results aids our team by understanding what forces our payload would undergo and how to properly mitigate effects.

Results, Conclusions, and Lessons Learned:

4.3.4.3 Camera and Self-Orientation

Person(s) on project:

Date of test:

Test Objective: Observe the effects and performance of software in experimental payload when dropped from a high altitude.

Testing Variable:

Success Criteria: Payload is fully functional upon impact with the ground. Camera is able to deploy and performed commands and maneuver. Payload is able to self-orient parallel to the horizon by using the center of gravity.

Why it is Necessary: This test is necessary for our payload because the self-orientation of the payload is essential for camera deployment. Furthermore, this test can confirm the proof of concept for self-orientation with a physical demonstration.

Methodology:

Impact of Results: The impact of the results gathered from this experiment would be the understanding of the materials being used and their effects from being under high stress. Furthermore, the results aids our team by understanding what forces our payload would undergo and how to properly mitigate its' effects.

Results, Conclusions, and Lessons Learned:

4.3.5 Battery Drain Test

Person(s) on project

Date of test:

Test Objective: Measure how long the battery lasts

Testing Variable: Battery life

Success Criteria: Battery lasts for more than 3 hours

Why it is Necessary: To make sure the PILL can remain launch ready on the pad for at least 2 hours as mentioned on the student handbook

Methodology:

- Insert batteries into the container
- Connect pi to a display
- Turn pi on
- Start timer
- Run diagnostics script
- Check battery indicator, and check voltage using program every 10 minutes
    - If 3 hours passed, run script again and compare results to beginning of test

        - Turn pi off and stop timer
    - If pi dies, stop the timer as soon as possible
        - Compare time to desired time of three hours and see how much longer we need the pi to last

Impact of Results: We would know how long our pill lasts using our battery

Results, Conclusions, and Lessons Learned:

4.3.6 Camera, IMU, Limit Switch, RTC Test

Person(s) on project:

Date of test:

Test Objective: Test that the camera works with the RTC as well as testing whether the

Testing Variable: Camera, IMU, Limit Switch, RTC

Success Criteria: RTC gives correct output and works with camera, IMU correctly measures every couple of seconds, limit switch performs as expected when in a controlled enviorment.

Why it is Necessary: We want the RTC to give us the most accurate time and have the IMU provide precise measurements for the limit switch.

Methodology:

1. Similar to code test, verify that camera works as expected
2. Check if RTC is installed in Pi via command line
    1. If RTC time is missing on output, check if RTC is installed correctly
3. Verify RTC time gets printed onto camera photos as timestamps
    1. If not, debug Pi and/or code
4. Verify IMU is installed
    1. Check that IMU measures and returns output of measurements every couple of seconds
5. Verify limit switch is properly connected to the Pi and that the input is being properly read and responds accordingly
    1. Detect if switch properly detects and triggers desired actions
    2. If not, check the wiring or that the Pi is receiving input signals for the switch

6. If any tests fail, debug code for their respective sections and check components to make sure they're not faulty

Impact of Results: This helps us verify that the camera will be able to work with the various components installed on the Pi

Results, Conclusions, and Lessons Learned:

4.3.7 Radio Test

Person(s) on project:

Date of test:

Test Objective: Be able to receive signals from ground station to pi

Testing Variable: Raspberry Pi's ability to receive and understand radio messages

Success Criteria: The pi receives signals from the ground station and performs the appropriate commands

Why it is Necessary: In order to complete the task from NASA, the Pi needs to receive and perform actions based on the radio signals from the ground station. This test will let us check that it can do that.

Methodology:

- Write code for the pi to scan certain radio frequency and print received messages into console, and then read those messages to perform certain actions when receiving certain messages
- From ground station, send messages on the radio frequency and test if Pi can receive the signals and display them in console
    - If not, reconnect radio receiver and check if it is reading on the correct frequency
- Test if Pi can scan the message for certain components (I.E. A1, B2, C3, etc..) and print messages for each one if successfully read.
    - If pi cannot scan the message, find section of code that handles it and rewrite it to read the APRS transmission message in the console
- Evaluate success rate of Pi receiving correct message and performing appropriate actions based upon that message.

Impact of Results: Knowledge gained from this test will allow us to have a deeper understanding of how to perform the radio commands and how to implement them.

Results, Conclusions, and Lessons Learned:

4.3.8 Camera Deployment

Project procedure format:

Person(s) on project:

Date of test: March 2nd

Test Objective: Test if the camera deploys properly

Testing Variable: Camera deploys

Success Criteria: Camera deploys and script runs

Why it is Necessary: It is necessary for the camera to see the horizon and complete the challenge

Methodology:

- Connect the servo and camera to the interior of the PILL on the moving platform
- Ensure the hatch is closed before testing
- Set PILL on level surface and let it self-orient
- Run the code to push the camera out of the PILL
- Make sure the hatch opens and the camera is out of the PILL
- Run code and test to see if the camera is able to perform all tests successfully

Impact of Results: knowledge gained from the test will show if the camera executes its purpose

Results, Conclusions, and Lessons Learned:

4.3.9 Self-Orientation Test

Project procedure format:

Person(s) on project:

Date of test:

Test Objective: Test if the PILL ends upright after landing

Testing Variable: PILL always stops moving in the upright position

Success Criteria: PILL is in upright position, ready to deploy the camera

Why it is Necessary: To make sure that the pill is able to deploy the camera upright towards the horizon

Methodology:

- Make sure bearings and outer casing move freely over the interior section

    - If the outer shell does not move freely, add more lubricant and ensure there is a small gap between the outer shell and inner part

- Roll PILL on multiple surfaces
- Drop PILL on multiple surfaces
- Make sure the PILL self-orients to the upright position for camera deployment for both rolls and drops

Impact of Results: knowledge gained from this test will help us see if our self-orientation mechanism works

Results, Conclusions, and Lessons Learned:

4.3.10 Software Test

Project procedure format:

a

Person(s) on project:

Date of test:

Test Objective: Determine if the code for camera functions as it should, this means determining whether the camera can take the required photos depending on received radio input as well as changing orientation to a specified angle

Testing Variable: Camera, Pi, Code

Success Criteria: The code is able to run and perform the required actions for the camera

Why it is Necessary: We want to make sure the code for the camera successfully takes photos as well as turn at the correct angles

Methodology:

1. Determine if Pi is connected correctly
2. Run code that turns the camera on
3. Check if camera/raspberry pi can receive radio signals
    a. If not, print error message and exit as code cannot perform without receiving commands from radio
4. Upon receiving radio signals, code should perform the correct task and return the correct output
    a. Verifying if a grayscale image is created when the signal for grayscale is received, etc.
5. Verify that images are saved onto SD card
6. Debug code if output is not as expected

Impact of Results: This will confirm that the camera works as expected and help us see if any adjustments need to be made

Results, Conclusions, and Lessons Learned:

4.4 Telemetry System

4.4.1 System Overview

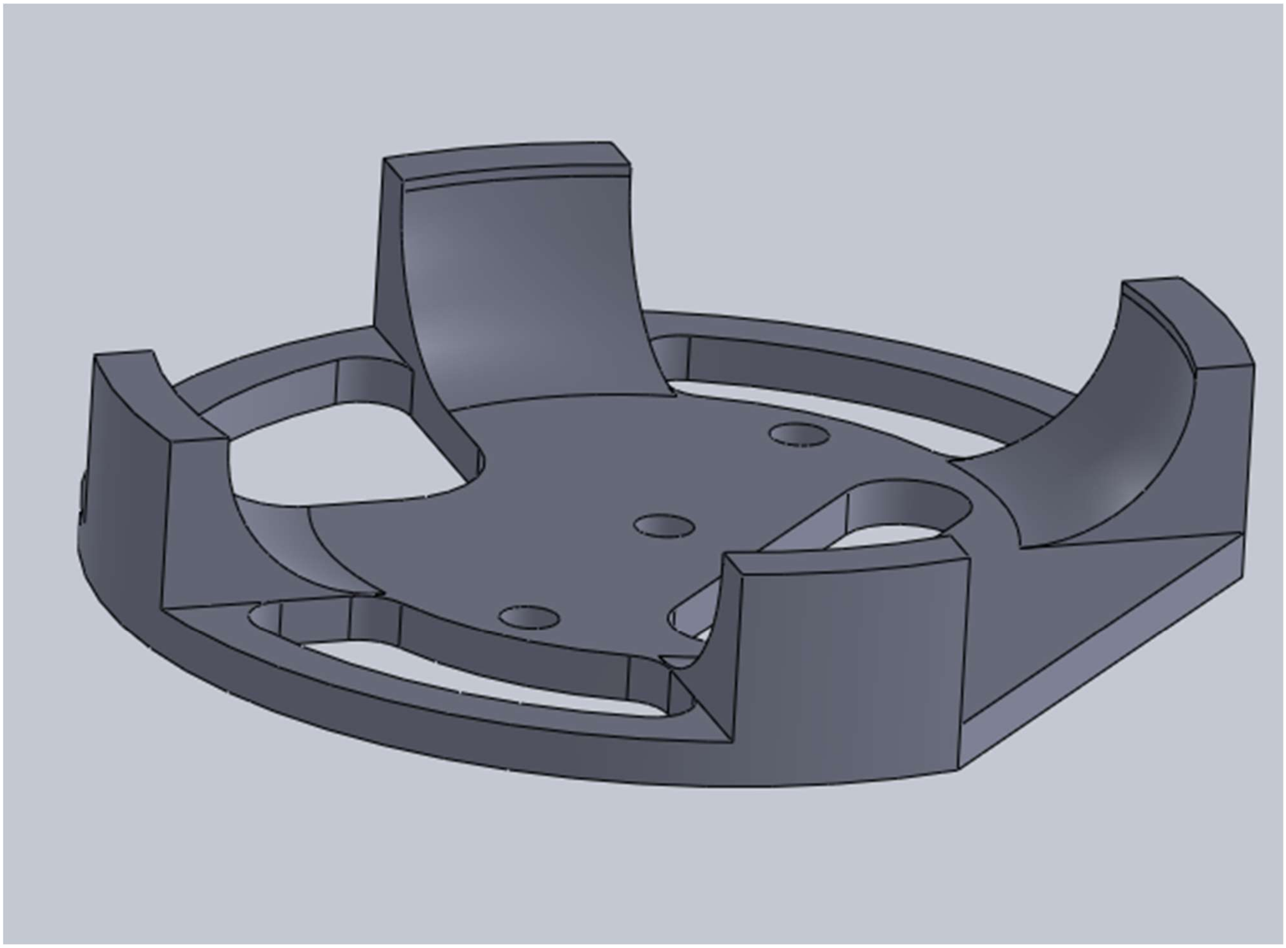
The Telemetry system currently consists of the inner structure of the nosecone which houses all avionics components. This system powered by a 2200 mAh LiPo battery provides dual redundant GPS along with live telemetry to monitor flight status real time. The structure of the nosecone provides a high strength attachment-point to allow for our nosecone to be the point of detachment to release our main parachute.

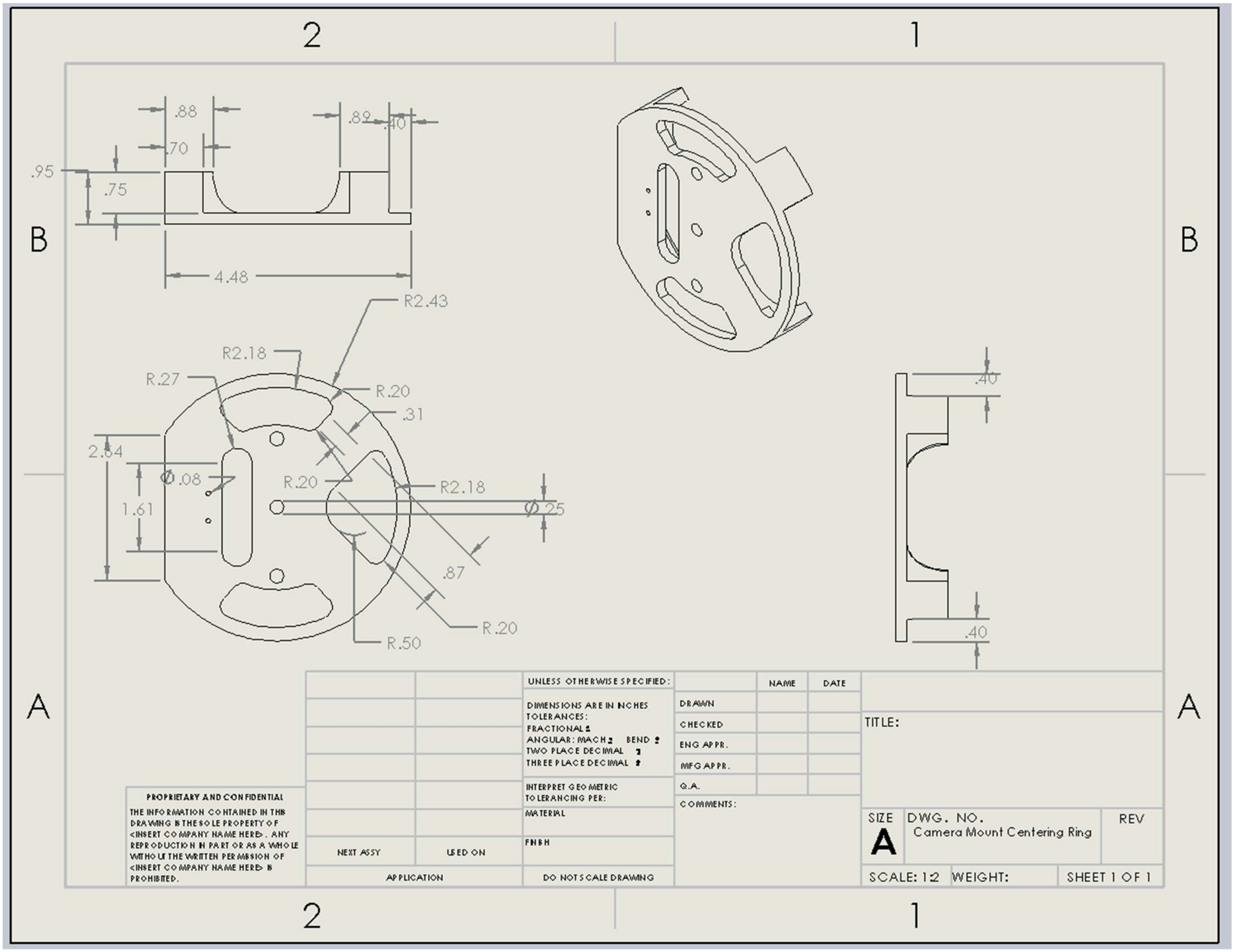
4.4.2 Current Design

4.4.2.1 ADSAB

The ADSAB (Asclepius Double Sled Avionics Bay) provides support to the bulkhead attached to the nosecone and houses the avionics of our rocket. A ¼" steel threaded rod is run through the entire nosecone and through the bulkhead. This rod is secured through the fastening of our aluminum nosecone tip to the top lip of our fiberglass nosecone. An inner friction plate is fastened with nylon lock nuts preventing any movement of the threaded rod when tension is added from the nosecone tip. Within the center of our nosecone are 2, 1/8" laser cut plywood sleds that all our electronics are fastened to. These plates are not load bearing. Beneath these sleds is a G10 fiberglass plate that fits within the shoulder of our nosecone. This is the upper plate of our bulkhead. Two additional ¼" steel rods run through the entirety of our bulkhead along with the central steel rod running from the nosecone tip. Compression force is provided to this assembly by attaching the bottom G10 fiberglass bulkhead plate.

4.4.2.1.1 Camera Mount





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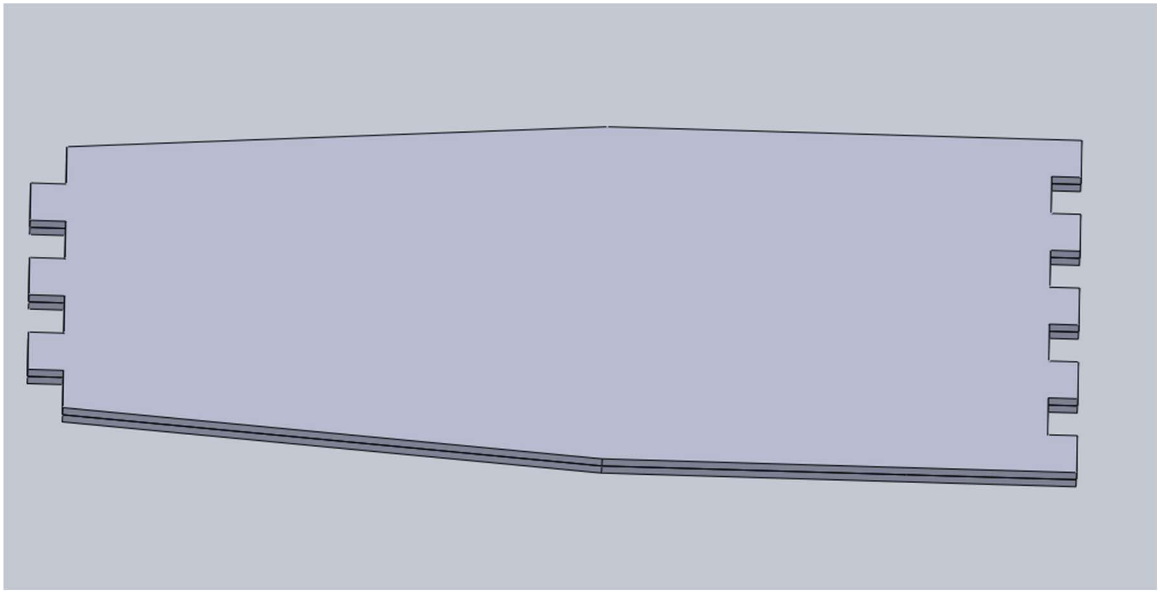
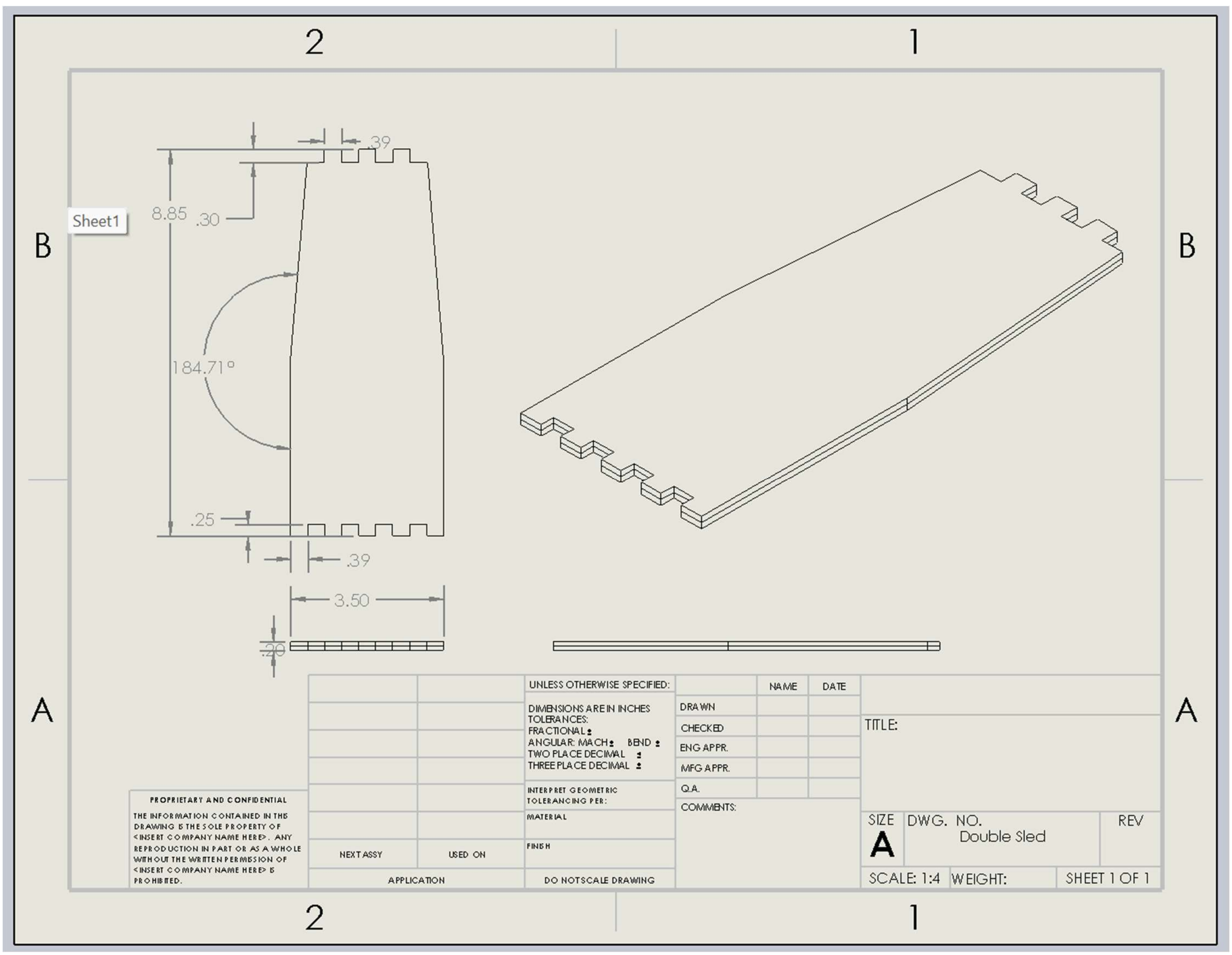
4.4.2.1.2 Sled





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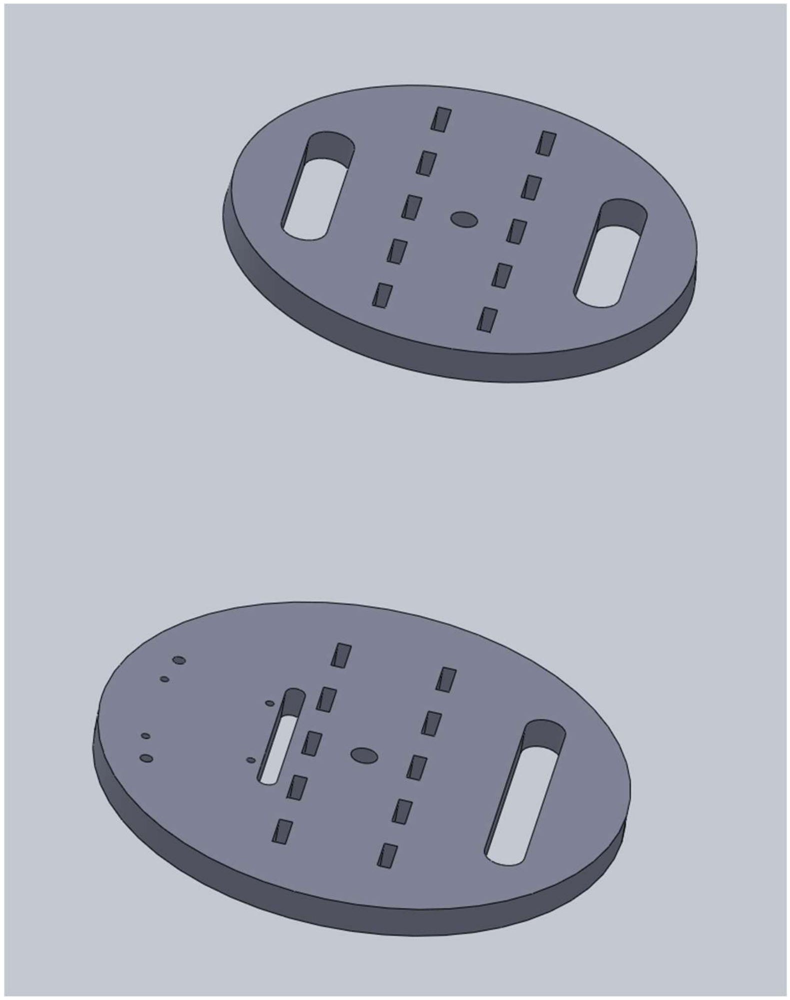
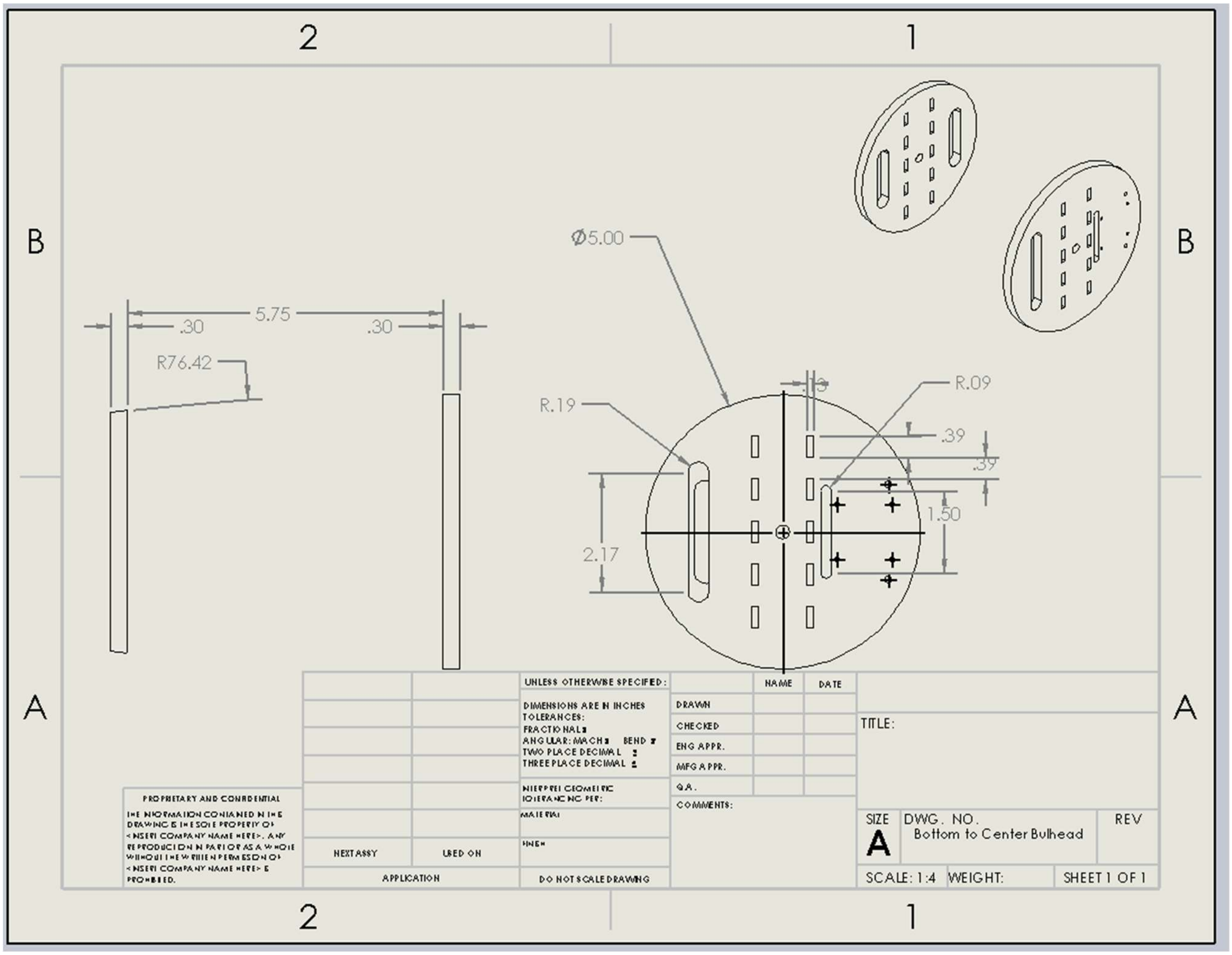
4.4.2.1.3 Shoulder Bulk Heads





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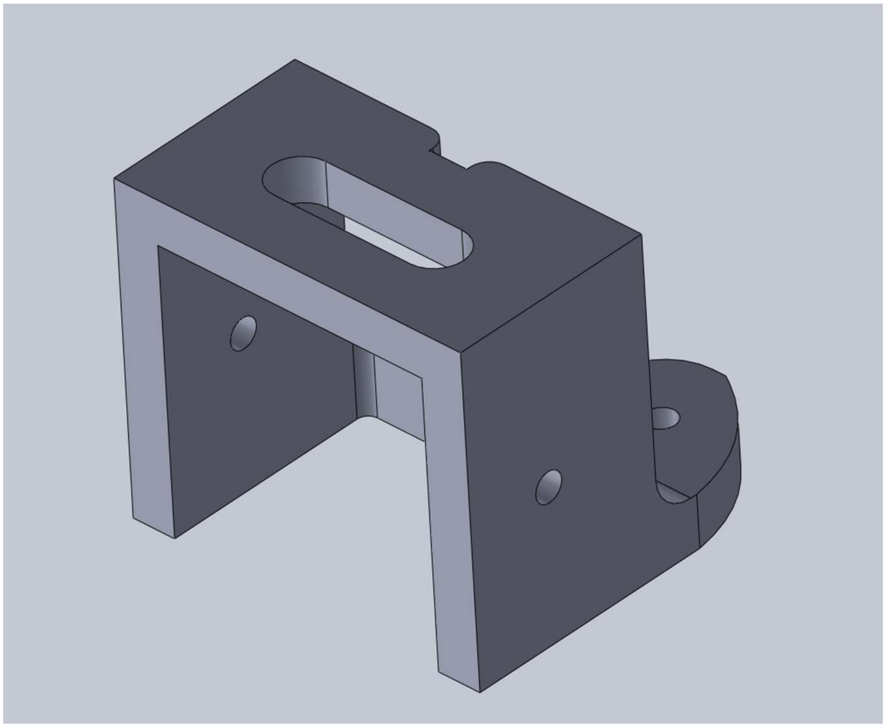
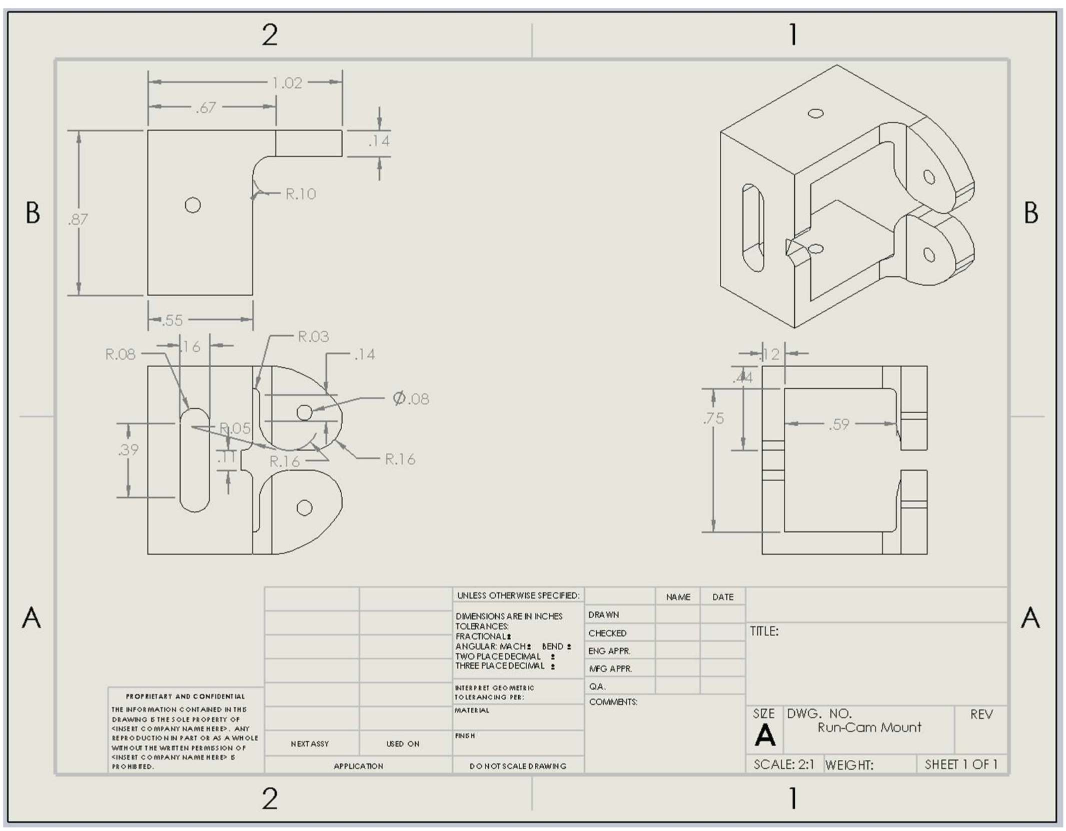
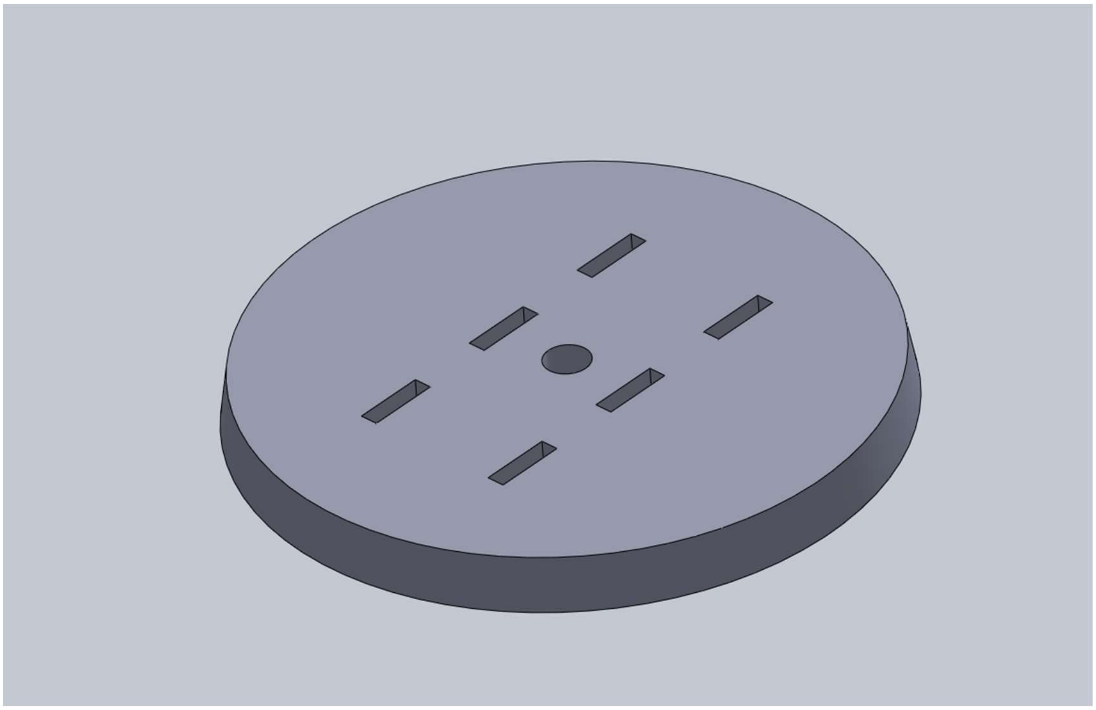
SHEET 1 OF 1

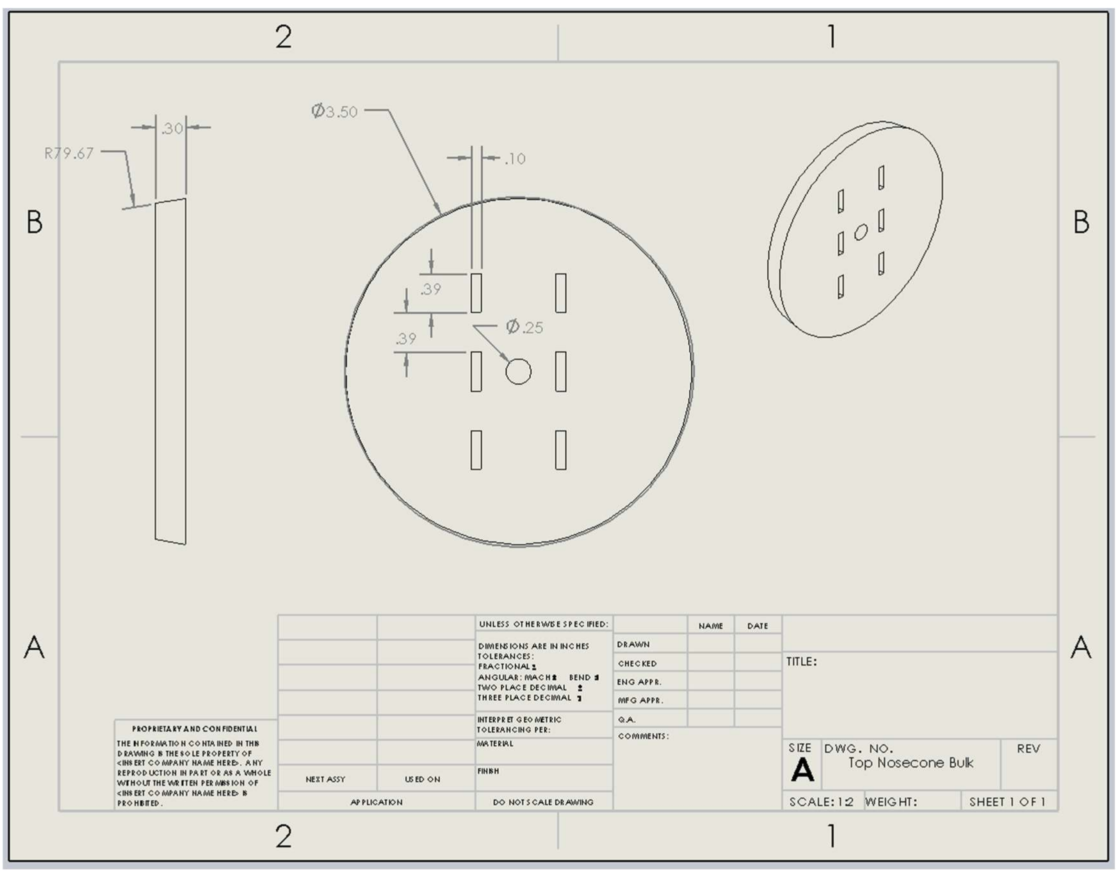
4.4.2.1.4 Camera Mount





4.4.2.1.5 Centering Ring

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UNLESS OTHERWISE SPECIFIED:
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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
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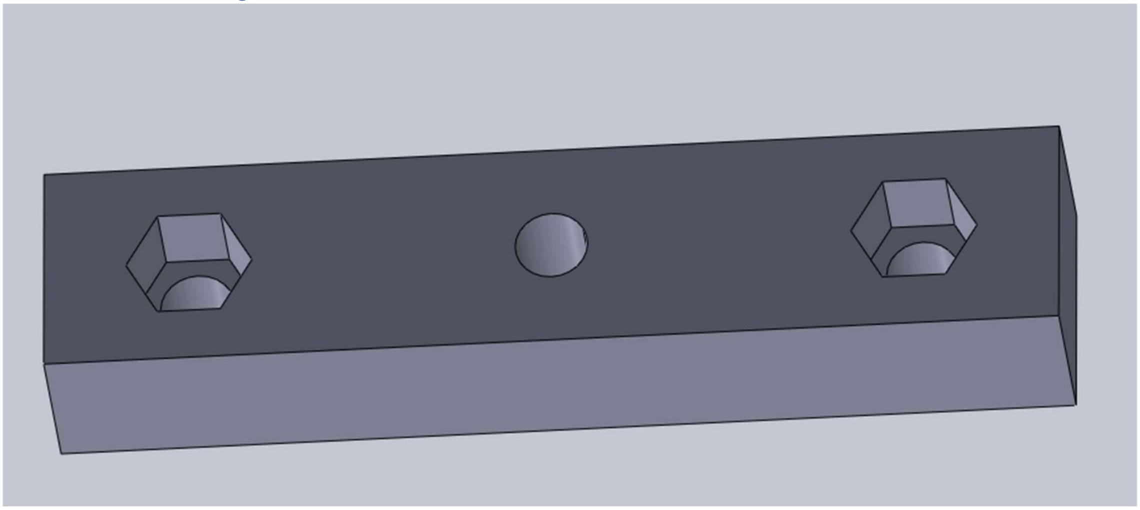
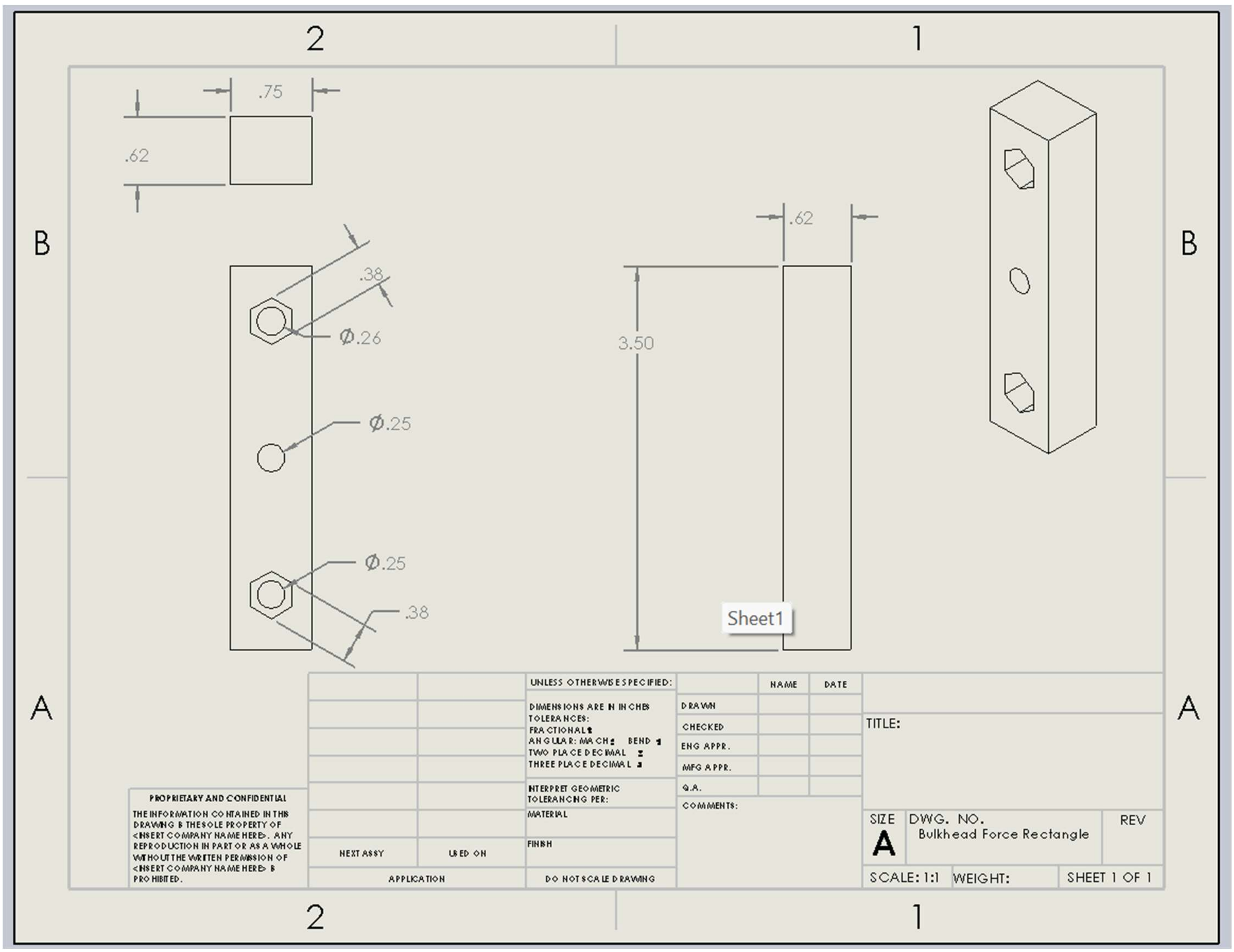
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION

4.4.2.1.6 Bulkhead Force Rectangle





4.4.2.2 Flight Computer

The flight computer is a crucial component of a rocket that provides valuable data during the flight. In this report, we will discuss the components and their uses in designing a flight computer for a full-scale rocket, with a particular focus on data collection, logging, and transfer functionalities.

4.4.2.2.1 Components

ESP-32: The ESP-32 is a powerful microcontroller with integrated Wi-Fi and Bluetooth connectivity. It is used as the main processing unit of the flight computer and is responsible for executing the data logging and transfer functions.

MicroSD Breakout (Adafruit): The MicroSD breakout board is used to store flight data such as sensor readings, GPS coordinates, and flight parameters. The microSD card provides a reliable and fast storage medium for data logging during the flight.

Ultimate GPS Breakout v3 (Adafruit): The GPS breakout board is used to determine the rocket's position, velocity, and altitude during the flight. It provides accurate position data that can be logged for post-flight analysis.

LoRa RFM9x (Adafruit) Transmitter: The LoRa RFM9x is a long-range radio transmitter used to send telemetry data from the rocket to the ground station. It uses low-power, long-range communication technology, making it suitable for use in remote areas.

BMP280: The BMP280 is a barometric pressure sensor used to measure the ambient pressure and temperature during the flight. It provides valuable data for monitoring the environmental conditions and recording the flight's performance.

BNO055 (Adafruit): The BNO055 is a 9-axis inertial measurement unit (IMU) that measures acceleration, orientation, and magnetic fields. It provides critical data for monitoring the rocket's orientation and velocity during the flight and recording the flight's performance.

4.4.2.2.2 Function

Data Collection: The flight computer collects data from various sensors, including GPS, barometric pressure, and IMU sensors, during the flight. This data is used to monitor the rocket's performance, environmental conditions, and position.

Data Logging: The microSD breakout board is used to store flight data, including sensor readings, GPS coordinates, and flight parameters. This data can be used for post-flight analysis to improve the rocket's performance.

Data Transfer: The LoRa RFM9x transmitter sends telemetry data from the rocket to the ground station. This data includes the rocket's position, velocity, altitude, and other flight parameters. It allows the flight team to monitor the rocket's progress during the flight and to make any necessary adjustments.

4.4.2.2.3 Overview

In conclusion, the flight computer is a crucial component of a full-scale rocket, providing valuable data during the flight. The components used in this report, including the ESP-32, microSD breakout board, GPS breakout board, LoRa RFM9x transmitter, BMP280, and BNO055, provide essential functionalities for data collection, logging, and transfer. The flight computer's primary purpose is to collect and log data, which can be used for post-flight analysis to improve the rocket's performance. The LoRa RFM9x transmitter allows for telemetry data to be transferred to the ground station in real-time, providing valuable information during the flight.

4.4.2.3 Software

The flight computer software needs to initialize the microcontroller and sensor, log data during flight, transmit telemetry data to the ground station, handle errors and exceptions, and save and upload data for post-flight analysis. The software must be carefully designed to ensure the flight computer can function correctly and provide accurate data during the flight.

Logic

Setup the microcontroller: The first step is to initialize the microcontroller and set up the communication channels. This involves configuring the many pinouts, SPI communication protocol, numerous libraries, and variables for the sensors,

```
// KXR NASA SL FLIGHT COMPUTER - V1

// Any and all .h libaries that are utilized will be included

#include <Adafruit_BMP280.h>

#include <Adafruit_BNO055.h>

#include <Adafruit_GPS.h>
```

```
#include <SPI.h>

#include <LoRa.h>

#include <SD.h>

#include <Wire.h>


// Here sits all of our constant pins that are referenced through initialization

#define BMP280_SDA 21

#define BMP280_SCL 22


#define BNO055_SDA 21

#define BNO055_SCL 22


#define GPS_SERIAL Serial2


#define LORA_CS 5

#define LORA_RESET 14

#define LORA_DIO0 2


#define SD_CS 15


Adafruit_BMP280 bmp;

Adafruit_BNO055 bno = Adafruit_BNO055(55);

Adafruit_GPS gps(&GPS_SERIAL);
```

Configure the sensors: Once the microcontroller is initialized, the next step is to configure the sensors. This involves setting up the GPS, BMP280, and BNO055 sensors to obtain the necessary data. The GPS sensor is used to determine the rocket's position, velocity, and altitude, while the BMP280 and BNO055 sensors provide data on the environmental conditions and the rocket's orientation and velocity.

```
void initializeSD(void)
{
  // Initialize SPI interface with appropriate settings for SD card communication
  if (!SD.begin(SD_CS)) {
    Serial.println("microSD failed, check pin connections");
  }
  else {
    Serial.println("microSD Initialization sucessful");

  }
}

void initilizeLORA(void)
{
  // Initlize our LoRa transmitter over SPI
  LoRa.setPins(LORA_CS, RST, DIO0);

  if (!LoRa.begin(915E6)) {
    Serial.println("LoRa initialization failed. Check your connections.");
    while (1); // halt the program

  // Set our sync word, transmitting power, and frequency
  LoRa.setSyncWord(0xF3);
  LoRa.setTxPower(20);
}

void initializeBMP(void)
{
  // Initialize the Wire library for I2C communication
  Wire.begin();
```

```
 // Check if BMP280 sensor is present on I2C bus
 if (!bmp.begin(0x76)) {
  Serial.println("Could not find BMP280 sensor!");
  return;
 }
 // Set default measurements
 bmp.setSampling(BMP280::MODE_NORMAL,     /* Operating Mode. */
                BMP280::SAMPLING_X16,    /* Temp. oversampling */
                BMP280::SAMPLING_X16,    /* Pressure oversampling */
                BMP280::FILTER_X16,      /* Filtering. */
                BMP280::STANDBY_MS_500); /* Standby time. */

 Serial.println("BMP280 initialized.");
}


void initializeBNO(void)
{
 // Initialize the Wire library for I2C communication
 Wire.begin();
 // Check if BNO085 sensor is present on I2C bus
 if (!bno.begin()) {
  Serial.println("Could not find BNO085 sensor!");
  return;
 }

 // Set default measurement sizes
 bno.setAccelerometerRange(BNO080::RANGE_16G);
 bno.setGyroRange(BNO080::RANGE_2000DPS);
 bno.setSamplingRate(100);

 Serial.println("BNO085 initialized.");
```

```
}
void initialize_GPS() {
 GPS_Serial.begin(9600, SERIAL_8N1, 16, 17); // begin GPS serial communication on pins 16 (RX2) and 17 (TX2)

 // send some initialization commands to the GPS
 GPS_Serial.println(PMTK_SET_NMEA_OUTPUT_RMCGGA); // turn on recommended minimum specific GPS sentences
 GPS_Serial.println(PMTK_SET_NMEA_UPDATE_1HZ); // update rate at 1Hz
 GPS_Serial.println(PMTK_API_SET_FIX_CTL_1HZ); // fix control at 1Hz

 // wait for GPS to stabilize
 delay(1000);

 // discard any existing GPS data
 while (GPS_Serial.available() > 0) {
  GPS_Serial.read();
 }
}
```

1). Collect and log data: With the sensors configured, the flight computer can now start collecting data. This involves reading the sensor values and storing them in the microSD card. The data logged includes sensor readings, GPS coordinates, and flight parameters.

2). Transmit telemetry data: During the flight, the flight computer needs to transmit telemetry data to the ground station. This involves setting up the LoRa RFM9x transmitter and sending data packets containing the rocket's position, velocity, altitude, and other flight parameters.

1 & 2 Code:

```
void loop() {
 // Read sensor data
 temperature = bmp.readTemperature();
```

```
pressure = bmp.readPressure() / 100.0F;
altitude = bmp.readAltitude(1013.25);

if (gps.newNMEAreceived()) {
  if (!gps.parse(gps.lastNMEA())) {
    return;
  }
}

latitude = gps.latitudeDegrees;
longitude = gps.longitudeDegrees;

// Log data to microSD card
File dataFile = SD.open("flight_data.txt", FILE_WRITE);
if (dataFile) {
  dataFile.print(temperature);
  dataFile.print(",");
  dataFile.print(pressure);
  dataFile.print(",");
  dataFile.print(altitude);
  dataFile.print(",");
  dataFile.print(latitude, 6);
  dataFile.print(",");
  dataFile.println(longitude, 6);
  dataFile.close();
}

// Transmit telemetry data via LoRa
String telemetryData = String(latitude, 6) + "," + String(longitude, 6) + "," + String(altitude) + "," + String(temperature) + "," +
String(pressure);
LoRa.beginPacket();
```

```
  LoRa.print(telemetryData);

  LoRa.endPacket();

}
```

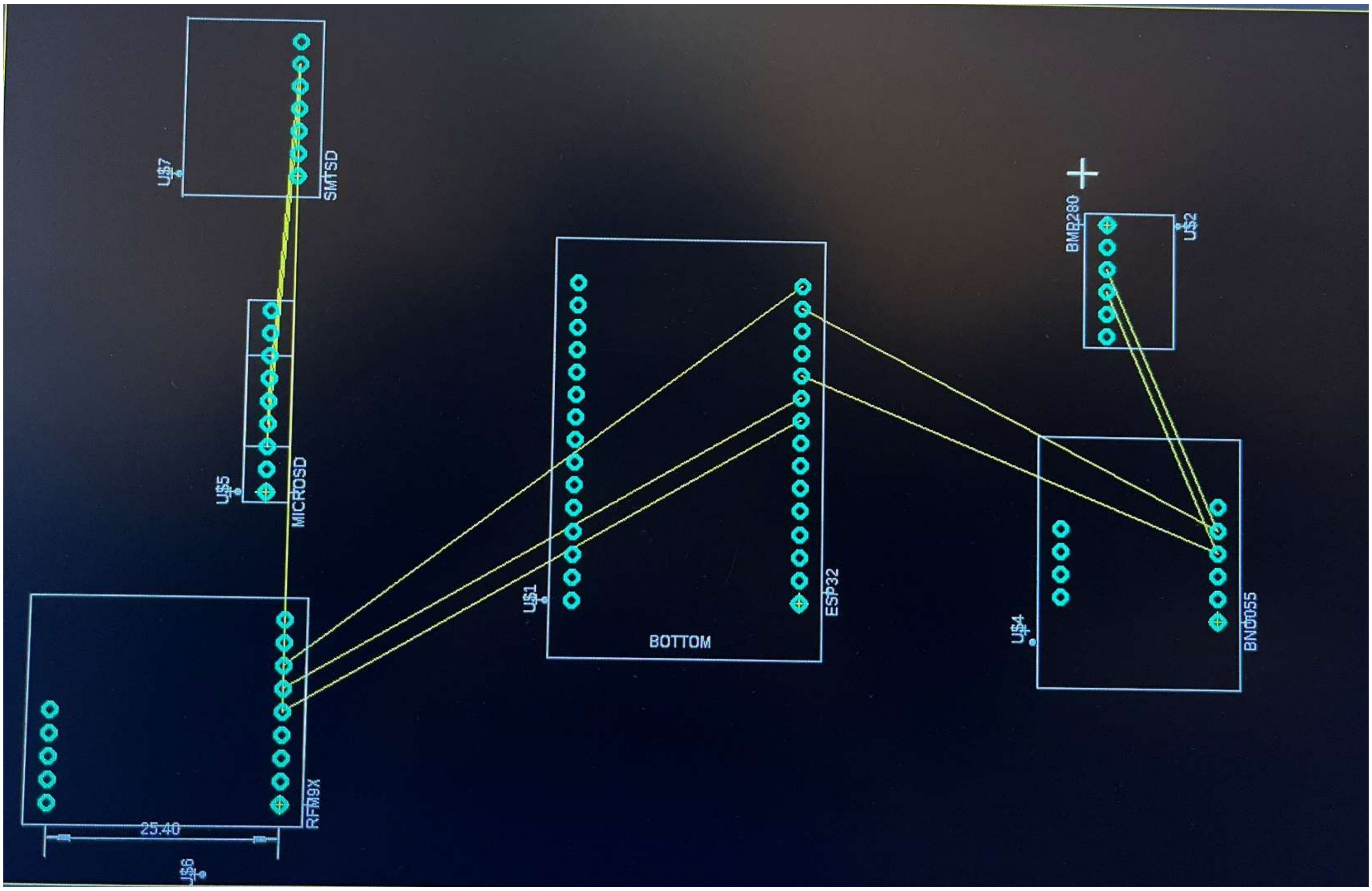
Save data: Once the flight is complete, the flight computer saves the data to the microSD card for later retrieval.

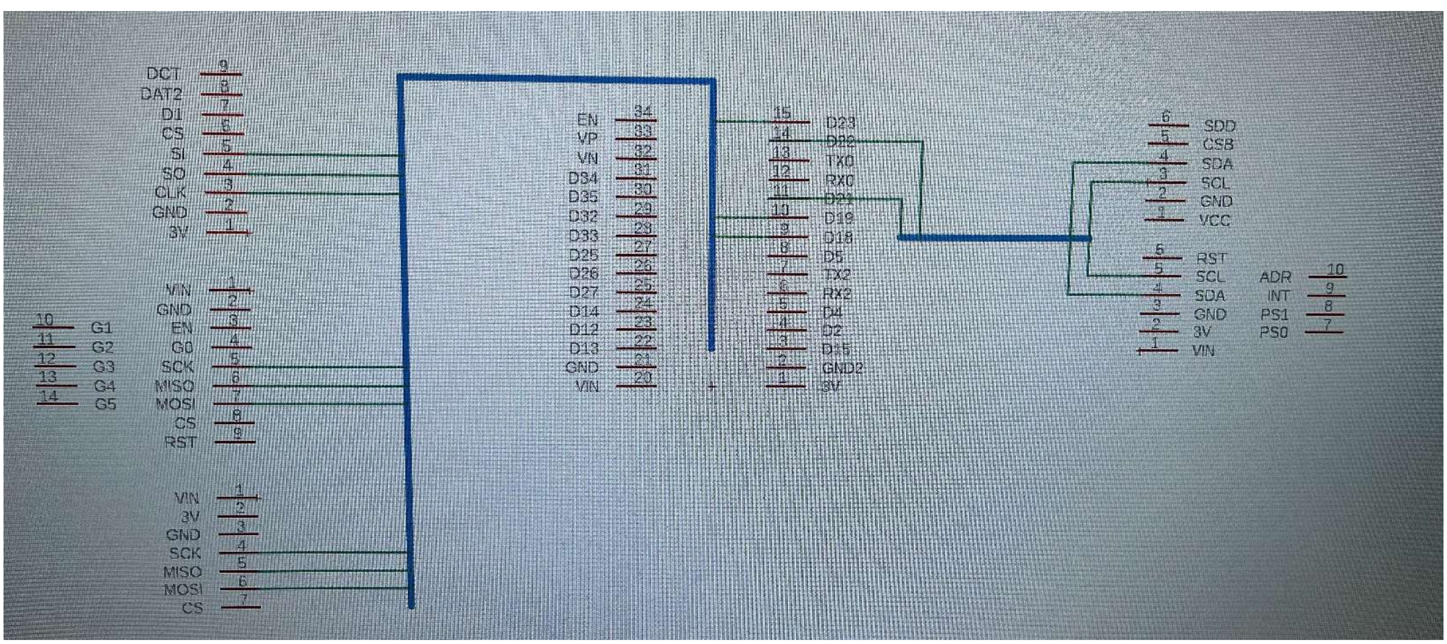
```
void saveData() {

  // Save data to microSD card

  File dataFile = SD.open("flight_data.txt");

  File saveFile = SD.open("flight_data_save.txt", FILE_WRITE);

  if (dataFile && saveFile) {

    while (dataFile.available()) {

      saveFile.write(dataFile.read());

    }

    dataFile.close();

    saveFile.close();

  }

}
```

4.4.2.4 Printed Circuit Board

Currently the flight computer will rest on a custom, student designed, PCB breakout board. The .gerber file is currently being refined as the traces were deem unsatisfactory to use in good conscious. The PCB, whilst not mission critical as we can resort to PERF boards, would be a strong tool regardless and will be completed as of March 8th in order to be flown in the subsequent payload demonstration flight.

The following images are by no means the content we will be using, certain pins must be clarified based on software requirements so certain components are not on the design.





4.4.3 Testing

To ensure the reliability of the avionics system, we are acknowledging the pain points of our system and creating rigorous tests. By Documenting precise calculations we can ensure a high safety factor of the entire avionics system.

4.4.3.1 Battery Longevity

ESP 32 – 240mA max

Adafruit 9-DOF Absolute Orientation IMU – 13.7mA draw 2.4 - 3.6v input

Adafruit BMP280 – 2.7 mA(or 2.7µA needs confirmation) at 3.3v max sensor consumption

Adafruit RFM96W LoRa Radio Transceiver – 100mA peak at 3 - 5v

Adafruit Ultimate GPS – 20mA draw, 3.3 - 5v

Run Cam Split HD – 540 mA max

Total: 280 mA

Battery: 2200 mAh

Battery life is approximately 2 hours and 41 minutes. This results in a factor of safety of roughly 1.3 to make sure we can safely accommodate our max time on the pad of two hours. This is also under the max conditions of each component and is likely an over estimate whilst still falling within our range.

4.4.3.2 Featherweight

This primary GPS system has been tested through multiple launches of our Sub-Scale rocket. This device has been proven reliable even upon mid-flight failure.

4.4.3.3 Flight Computer

Only Prototype development boards have been flown our previous launches. Through these flights, the efficacy of our chosen components has been ensured.

4.4.3.4 Secondary Experiment

The Run-Cam HD that is acting as our secondary payload has been launched on multiple Sub-Scale flights and has been proven to be a reliable capturing device.

4.5 Ground Station

The ground station and consequently live telemetry is a self-imposed requirement; however, we will be using an esp32 and LoRa transceiver to display the data on telemetry viewer. The ground station will be displaying a 3D Cad model of the rocket, as well as the telemetry being collected during flight.

4.5.1 Design

The Ground Station was designed and built around a breadboard with a LoRa(Long Range Radio) Transceiver wired to an ESP 32. The LoRa Transceiver acts as the receiver for the GPS onboard the rocket. In the case of the NASA Student Launch rocket the GPS is a BNO08x. The data received from the GPS by the LoRa transceiver is then sent to the ESP 32. The ESP 32 is then connected to a laptop, which receives the data, as well as simultaneously running code written in Arduino IDE.

The data is then run through a program called Telemetry Viewer. Telemetry Viewer allows for the data received to be displayed in the form of a 3D CAD model rocket. In this case, the data is also converted into quaternions, a three-dimensional rotation axis, to prevent gimble lock. The CAD rocket displays the actual rocket's flight path in 3D space.

The program written in Arduino gives instructions to the ESP 32, thus directing the LoRa transceiver, as well as the BNO055. The BNO055 acts as Telemetry Viewer's GPS for the digital rocket.

4.5.2 Software

As initially stated in the design, the software written in Arduino tracks and displays data received from the rocket. The radial data is then converted into quaternions. The reason for the conversion is quaternions do not suffer from gimbal lock. This data is then sent and displayed to Telemetry Viewer.

4.5.3 Interface

The interface display is shown through Telemetry Viewer. Telemetry Viewer takes the quaternion data and displays it using a 3D CAD model of the rocket. After testing the full-sized rocket, the data was compared to the sub scale rocket in Telemetry Viewer. The comparison showed many similarities between the subscale and the full-scale rocket.

Additionally, telemetry viewer provides another tab aside from the 3D model where we can observe our live telemetry in terms of time similar to the serial plotter commonly found in most IDEs.

4.6 Payload Demonstration Flight

The payload demonstration flight will occur March 18th. The payload demonstration flight will be used to assess our ability to successfully and safely fly our payload without inhibiting it's mission success criteria.

4.6.1 Success Criteria

Criteria	Status
Section 4.1 (Payload Criteria) all met	To be completed
Vehicle is unscathed and deemed safe for re-flight	To be completed
Experiment is unscathed and deemed safe for re-flight	To be completed
Images are able to be recovered from onboard SD Card	To be completed
Flight video is able to be recovered from onboard SD Card	To be completed
Ground Station CAD model is accurate to flight profile before separation points	To be completed
Live telemetry holds for the entirety of flight and after ground hit	To be completed
Personnel follows safety procedural documents and no physical harm is observed	To be completed
Assembly and fine-tuning is completed within a 45-minute time frame	To be completed
Post-inventory check is complete and accounted for	To be completed

4.6.2 Future Plans

Our payload demonstration will occur at Adonis Ave SW, Palm Bay FL, 32904 on March 18th Saturday at 10:00pm when the launch pads provided to us open. This past year, we have observed many successes and failures in our first year competing NASA's Student Launch initiative. We have noted the possible severity of our failures and have moved towards plans to prevent any harm be it physical, environmental, etc. Our payload demonstration flight will not only be a means to prove our payload system's efficacy and ability to perform, but will additionally serve as another bed for us to practice safety procedures and documentations for Huntsville come April. Safety documentation and procedural lists have been flushed out further and will ensure any extraneous factors can be mitigated. Ground station requirements will also be expanded within in the two weeks between FRR and our payload demonstration flight but this will not affect final costs or weight of the vehicle as this will solely exist on the interface section of our ground station and serves as member enrichment.

We are confident in our capacity to fulfill all our requirements and hope to provide a foundation for UCF's subsequent launches this year, as well as the following. Additional documentation will be found in the safety section including but not limited to the aforementioned checklists and procedural lists. Overall, our student body has practiced diligently for the following launch cycle and can ensure the USLI judges that we will be prepared as best as possible come April.

5 Demonstration Flights

5.1 Flight Information

We flew our Vehicle Demonstration flight on March 4th, 2023 in Palm Bay with Spaceport Rocketry Association. The weather was not ideal due to fourteen mile per hour winds on the ground. The motor we flew on our test flight was the Aerotech K1000T, which is the same motor we will be using for all future flights. There was no ballast used on this flight and we do not plan on using any amount of ballast. We predicted an altitude of 5132 feet for our vehicle demonstration flight. We ended up targeting a lower altitude than 5507 feet due to the change of material from pre-preg carbon fiber to having to wet-lay carbon fiber.

5.2 Analysis of Vehicle Demonstration Flight

The vehicle demonstration flight was done to verify the vehicle design was good for launch aside from simulation. This was an attempt to show the capability of our rocket with a mock payload. A successful VDF would be based on the flight data as well as both parachutes fully deploying, and the rocket being safely recovered. Unfortunately, our rocket charges did go off in flight, but the main parachute did not deploy. We believe the reason for not deploying to be that the force of drag was higher than the black powder force as well as the payload's force on to the nosecone. This had deemed our VDF unsuccessful.

Vehicle Demonstration Flight	Conducted, Unsuccessful
Payload Demonstration Flight	Incomplete
Launch Day Criteria	March 4th, 2023 Palm Bay Partly Cloudy 75°F Windy
Motor Flown	K1000T
Target Altitude	5507'
Predicted Altitude	5132'
Actual Altitude	4215'

The following tables are from the Stratologger CF altimeter during the VDF. In figure 5.1, it can be noted that the recovery subsystem worked as intended with the drogue charge detonating at apogee and the main charges detonated at 600' as predetermined before flight. In figure 5.2, the velocity of the descent was recorded to be an average of 130ft/s with a maximum at roughly 143 ft/s.

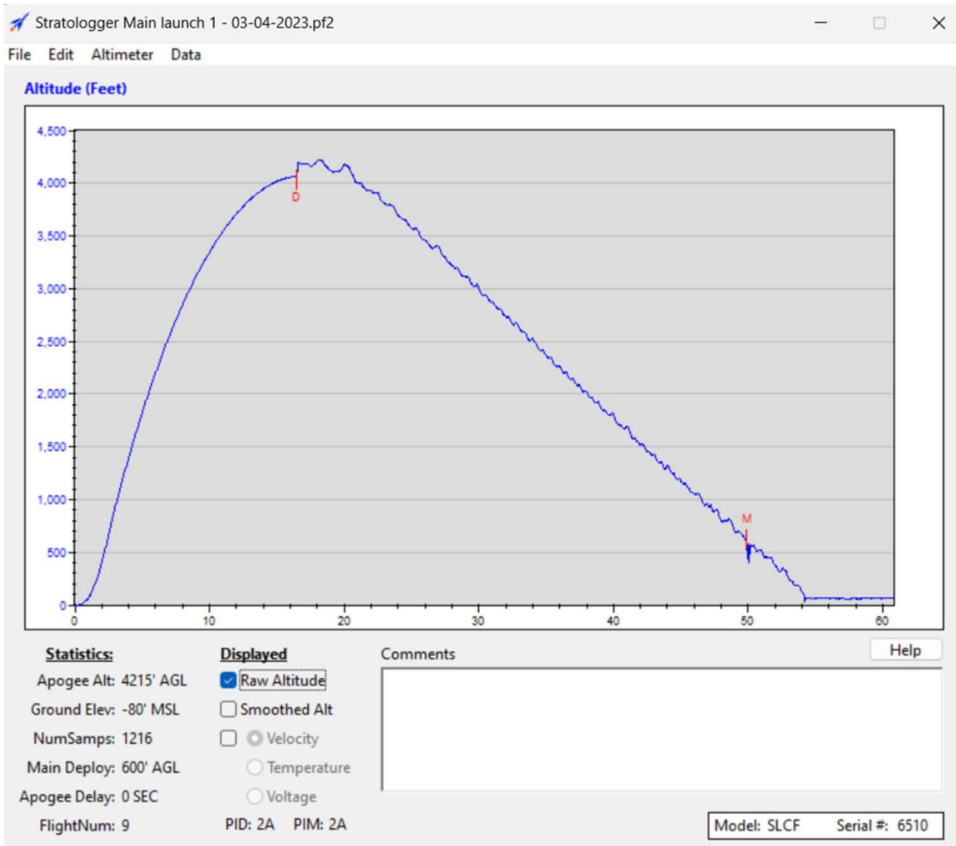


Figure 5.1: Flight path and Raw altitude

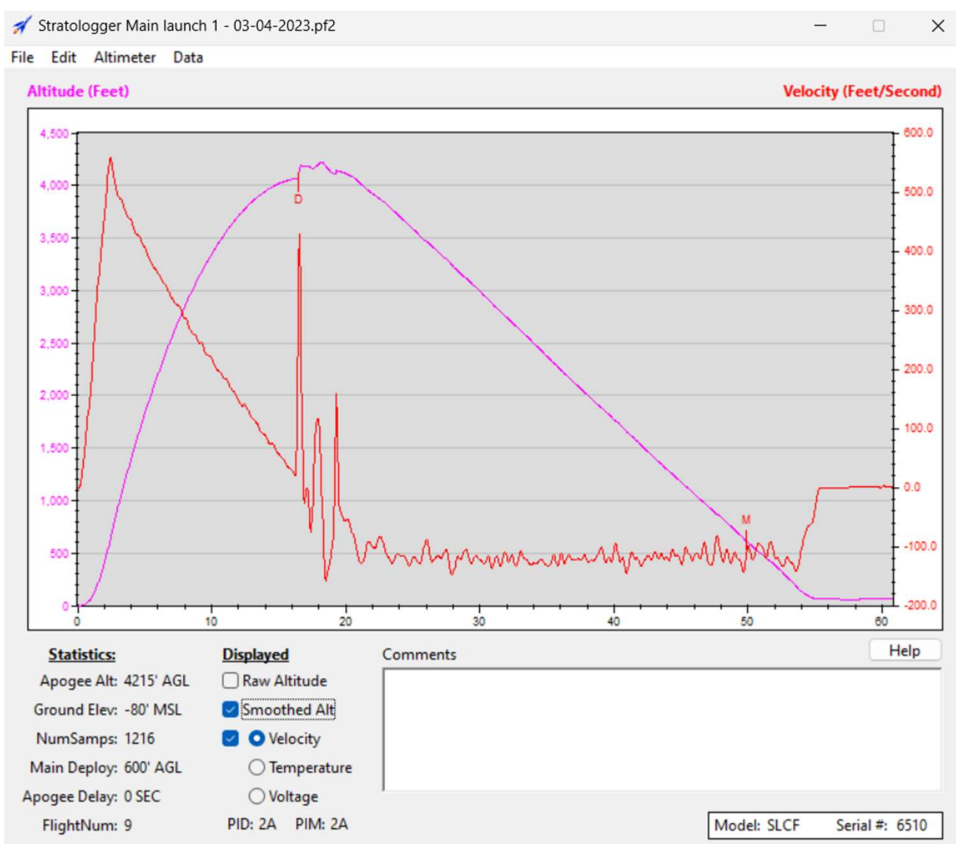
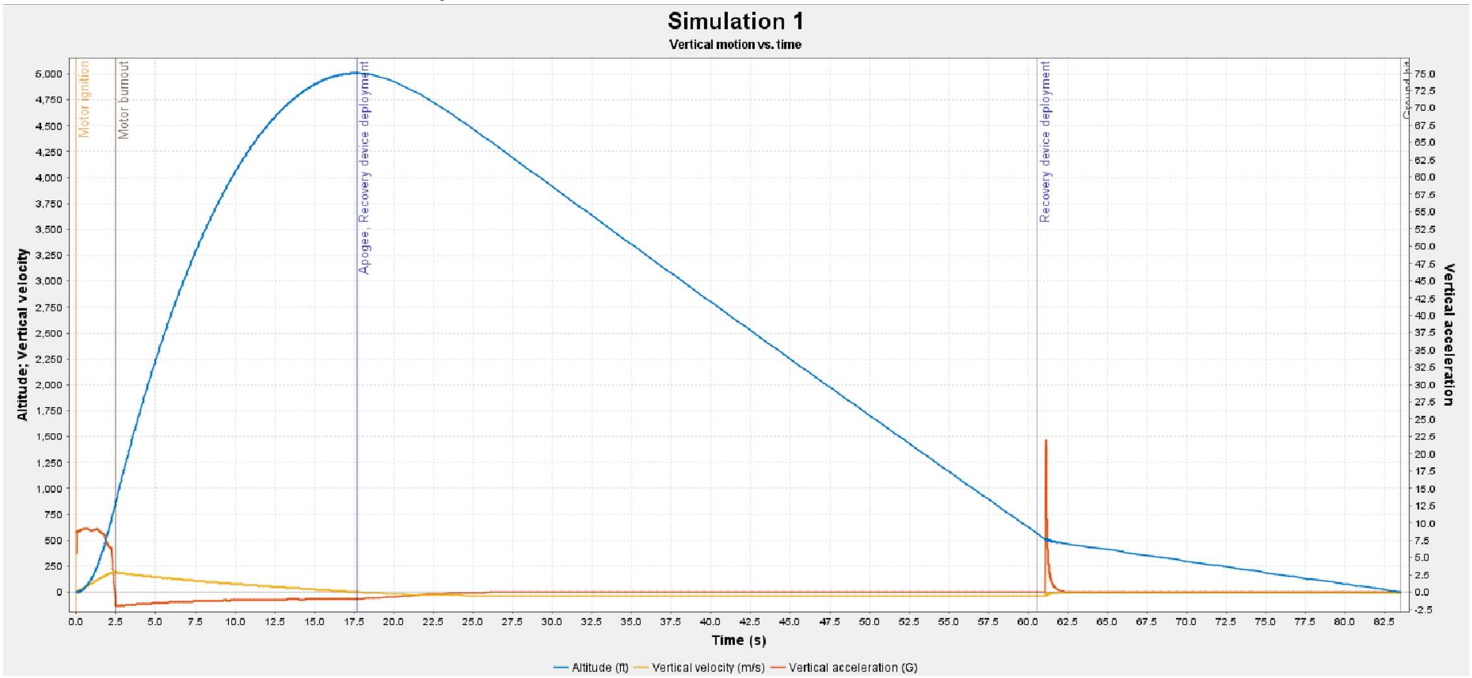


Figure 5.2: Flight Path with Velocity

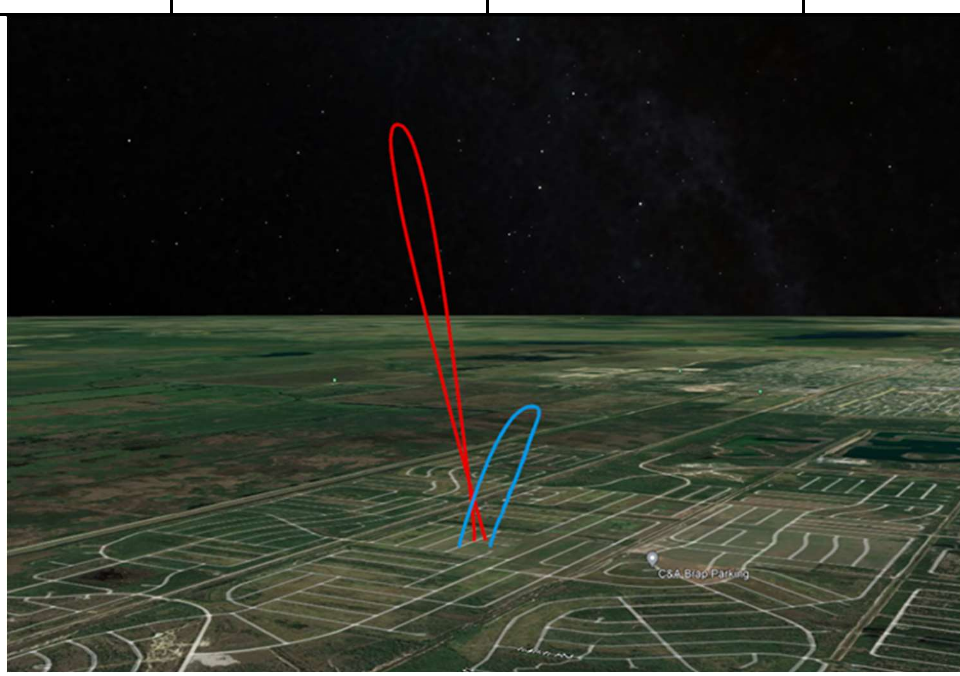
5.3 Simulation with Launch Day Conditions



Our simulated apogee under the given flight conditions was roughly 5040ft high.

5.4 Comparison to Subscale Flight

Subscale Apogee (ft)		Full Scale Apogee (ft)	
Simulated	Actual	Simulated	Actual
1355	1374	5040	4215



Recorded flight data from Featherweight GPS trackers overlaid onto Google Earth (Blue: Subscale, Red: Full scale)

The table above shows that while our subscale launch ended up very close to our projected apogee, our full-scale launch was roughly 800ft below our simulations. This discrepancy may have occurred due to poor launch day conditions, which were towards the upper limit of our safe operating conditions.

5.5 Hardware Damaged and Plan of Action

For hardware, the secondary experiments run cam was disconnected during flight. This was due to the wires being jostled around in flight and disconnecting in the process. Our tailcone for the rocket that was made of PETG had shattered on impact with the ground. Our metal nosecone tip took minor damage and our actual nose cone had cracks from the impact. For our payload demonstration flight, our plan of action is to sand the inside of the upper body tube and the nose cone to allow for a better fit as the parachute and the payload were tightly fit. Orientation of our payload and the parachute will be arranged so that the parachute cushions our payload when the black powder charges go off as well.

5.6 Lessons Learned from the Flight

In terms of recovery, our main lesson learned was that drag can cause a lot of force. This caused serious discussion about several factors in our design including the tightness of the upper body tube as well as the nose cone, the amount of black powder being used during flight as well as the black powder used for main vs. Redundant charges, the orientation of our payload and parachute in the rocket, and even changes in where deployment occurs in the rocket. Doing this flight has opened our eyes to flaws in our rocket that can be fixed.

5.7 Planned Future Demonstration Flights

We will be re-flying our rocket to meet the payload demonstration flight requirement on March 18th, 2023 as well as to test fly the rocket to make sure we have a safe recovery this time around. With the PDF we will also implement changes to the rocket from VDF to fix the issue with our main deployment.

Safety

In any project, risk is inevitable. It is our job to be able to recognize those risks and treat them accordingly. In order to avoid undesirable results, especially physical injury, it is crucial to have clear procedures in place. This section provides methods that will limit risks at assembly and launch, as well as specific descriptions of possible hazards and their prescribed solutions.

As we move forward into the operational phase of the project, while manufacturing hazards are behind us, continued testing and dangers related to launches remain present. The cooperation and collaboration of members is especially crucial during this period. Continuing to foster a culture of safety, and modeling behavior for new members and others to follow remains a priority.

Launch Operations Procedures

By writing and utilizing lists of items to have present and events to occur before, at, and after launches, the success of the rocket can be better ensured. Events and inventories are categorized according to subsystem, which may occur simultaneously. Exceptions to this rule are the Full Rocket Assembly and initial deconstruction procedures. Troubleshooting and verification steps are listed where necessary.

General Preparation and Procedures:

PPE Present on Site:

- Box of nitrile gloves
- 5x NIOSH masks, 12x NIOSH filters

- 5x Safety Goggles
- 5x Safety Glasses
- 5x pairs of Kevlar gloves

Checks for environment:

- Ensure wind speeds are below 25 mph.
- If above 5 mph, alter the direction of the launch rail.
- Ensure clouds or obscuring phenomena of more than five-tenths coverage are not present.
- Check humidity and terrain for excessively dry conditions.
- If so, a fire blanket must be placed below the launch pad.
- Remove any dry brush that could act as tinder in case of a fire from the area.
- Ensure no high voltage electrical lines or major highways are present at the launch site.
- Ensure no buildings or structures are within 1500 feet of the launch site.
    -

Briefing to team members by Safety or Systems Team Lead:

- Timeline of events prior to, during, and after launch
- Launch field etiquette
- Assurance of NAR minimum safe distances, per our motor's impluse
- Minimum diameter of cleared area: 125 ft
- Minimum personnel distance: 2000 ft
- Overview of troubleshooting measures
- Designate members to observe trajectory for ballistic collision
- Identification of fire suppression and first aid equipment
- Designate member(s) to administer fire suppression and first aid in case of emergency

Recovery Pre-Flight Checklist

Inventory

- StrattoLogger
- RRC2
- LiPo Bags
- Zipties
- Shaft Guards
- Bulkheads
- 9V Alkaline Batteries
- Dupont Wire
- Wrench
- Arming Pin
- Limit Switches
- Wire Cutter
- Wire Strippers
- Car Battery
- Car Power Inverter
- 9V battery adapter
- Locknuts
- 5-minute epoxy
- Drill

- Masking Tape
- Standoffs
- Recovery Box
- Parachutes
- Shock Cord
- Heat Shrink
- Terminal Blocks
- Quick Links
- Rubber Gloves
- E-matches
- Locktite
- Electronic Screwdriver

Internal Assembly

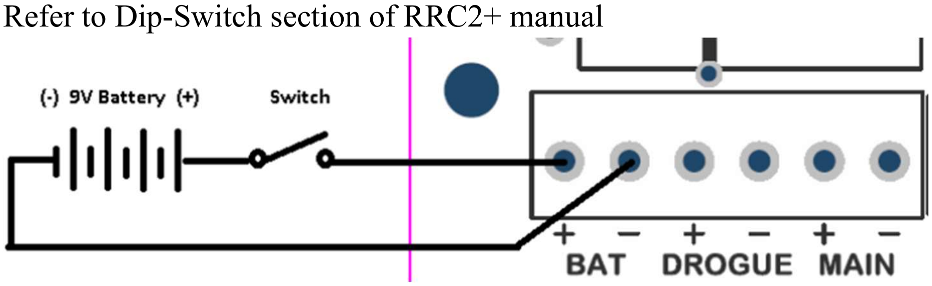
☐ Black powder amounts are confirmed with team lead, Nathan
☐ Bulkheads are properly labeled for alignment
☐ LiPos are charged using balance charger
☐If not, 9V alkaline batteries are kept on hand
☐ Terminal Blocks are epoxied in and screwed
☐ Blocks are epoxied in
☐ Limit Switches are functional
☐ Terminals Checked for continuity
☐ Stratologger is properly programmed, information can be extracted using data line

ABNORMAL CONDITIONS DETECTED:
Siren tone, then corresponding number of digits:

1: Total power loss during last flight.
2: Momentary power loss during last flight.
3: Drogue current exceeded 6 amps.
4: Main current exceeded 6 amps.
5: Problem detected with FLASH memory.
6: Problem detected with pressure sensor.

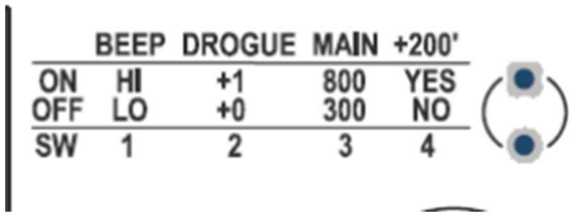
☐ RRC2+ is properly set up

☐ Refer to Dip-Switch section of RRC2+ manual



☐ Mounted with 4-40 screws on plate

☐ Wires stripped no more than a ¼"
☐ **Dip settings are only read on powerup, make sure to pre-program the altimeter**



1 = OFF, 2 = ON, 3 = OFF, 4 = ON

☐ Threaded Rods are inspected for damage
☐ Parachutes are packed, refer to team lead – Nathan
☐ Coupler is confirmed to fit properly into airframe
☐ **Successful completion of practice assembly within 45 minutes**
☐ **Coupler is fully assembled, pin in place**

Launch Day Procedure

Structural Assembly

- With nuts facing the same side as the U-Bolt, slide the 4 threaded rods into corresponding holes in the bottom bulkhead.
- Place one PVC pipe on each threaded rod.
- Slide on Stratologger plate, ensuring correct orientation.
- Repeat Steps 2 and 3 for the plates containing the Arming Pins, RRC3, and finally the top bulkhead, in that order.

Wiring

- Wire the limit switches by connecting the marked switch to the corresponding altimeter switch port for both the Stratologger and RRC3.
- Wire the primary and redundant main wires, designated yellow, to the corresponding terminals for the main charge.
- Wire the primary and redundant drogue wires, designated blue, to the corresponding terminals for the drogue charge.
- Connect only positive wires of each altimeter to their corresponding battery, and tape off negative wire.
- For redundancy, install the recovery pin into the hole between the switch plates.

Before Starting

- If eBoard, Safety Officer, or managers present a concern, any and all activities will cease.
    - This applies to members, leads, managers, safety officer, and eBoard themselves
- Organize the workstation, checking each item on the inventory list. All items should be easily accessible. When done using a tool or item, replace it in its designated place.
- Ensure all items preceding insertion into the airframe on the preflight checklist are marked before continuing to assembly.
- Ensure a static-free, grounded environment when wiring.

Launch day Assembly

- Untape the negative wires for each altimeter and wire to the negative battery terminal.
- Remove the recovery pin to activate limit switches

- Refer to section to identify the sequence of beeps that sounds. Ensure that both altimeters are signifying proper function before continuing.
- Slide Electronics Assembly into coupler
- Install shear pins (See Aerostructures Full Assembly Checklist)
- Replace Recovery pin
    - Both altimeters should silence.
- Screw the four locknuts into the bulkhead to secure the coupler and electronics bay assembly
- Connect primary and redundant drogue charges to their corresponding terminal, through the holes labeled DP and DR respectively.
- Connect primary and redundant drogue charges to their corresponding terminal, through the holes labeled MP and MR respectively.

Experiments

Inventory:

- All of the following components should be present:
    - Raspberry Pi
    - Battery Hat
    - Real-Time Clock Module
    - BNO055 Inertial Measurement Unit
    - Radio SDR Dongle
    - Radio Antenna
    - Camera
    - Continuous Servo
    - Rotational Servo
    - Limit Switch
- Tools and materials:
    - Pill casing
    - LiPo batteries
    - Threaded rods
    - Outer pill prototype
    - Inner pill prototype
    - Zip ties
    - Popsicle sticks
    - Servos
    - Camera
    - Raspberry Pi kit
    - Black polycarbonate printed pieces
    - Bondo
    - Masking Tape

Assembly Procedure:

Perform a visual inspection of the PILL.

- Inspect the exterior of the PILL for any dirt, debris, damage, or other concerns.
- This may include but is not limited to: dust or dirt buildup, cracks in the casing, or plastic deformation.

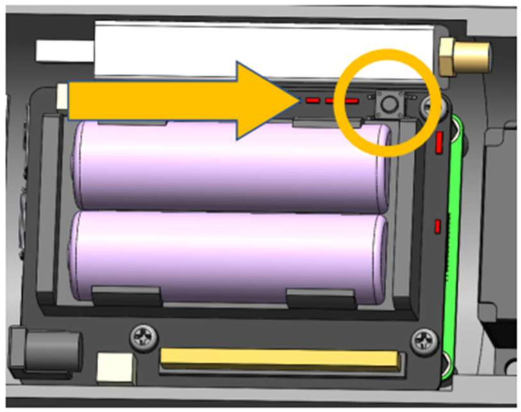
Inspect and verify all PILL internals.

- Remove the primary endcap (the one with a U-bolt) from the PILL by loosening the six screws on the outer rim.
- Slide the Electronics Sled carefully out of the PILL through the endcap opening.
- Confirm all electronics and linear elevator components are present, free of dust or debris, and undamaged.

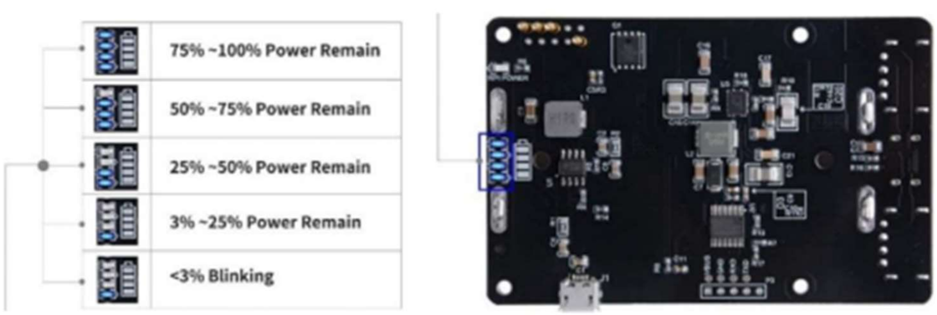
Replace the two AA batteries in the Battery Hat.

- Ensure both batteries are fully charged before installing.

Provide power to the Raspberry Pi by shortly pressing, then depressing the power button found on the Battery Hat.



- Ensure the startup procedure executes properly by watching for the following indicators:
    - Flashing lights on the Raspberry Pi
    - Continuous servo motor moving the linear elevator up, then down.
    - Camera rotation servo rotating the camera 360 degrees.
- Should any of the previously mentioned startup indicators fail to execute, perform the following troubleshooting steps.
    - Ensure all cables are undamaged and not twisted or caught on any mechanisms.
    - Disconnect all power connectors, ensure they are undamaged and free of debris, then reconnect them.
    - Ensure the two AA batteries in the Battery Hat are fully charged. A low charge may be indicated by the LEDs present on the Battery Hat.



    - With all the above steps performed, attempt to power on the Raspberry Pi again.

Ensure the linear elevator and camera rotation servo are fully functional.

- Upon correctly powering on, the continuous servo and rotational servo will attempt to spin. Verify that their movement is smooth and unrestricted.
- If any issues with rotation are observed, perform the following troubleshooting steps:
  - Find and remove any blockages from the gears and motors.
  - Ensure all gears and motors appear undamaged.
  - Test the air for the smell of burning and look for smoke.
  - If smoke is detected or either servo motor continues not to spin, a motor replacement may be necessary.

Connect to the Pi via ethernet and verify output log data.

- Plug one end of an ethernet cable into the RJ45 port on the Raspberry Pi. Plug the other end into a laptop, either directly into an RJ45 port or through an adapter.
- Open a command prompt window on the laptop and SSH into the Raspberry Pi. Details of this process will be documented once the Raspberry Pi has been received and programmed.
- Once connected to the Raspberry Pi, read the output logs to ensure the PILL is functioning correctly. The following log statements should appear in some form:
  - PILL powerup sequence initiated.
  - Raspberry Pi is online
  - PILL script executing
  - Power input adequate
  - Real-Time Clock reporting
  - BNO055 readings within bounds
  - Radio is operational
  - Camera is operational
- Should the Raspberry Pi SSH connection fail, perform the following troubleshooting steps:
  - Ensure all cables are undamaged and not twisted or caught on any mechanisms.
  - Disconnect all power connectors, ensure they are undamaged and free of debris, then reconnect them.
  - Ensure the two AA batteries in the Battery Hat are fully charged. A low charge may be indicated by the LEDs present on the Battery Hat.
  - With all the above steps performed, attempt to power on the Raspberry Pi again.
- Should any of the log statements fail to appear or return an error, perform the following troubleshooting steps:
  - Confirm that the correct software has been loaded onto the Raspberry Pi.
  - Follow any troubleshooting steps proposed in the error statements.

Return the Electronics Sled and seal the PILL.

- Slide the Electronics Sled carefully back into the PILL.
- Place the primary endcap (the one with a U-bolt) on the PILL and tighten the 6 screws
- Ensure that both endcaps of the PILL are tightly secured and not at risk of coming loose.
- If either endcap is loose, tighten the bolts as far as possible without using excess force.
- Verify the Hatch and Bearing Mechanism are operating smoothly.
- Exercise the Hatch by moving it from fully closed to fully open.
- Rotate all sections of the PILL independently by hand to ensure that they are spinning freely.
- If the hatch or bearing mechanism is not moving freely, perform the following troubleshooting steps:
  - Find and remove any debris or blockages from the hatch and bearing mechanism.
  - Apply lubricant to the hatch or bearings if necessary.

    - Place the PILL on a flat surface and ensure that it naturally aligns such that the camera and electronics face directly upward.
  - Should the PILL not naturally align correctly, perform the following troubleshooting steps:
    - Remove any foreign objects from within the PILL.
    - Perform the troubleshooting steps found in the previous section.

Seal the Hatch

- Move the hatch into the closed position such that it is held in place by the rubber seal.
- Ensure the hatch does not open if the PILL is held upside-down or at an angle.

Attach and test the U-Bolt

- Ensure the U-bolt is securely fastened to the primary endcap of the PILL.
- Coordinate with aerostuctures to attach shock cord.
- Tug on the shock cord while holding the PILL to ensure it does not come loose.

Final Inspection

- The team lead will ensure that all steps listed above have been followed.
- A final visual inspection will be conducted
- Confirm that the lights on the Raspberry Pi are on and blinking
- Ensure that all elements remain in prime condition, free from debris or damage.

Aerostructures

Inventory

- 6-32 bolts (16)
- 4-40 pins (20)
- Upper and lower body tube, coupler, nosecone
- Motor
- PVC pipe stand
- Screwdriver (flathead)
- Screwdriver (Philips)
- Tyvex Suits
- Sandpaper bag
- Mouse Sander kits
- Solo Cups
- Ziploc Bags
- Microfiber cloths
- Tarps

Full Rocket Assembly

In advance:

- All subsystems must be ready for full rocket assembly.
- The avionics bay and recovery electronics unit are fully armed and functional.
- All subsystem pre-flight checks have been completed.
- When handling carbon fiber pieces, use gloves impermeable to splinters.
- All assembly should be done with as few hands as possible. Keeping to a small crew improves communication and limits confusion and disorder.

Nosecone:

- Tighten the three nuts to secure the shoulder, sled, and bulkhead together.
- Insert active telemetry sled into shoulder and bulkhead.
- Check for alignment between holes for the camera and 6-32 steel bolts.
- Tighten the three nuts until they secure the shoulder, sled, and bulkhead together
- Screw in the four 6-32 steel bolts with a flathead screwdriver, in the order 0°, 180°, 90°, 270° regarding their position on the circumference of the tube.
- Screw in nosecone tip.

Upper body:

- Verify all four shear pin holes in both the shoulder and upper body are clear of debris.
- Attach the shock cord to the nosecone's U-bolt with a quick link, and thread it through the upper body
- Align the body tube to ensure that the side that says "top" faces the end that will receive the coupler, while the other side will receive the nosecone
- Load in the main parachute and the P.I.L.L. while ensuring the quick link is available for the shock chord to attach to the coupler
- Line up witness marks on the upper body so the shoulder and nosecones witness marks line up with their respective numbers, and ensure 4-40 shear pin holes line up
- Verify all vent holes are clear
- Screw in four shear pins
    - Use a flat head screw driver if using apogee short 4-40 shear pins.
    - Use a Philip's head screwdriver if using longer 4-40 shear pins.
    - Do so in a 0°, 180°, 90°, 270° order, regarding their position on the circumference of the tube.

Coupler

- Connect the upper body quick link to the side of the coupler that has a bulkhead stating "UP"
- Line up numbered witness marks and insert the coupler.
    - Be aware of black powder charges, wires and other recovery components. They can be easily caught during this step.
- Ensure the four 6-32 steel bolt holes line up in accordance with the witness marks
- Screw in four 6-32 steel bolts using a flathead screwdriver in the order in the order 0°, 180°, 90°, 270° regarding their position on the circumference of the tube.
- Verify all three shear pin holes in the coupler are clear of debris.

Lower body:

- Ensure the shock cord is attached to the centering ring U-bolt, and the drogue parachute is inserted into the lower body.
- Verify all three shear pin holes in the lower body are clear of debris
- Connect the lower body quick link to the coupler.
- Line up numbered witness marks and insert the lower body into the coupler
    - Be aware of black powder charges, wires and other recovery components. They can be easily caught during this step.
- Ensure 4-40 shear pin holes line up.
- Screw in three shear pins
    - Use a flat head screw driver if using apogee short 4-40 shear pins.
    - Use a Philip's head screwdriver if using longer 4-40 shear pins.

- Do so in a 0°, 180°, 90°, 270° order.

Motor installation

- Only the student mentor may perform this step, with proper PPE, which may include gloves and safety glasses, to his discretion.
- Insert motor tube into lower airframe, ensuring centering rings hold securely.
- Screw on the tailcone.
- Screw motor retainer onto motor tube.

Preparing for launch

Go/No Go poll

- The systems manager will conduct a poll for each system, where "Go" means that their components are prepared for launch, and "No Go" means that any component is not ready for launch. Check each box to verify that system is fully functional.
    - Recovery
    - Telemetry
    - Experiments
    - Aerostructures
    - Integration
- If any are "No go", all operations halt and the corresponding subsystem will solve the issue. Repeat the previous step until all systems are "Go".
- If all systems are "Go", operations may proceed.

Launch Pad Preparation

- A team of essential launch personnel, including the Aerostructures Manager and Student Mentor, will be determined. Only this team of no more than 4 personnel may accompany the rocket to the launch pad.
- Two participants will carry the rocket from either end.
- Before installing the vehicle onto the launch rail, check:
    - The launch controller is disarmed
    - The launch rail is the minimum distance of 2000 feet from spectators
    - Conditions remain favorable as per the Environment Checklist
    - The launch pad is stable and sufficiently sized

Launch Rail Installation

- Point launch rail to predetermined angle, based on wind speeds.
- Slide the vehicle onto the launch rail along rail buttons
- If resistance is encountered, remove the vehicle and ensure proper alignment of rail buttons and, if necessary, apply lubricant.

Ignitor Installation

- Only the student mentor may perform this step, wearing proper PPE, which includes safety glasses and gloves.
    - Ensure alligator clips are clean and undamaged.
    - Ground alligator clips to remove excess static charge.
    - Install the ignitor through the nozzle of the motor and push the ignitor all the way up the core of the motor.

Vehicle Launch

- A 5 second countdown will ensure at adequate volume for all participants to hear.

- The launch controller officer will push the button to ignite.

At the scene of collision

- After a full 60 seconds have passed since collision, and no other rockets are set to launch in the vicinity, designated members of recovery, as well as one member from each subsystem, will go investigate the scene of the collision.
- Gloves impermeable to carbon fiber splinters must be worn by all those coming into physical contact with the rocket.
- Initially upon recovery, no members shall come into physical contact with the rocket.
- Photo documentation of the scene of collision will be collected. Members from each subsystem will ensure no evidence is left undocumented.
- It shall be determined that all sections are present, and any obvious damage will be taken note of.
- Once leads have agreed it is safe to proceed, each section of the rocket will be carefully lifted off the ground and consolidated into the hands of two members. It will then be carried back to the ground station.

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Deconstruction:

All members participating in deconstruction must wear gloves impermeable to carbon fiber splinters.

As few members as possible will participate in deconstruction, limiting to 5 sets of hands at once.

- Once back to ground station, set the rocket onto the PVC pipe stand.
- The recovery lead will interpret the tones from the RRC2+ and record the measured apogee.

If sections have failed to separate:

- Remove all shear pins
    - Use a flat head screw driver if using apogee short 4-40 shear pins.
    - Use a Philip's head screwdriver if using longer 4-40 shear pins.
- Unscrew the 6-32 steel bolts of the coupler and nosecone sections using a flathead screwdriver.
- Separate the applicable sections
    - Members will grip either side of the designated section, positioned out of the way of the direction of pull.
- Once the rocket is fully separated, each subsystem will split off with their section.

Coupler Disassembly

- Unscrew the four locknuts from the top bulkhead and remove it.
- Find the battery terminals on both altimeters.
- Disconnect the negative wires from the battery terminals.
- Tape over negative wires using masking tape.
- Remove the charges from the terminals on the bulkheads.
- For each charge, twist the two wires together to ensure no current can flow.
- Tape over the now twisted wires.

Inspections for Internal Damage

- Once the recovery unit has been removed from the coupler, check for signs of physical damage on the:
    - General structure, including each plate/sled and threaded rods.

  - Wires, including checks for loosening of wiring.
  - Electronic components, including GPS, altimeters, Transc
  - Batteries
  - Limit Switches
- Listen for audible signals from both altimeters indicating improper function.
- Descriptions of all damaged parts will be recorded.

Data Retrieval

By component:

Featherweight GPS: In the "Test Flight" application, use the option to email the document with altitude data to the user.

Strattologger: Use the Stratologger software, Perfect Flite Data Cap, utilizing the data line.

Onboard SD Card (ESP 32): carefully remove Micro-SD from the device, and, using a laptop, download the live telemetry.

Onboard SD Card (Run Cam): carefully remove Micro-SD from the device, and, using a laptop, download the recording.

6.2 Hazard Analysis Method

By assigning a letter and number to each event that corresponds to their respective likelihood and severity, we can more efficiently describe each event, and treat them accordingly.

6.2.1 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%

6.2.2 Severity of Event

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

6.2.3 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
Improbable - 1	1A	1B	1C	1D

6.3 Personnel Hazard

Hazard	**Description**	**Risk Rating**	**Mitigations**	**Verification**
Mishandling of 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
Skin contact with epoxy	Epoxy is a skin irritant. Contact dermatitis can occur with direct contact.	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

Inhalation of epoxy fumes	Fumes produced	2C	All members using epoxy will wear a NIOSH- approved mask in a well-ventilated setting.	Before using epoxy, team members will have to show the Safety Officer that they are wearing masks
Skin contact with Super glue (CA)	Super glue is a skin irrtant. If allowed to harden, layers of epidermis may be removed with it.	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.
Inhalation of motor fumes	Exposure to motor fumes while working with the motor can cause headaches, dizziness, nausea, and fatigue.	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
Inhalation of paint fumes	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
Projectile materials during manufacturing	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 required to wear safety glasses.	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.
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	A plexiglass cover in between the opening of the machine and the team members will be present. Protective eyewear and restrained clothing will be worn, and a dust collector will also be in place.	The Safety Officer or authorized mentor will be present whenever the CNC machine is being used.
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 multitude of injuries ranging from slight irritation to major blood loss.	2C	Using caution and focus when handling tools, making sure the item being drilled into is secured in place, and ensuring the proper drilll bit is in use.	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 driver. This may result in blood loss.	2C	Team members will ensure that the item is properly secured using clamps or vices whenever using a driver	Before working with drivers team members will have to show the Safety Officer that the item is properly secured
Contact with debris from ballistic collision	Destruction of the rocket resulting from Catarstrophic engine failure, caused by malfunction of the rocket during	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

(due to Catastrophic Rocket Engine Failure)	flight, would result in falling debris, potenitally burning, cutting or otherwise injuring participants.			
Contact with debris from ballistic collision (due to parachute deployment failure)	Failure of the paracuhte to deploy during the launch could result in the destruction of the rocket, which would create the risk of projectile debris which, if it hits participants, could cause burns, cuts, and other injuries.	2B	To prevent this, we will make sure that the parachute is inserted properly, and the cord is in a position where it 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	Everyone on the team will be properly instructed by our experienced high-powered rocketry mentor on how to properly pack a parachute and the Safety Officer will double-check the process on all launch occasions
Inhalation of fiberglass dust particulates	Lung irritation may occur with inhalation of fiberglass dust.	2C	All participants must wear NIOSH-approved masks while in the presence of fiberglass dust, especially during sanding.	The Safety Officer or highest ranking present leader shall ensure that any members are wearing the appropriate personal protective equipment.
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	Impermeable gloves must be worn when handling carbon fiber.	The Safety Officer or highest ranking present leader shall ensure that any members are wearing the appropriate protection.
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 slight irritation in your lungs	2C	All team members using carbon fiber will be required to wear masks.	The Safety Officer will make sure that all team members that are working with carbon fiber are wearing masks
Carbon Fiber shards cut skin	A team member is cut by a shard produced when cutting or sanding this carbon fiber. Injuries range from minor splinters to major blood loss. Carbon fiber is particularly dangerous due to its carcinogenic effects and lack of immune response.	1D	When working with carbon fiber, all members must wear bunny suits, leather gloves, safety goggles, and respirators. If in contact with carbon fiber, such as in transportation, leather gloves must always be worn.	All interactions with carbon fiber will be overseen by either the Safety Officer, Manufacturing lead, or Aerostructures lead, who will execute a debriefing to all members about carbon fiber safety and ensure proper PPE is worn.
Burns from soldering	Molten metal or the hot iron makes contact with skin when manufacturing electrical components, resulting in burns.	3D	All members who wish to participate in soldering must present competency in proper soldering iron handling.	All members participating in soldering must read the provied materials regarding soldering safety, and experienced members, such as the Telemetry lead, will observe all activities.
Particulate matter from explosion impacting participant members	Projectiles resulting from the explosion at launch could harm participants.	1B	All members present at the launchpad will be wearing proper PPE, and everyone will be 25 feet away from the launchpad at launch.	Safety officer will ensure proper equipment is worn and proper distance is kept before allowing

Hearing Damage	Proximity to loud noises, such as those present at launch and from tools and machines during manfucturing, can cause long term hearing loss or tinnitus.	3D	Seek alternative machines and methods if possible. Noise cancelling equipment, such as earplugs, shall be worn.	Team leads will see that all possible hazards have been reduced in the design process, and that proper PPE is worn during all operations.
Tripping Hazards	Any objects, especially cords along the ground or from above, in the path of a participant pose a tripping threat. Injuries from tripping include bruising, but can be a catalyst for worse injuries if one falls into a secondary hazard.	3C	An organized, controlled environment shall be prioritized at all times. Participants shall be expected to clean up after themselves per every task, and not leave things such as tools laying around.	Participants shall hold each other accountable to keeping an organized environment, with team leads responsible for the state of the environment.
Injury from rotary machines	Rotary machines, including CNCs, drills, and sanders, pose a threat if clothing or accessories become caught. Injuries range from minor abrasions to severe blood loss.	2B	All members who wish to participate in rotary tool use must use protective guards when applicable and keep hair and loose articles tied back.	Members should present competency in tool use, either by participation in manufacturing workshops or proof of prior experience. The Safety Officer or highest ranking leader will ensure that members are using proper ettiquette.
Skin irritation from fiberglass dust	A rash can appear when the fibers become embedded in the outer layer of the skin. No long-term health effects should occur from touching fiberglass.	2B	When sanding fiberglass, as much skin as possible should be covered, which includes the wearing of long sleeves and pants, goggles, and masks.	The Safety Officer or highest ranking present leader shall ensure that any members within 20 feet of fiberglass sanding are wearing the proper personal protective equipment.
Inhalation of Frekote Mold Release fumes	Frekote Mold Relase fumes are a severe lung irritant.	2B	All participants using this chemical shall wear NIOSH approved masks.	The Safety Officer or highest ranking present leader shall ensure that any members within range during use of Frekote are wearing the appropriate protection.

Dehydration	Due to Florida climate, launch sites pose a particular hazard for dehydration.	4A	Adequate access to water shall be made available.	Before leaving for launch sites, it shall be ensured that enough water is brought to hydrate all members present.
Sunburn	Due to Florida climate, launch sites pose a particular hazard for sun damage to skin.	4A	Protection from UV rays, including sunscreen and shade, shall be provided.	Leads will model safe behavior by applying sunscreen themselves and encourage others to apply sunscreen. Shade shall be provided by tents.

6.4 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	Esnure all measurements and manufacturing methods are done properly, and that adequate materials are used for the purposes they are expected to serve.	Manufacturing leads are to inspect every simulation and CAD design, as well as research on materials and manufacturing processes.
Ignition Failure	Issues with the continuity on the launch pad lead to an inability to start the motor and failed flight.	2D	Make sure to check the continuity before loading the pad.	On the pre-flight checklist, this item will be performed by the Aerostructures manager and checked off by the Systems Manager.
Altimeter Failure	Loss of connection to the altimeters would cause a failure to ignite charges, which would result in ballistic collision. Anything in the path of the rocket	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, as well as redudancies such as the attachment of a shock cord to the motor if deemed necessary.	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. A safety factor of 2 shall not be exceeded.	Measurements shall be triple checked by the Aerostructures Manager, the Recovery lead, and the student mentor. Determination of measurements shall be left to the Aerostructures manager and Student mentor.
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.
Fin failure	Fins are not properly bonded to the rocket which could lead to the failure of the flight.	3A	The fillet epoxy shall be of an adequate thickness and cured properly. The fin cage will be made of adequaetly strong materials, and ensured to be stable.	During the design and manufacturing phase, the Aerostructures manager shall research and implement proper technique to ensure the fins are securely connected.
Failure to retrieve flight data	Connection loss or programming issues could lead to an inability to retrieve flight data.	3C	Testing of the system used to retrieve flight data prior to launch.	Ensure the system is complete in proper time to perform testing, then test each component before launch day to ensure function

Parachute Disconnection	The parachute detaches from the rest of the system after deployment due to an inability to withstand the snatch force. This would ersult in a ballistic collision.	1A	Comparing data on the expected snatch force with the max tension on the cords and max force on the connection between the u-bolts and bulkheads.	Collection of this data and proper analysis must be done before manufacturing.
Failure of Parachute Deployment	The parachute fails to release from the body tube. This would result in a ballistic collision, which poses a threat to the rocket and anything on the ground in its path, including participants, which could result in severe injury or death.	3A	Ensuring that both the main and drogue parachutes are able to move freely in and out of the body tube.	The Recovery lead shall witness that the folding of the parachutes are optimal and ensure their mobility.
Unstable flight	If the centers of gravity and pressure on the rocket are improperly placed, the rocket will experience unstable flight. This is a variable which can affect every aspect of flight.	2D	Ensure that stability is within the two to four caliber range.	Models done using OpenRocket will produce data within this range, and expirermental values will be verified.
Brownout	Components accept more current than they are rated for and are damaged.	2C	Ensure that all components are rated for the voltage of the battery we are using, and inserting proper resistors into the circuit when necessary.	User manuals for each compnent shall be read and maximum amperage will be taken note of. All circuits will be composed according to these specifications.
Heat Damage to Payload	The payload may take heat damage from exposure to black powder charges.	2B	The PILL shall be positioned strategically within the upper body, to be as far as possible from explosions, and be covered in a Nomex blanket.	The Aerostructures Manager and Experiments lead shall coordinate to ensure the best position and protection for the payload.

High Launch Rail Friction	Friction between the rail buttons and rail during launch could prevent the rocket from leaving the pad, and otherwise affect the flight path.	2C	According to weather conditions, rail type, and other extraneous factors, lubricant may be applied to the launch rail.	When installing the rocket, if friction is felt between the buttons and the rail, lubricant shall be applied.

6.5 Environmental Concerns Analysis

Hazards	**Description**	**Risk Ratings**	**Mitigations**	**Verifications**
Damage to 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.
Humid Conditions	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.
Windy conditions	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 from ignition	The combustion at ignition poses a risk of fire if there are flammable materials near the launch pad.	3C	The launch pad will be cleared from vegetation and other possible hazards before setup	The launch pad environment will be verified by the Safety Officer and, if conditions are dry, a fire blanket will be placed below the launch rail.

Interaction with wildlife	Any interaction with wildlife could be detrimental to the rocket and the deadly to the animal that encounters it.	2B	Limiting the presence of local wildlife at location.	Researching local wildlife and ensuring they are not within the path of the expected trajectory at time of launch.
Precipitation	Due to Florida climate, precipitation can be unpredictable. Precipitation during anticipated launches could set back schedule due to an inability to launch.	3A	Keeping track of expected precipitation, and attempting to fit our schedule around it.	Leads will be sure to keep tabs on weather expectations and communicate about schedules regarding it.
Release of chemicals into water systems	Chemicals used during manufacturing, including Epoxy, Frekote Mold Release, Marine 822 Hardener, and Bondo, pose a hazard to people and wildlife if they are to enter water systems.	1C	Safety data sheets for each chemical used during manufacturing shall be used as a guide for proper disposal techniques, aided by local legislation.	During and after each manufacturing session, all materials will be collected and taken inventory of, and all hazardous chemicals will be delegated to be properly disposed of.
Release of Chemicals into atmosphere during manufacturing	Chemicals used during manufacturing pose a threat of air pollution	3B	Information about chemicals used and their effect on the atmosphere shall be utilized in manufacturing processes.	Safety Data Sheets shall be made available and utilized by present leads during manufacturing. Ventilation systems shall be used whenever possible.

7 Project Plan

7.1 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 a place of easy of access	The Systems Lead Manager will communicate effectively with NASA all of our information and with the Vehicle Design Manager to 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 Vehicle Design Manager will ensure that all motor designs fall within specifications outlined by NASA

					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	
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 methodology and iterative design	The Experiements subsystem will utilize decision matrix methodology and comparison and contrast methods to determine structural design choices

7.2 Business

7.2.1 Budget

7.2.1.1 General Budget

Components Description	**Sum of QTY**	**Sum of Price Each**	**Sum of Total Cost**
1,200lb Kelvar Shock Cord 30'	1	35.5	35.5
1,200lb Kelvar Shock COrd 25'	1	28.5	28.5

1/4 by 36in	3	8.47	25.41
1/4 in. x 2 ft. x 4 ft. Medium Density Fiberboard	4	12.49	49.96
1/4"x4'x8' Hardwood PureBond Plywood	1	44.68	44.68
100 pack of popsicle sticks Jumbo	1	6.95	6.95
120-3000 grit sandpaper for sanding composite	2	7.99	15.98
14x14 Micorfiber Cloth blue 24 pack	1	14.99	14.99
18” x 18” Chute Protector	1	26.5	26.5
1ft G12-3.0	1	22.56	22.56
316 Stainless Steel Washer for 1/2" Screw Size, 0.531" ID, 1.25" OD	1	12.09	12.09
5" G12 Coupler (10")	1	47.41	47.41
5" G12 Coupler (12")	1	56.89	56.89
5ft 5/8” 3,200lb Tubular Nylon Shock Cords	1	18	18
5in. Orbital Sander w/ Dust Bag	0	26.88	0
6” x 6” Chute Protector	1	11.5	11.5
Airtech A4000 High Performance Fluoropolymer Release Film – Violet	0	13.9	0
Black-Oxide Steel U-Bolt with Mounting Plate, 3/8"-16 Thread Size, 1-3/4" ID	5	2.66	13.3
E-Glass - Style 7500, 9.4 Oz (319 GSM) Total Weight - 50" Wide X 0.012" Thick	0	38.79	0
Extra-Wide Thin Nylon-Insert Locknut Zinc-Plated Low-Strength Steel, 1/2"-13 Thread Size	1	13.46	13.46
Frekote 700-NC Mold Release	1	30.67	30.67
G-10 FR4 .125" x 12"' x 24"	5	33.69	168.45
Gator 5-inch 8-Hole Red Resin Aluminum Oxide Multi-Surface Hook and Loop Sanding Discs, 60-Grit, 5-Pack, 3725-30	2	4.69	9.38
IDL Packaging Concord Packing Tape - 2" x 1.6 mil x 110 Yards, Clear (Pack of 6)	1	31.54	31.54
LARGE RAIL BUTTON (FITS 1.5" RAIL - 1515)	2	5.7	11.4
Nylon Pan Head Screws Phillips, 4-40 Thread, 5/16" Long pack of 100	1	8.48	8.48
Oval-Shaped Threaded Connecting Link ype 316 Stainless Steel, 3/8" Thickness, 1/2" Opening, Not for Lifting	10	7.77	77.7
Publix Dry Ice	40	1.89	75.6
Shipping	5	152.94	152.94
Shop Towels 6 pack	1	11.98	11.98
Solo Disposable Plastic Cups, Red, 18oz, 50 count	2	4.29	8.58
T6511 2.000" ALUMINUM 6061 ROUND BAR 5" long	1	27.93	27.93
Thixo Cartridge Mixing Tips (12)	1	11.99	11.99
Thixo Fast Cure 2:1 Epoxy Adhesive - One 185 ml Cartridge & 2 Mixing Tips Code: TBTotalXyla	1	27.92	27.92
5.000 x 0.125 ALUMINUM 6061 ROUND TUBE 50" long	1	175.99	175.99
1' Standard Parachute	1	28.5	28.5
Grand Total	**102**	**1016.18**	**1302.73**

7.2.1.2 Vehicle Design Budget

Subsystem	Item Label	Components Description	QTY	Price Each	Total Cost	Total w Tax (If Appl.)	Vendor
Manufacturing	Frekote Mold Release	Frekote 700-NC Mold Release	1	$30.67	$30.67	$30.67	Composite Envisions
Manufacturing	Uni Directional CFF Pre preg	711 KSI HIGH TENSILE STRENGTH FIBER ■ 36 MSI STANDARD MODULUS CARBON FIBER ■ 250F EPOXY RESIN ■ 0.006" THICK	0	$41.39	$0.00	$0.00	Rockwest Composites
Manufacturing	Fiberglass Sheets	E-Glass - Style 7500, 9.4 Oz (319 GSM) Total Weight - 50" Wide X 0.012" Thick	0	$38.79	$0.00	$0.00	Rockwest Composites
Manufacturing	Fillet Epoxy	Thixo Fast Cure 2:1 Epoxy Adhesive - One 185 ml Cartridge & 2 Mixing Tips Code: TBTotalXyla	1	$27.92	$27.92	$27.92	TotalBoat
Manufacturing	Mylar	VIVOSUN Highly Reflective Mylar Film Roll 4FT x 100FT for Outdoor Grow RoomIndoor Decoration Aluminum Paint	1	53.49	$53.49	$53.49	Amazon

		Coated 2 Mil Silve					
Manufacturing	Bondo	Bondo All-Purpose Putty, Designed for Interior and Exterior Home Use, Paintable, Permanent, Non-Shrinking, 1.9 lb., 1-Quart	1	16.03	$16.03	$16.03	Amazon
Manufacturing	Particulate Fileter	3M P100 2091 Particulate Filter, 6 PCS (3-Pack)	4	17.94	$71.76	$71.76	Amazon
Manufacturing	Paint Brushes	Pro Grade - Chip Paint Brushes - 36 Ea 2 inch Chip Paint Brush	1	18.49	$18.49	$18.49	Amazon
Manufacturing	Gas Mask	3M OV AG P100 Replacement Respirator Cartridge for Professional Multi-Purpose Reusable Respirator (1-Pair)	1	$26.59	$26.59	$26.59	Home Depot
Manufacturing	PVC End Pipe	Charlotte Pipe 1-1/4 in x 10 ft Plastic End Pipe	1	$10.44	$10.44	$10.44	Home Depot
Manufacturing	1/2 Threaded rod	Everbilt 1/2 in x 72 in Zinc Threaded Rod	1	$15.90	$15.90	$15.90	Home Depot
Manufacturing	Manufacturing	PVC Eblows	1	$23.63	$23.63	$23.63	Home Depot
Manufacturing	Concrete Block	8"X8"X8" CONCRETE HALF BLOCK	2	$2.97	$5.94	$5.94	Home Depot
Manufacturing	Dowel	Dowel 3/4x36u 3/4 x3 / 4x36 Oak Dowel	2	$6.76	$13.52	$13.52	Home Depot

Manufacturing	Tap	KB TAP AND DRILL SET SAE(4-40)	1	$3.98	$3.98	$3.98	Lowes
Manufacturing	Tap	KB TAP AND DRILL SET SAE(6-32)	1	$3.98	$3.98	$3.98	Lowes
Manufacturing	Dremel Ez lock	dremel ez lock mandrel	1	$12.98	$12.98	$12.98	Lowes
Manufacturing	Oscilating Saw Blade	1-1/4" Carbide Metal Blade	1	$42.57	$42.57	$42.57	HomeDepot
Manufacturing	PVC Cross	PVC Cross 1-1/4" PVC Cross	2	$6.11	$12.22	$12.22	Home Depot
Manufacturing	Rasping Jab Saw	Rasping Jab Saw	1	$9.97	$9.97	$9.97	Home Depot
Manufacturing	Tarps	General Purpose Blue Tarp 6'x8'	2	$8.58	$17.16	$18.28	Home Depot
Manufacturing	Trash Bags	Husky 42 Gallon Contractor Trash Bags 32 pack	1	$24.97	$24.97	$26.59	Home Depot
Manufacturing	Hex Nuts	Hex Nut Zinc 1/2 (AHF)	4	$0.29	$1.16	$1.24	Home Depot
Manufacturing	Dry Ice	Publix Dry Ice (per pound)	4.98	$2.09	$10.41	$11.08	Publix
Manufacturing	Dry Ice	Publix Dry Ice (per pound)	6.94	$2.09	$14.50	$15.45	Publix
Manufacturing	Dry Ice	Publix Dry Ice (per pound)	2.35	$2.09	$4.91	$5.23	Publix
Manufacturing	Sanding Belt	CM 4x36 Zirc Belt 120# 2-PC	1	$15.98	$15.98	$17.02	Lowes
Manufacturing	Brasso	Brasso Multi-Purpose Metal Polish, for Brass, Copper, Stainless, Chrome, Aluminum, Pewter & Bronze, 8 oz	1	$8.85	$9.11	$9.11	Amazon
Manufacturing	Liquid Car Wax	Mothers 05750 California Gold Pure Brazilian Carnauba Liquid	1	$11.95	$14.99	$14.99	Amazon

		Wax (Ultimate Wax System, Step 3) - 16 oz.					
Manufacturing	Packing Tape	IDL Packaging Concord Packing Tape - 2" x 1.6 mil x 110 Yards, Clear (Pack of 6)	1	$31.54	$31.54	$31.54	Amazon
Manufacturing	Soild Car Wax	Mothers 05550 California Gold Pure Brazilian Carnauba Wax Paste (Ultimate Wax System, Step 3) - 12 oz.	1	$22.49	$22.49	$22.49	Amazon
Intergation	Rail buttons	LARGE RAIL BUTTON (FITS 1.5" RAIL - 1515)	2	$5.70	$11.40	$11.40	Apogee Components
Manufacturing	[Carbon Fiber Sheets]()	12K Uni Directional Sheets (Sku: 13024-D)	10	$28.49	$284.90	$284.90	Composite Envisions
Manufacturing	Fiberglass Plain Weave	Hexcel HexForce Fiberglass E-Glass Plain Weave 50"/127cm 9.41oz/319gsm Style 7500 F16 Finish	6	$6.92	$41.52	$41.52	Composite Envisions
Manufacturing	Release Film	Airtech A4000 High Performance Fluoropolymer Release Film – Violet	0	$13.90	$0.00	$0.00	Composite Envisions
Manufacturing	Fiberglass Plates	G-10 FR4 .125" x 12"' x 24"	5	$33.69	$168.45	$168.45	ePlastics
Manufacturing	Adtech 820/824 Hardener	AdTech 820 Marine Laminating Hardeners Only	1	$53.85	$53.85	$53.85	Express Composites

Manufacturing	Epoxy Resin	AdTech 820 Series Laminating Resin Only 1 gallon	1	$244.73	$244.73	$244.73	Express Composites
Manufacturing	Yelllow Sealant Tape	Yellow Sealant Tape	3	$9.95	$29.85	$29.85	Fiberglast
Manufacturing	Carbon Fiber Sleeves	5in 12K Carbon Light Sleeves	18	$7.62	$137.16	$137.16	Soller Composites
Manufacturing	Mixing Tips	Thixo Cartridge Mixing Tips (12)	1	$11.99	$11.99	$11.99	TotalBoat
Manufacturing	Coupler	5" G12 Coupler (12")	1	$56.89	$56.89	$56.89	Wildman Rocketry
Intergation	Motor Mount 75mm	1ft G12-3.0	1	$22.56	$22.56	$22.56	Wildman Rocketry
Manufacturing	Shoulder Coupler	5" G12 Coupler (10")	1	$47.41	$47.41	$47.41	Wildman Rocketry
Manufacturing	Microfiber Cloth	14x14 Micorfiber Cloth blue 24 pack	1	$14.99	$14.99	$14.99	Amazon
Manufacturing	Popsicle Sticks	100 pack of popsicle sticks Jumbo	1	$6.95	$6.95	$6.95	Amazon
Manufacturing	Sandpaper	120-3000 grit sandpaper for sanding composite	2	$7.99	$15.98	$15.98	Amazon
Manufacturing	Paper Towel	Shop Towels 6 pack	1	$11.98	$11.98	$11.98	Home Depot
Recovery	Nylon 4-40 Shear Bolts	Nylon Pan Head Screws Phillips, 4-40 Thread, 5/16" Long pack of 100	1	$8.48	$8.48	$8.48	McMaster
Recovery	Quick Links	Oval-Shaped Threaded Connecting Link ype 316 Stainless Steel, 3/8" Thickness, 1/2" Opening, Not for Lifting	10	$7.77	$77.70	$77.70	McMaster

Recovery	U-Bolt	Black-Oxide Steel U-Bolt with Mounting Plate, 3/8"-16 Thread Size, 1-3/4" ID	5	$2.66	$13.30	$13.30	McMaster
Recovery	U-Bolt Nuts (25 ct.)	Extra-Wide Thin Nylon-Insert Locknut Zinc-Plated Low-Strength Steel, 1/2"-13 Thread Size	1	$13.46	$13.46	$13.46	McMaster
Recovery	U-bolt Washer (25 ct.)	316 Stainless Steel Washer for 1/2" Screw Size, 0.531" ID, 1.25" OD	1	$12.09	$12.09	$12.09	McMaster
Manufacturing	Aluminum Mandrel Extrude	5.000 x 0.125 ALUMINUM 6061 ROUND TUBE 50" long	1	$175.99	$175.99	$175.99	Metal Supermarkets
Manufacturing	Nose Cone Tip	T6511 2.000" ALUMINUM 6061 ROUND BAR 5" long	1	$27.93	$27.93	$27.93	Metal Supermarkets
Recovery	Chute Protectors	18" x 18" Chute Protector	1	$26.50	$26.50	$26.50	Rocketman
Recovery	Chute Protectors	6" x 6" Chute Protector	1	$11.50	$11.50	$11.50	Rocketman
Recovery	Drogue Chutes	1' Standard Parachute	1	$28.50	$28.50	$28.50	Rocketman
Recovery	Kelvar	1,200lb Kelvar Shock Cord 30'	1	$35.50	$35.50	$35.50	Rocketman
Recovery	Kelvar	1,200lb Kelvar Shock COrd 25'	1	$28.50	$28.50	$28.50	Rocketman
Recovery	Nylon 7 ft Chute Main	7' Nylon Chute Main (20% discount)	1	$70.50	$70.50	$70.50	Rocketman
Recovery	PILL Shock Cord	5ft 5/8" 3,200lb Tubular Nylon Shock Cords	1	$18.00	$18.00	$18.00	Rocketman
Manufacturing	Orbital Sander	5in. Orbital Sander w/ Dust Bag	0	$26.88	$0.00	$0.00	Walmart

Manufacturing	MDF Boards	1/4 in. x 2 ft. x 4 ft. Medium Density Fiberboard	6	$12.49	$74.94	$74.94	Home Depot
Manufacturing	Plywood	1/4"x4'x8' Hardwood PureBond Plywood	1	$44.68	$44.68	$44.68	Home Depot
Manufacturing	Threaded Rod	1/4 by 36in	3	$8.47	$25.41	$25.41	Home Depot
Manufacturing	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	$4.69	$9.38	$9.38	Walmart
Manufacturing	Red Cups	Solo Disposable Plastic Cups, Red, 18oz, 50 count	2	$4.29	$8.58	$8.58	Walmart
	Shipping	Shipping	1	$55.11	$55.11	$55.11	Composite Envisions
	Shipping	Shipping	1	$29.96	$29.96	$29.96	Express Composites
	Shipping	Shipping	1	$21.95	$21.95	$21.95	Fiberglast
	Shipping	Shipping	1	$11.08	$11.08	$11.08	Soller Composites
	Shipping	Shipping	1	$34.84	$34.84	$34.84	Wildman Rocketry
Manafacturing	Popsicle Sticks	100Pcs Jumbo Wooden Craft Sticks Wooden Popsicle Craft Sticks Stick 6" Long x 3/4"Wide Treat Sticks Ice Pop Sticks for DIY Crafts, Home Art Projects,	1	$4.99	$4.99	$4.99	Amazon

		Classroom Art Supplies					
	Respirator	3M Half Facepiece Reusable Respirator 6200, Gases, Vapors, Dust, Paint, Cleaning, ...	2	$17.01	$34.02	$34.02	Amazon
	PVC Elbow	Carlotte Pipe 1-1/4 in. PVC Schedule 40 90-Degree S x S Elbow	1	$9.42	$9.42	$9.42	Home Depot

7.2.1.3 Payloads Budget

Item Label	Component Description	QTY	Price Each	Total	Vendor
ESP32	Adafruit ESP32 Microcontroller 2mb memory	1	$19.95	$19.95	Adafruit
LoRa radio transciever	Chicago Dst	2	$19.95	$39.90	Adafruit
Flash Memory SD	Adafruit SPI Flash SD 512 MB	1	$9.50	$9.50	Adafruit
Adafruit GPS	Adafruit Ultimate GPS	1	$29.95	$29.95	Adafruit
BNO085	BNO085 Absolute Orientation IMU	1	$24.95	$24.95	Adafruit
3.3v Voltage regulator	3.3V Buck Voltage regulator 5 pack	1	$12.49	$12.49	Amazon
5v Voltage regulator	5V Buck Voltage regulator 5 pack	1	$12.49	$12.49	Amazon

Male Female Bullet Connectors	yueton 30Pairs 3.5mm Male Female Banana Plug Bullet Connector Replacements	1	$7.99	$7.99	Amazon
BMP 280	Barometric pressure sensor	1	$6.99	$6.99	Amazon
SD Card	proprietary non-volatile flash memory card	1	$9.28	$9.28	Amazon
Camera Module	Run Cam Split	1	$79.99	$79.99	Amazon
Featherweight GPS	Full System Featherweight GPS + Ground Station + Battery	1	$365.00	$365.00	FeatherWeight Altimeters
PCB	Printed Circuit Board	1	$8.00	$8.00	JLCPCB
PLD Filament	Anycubia PLA 3D Filament	1	$16.99	$16.99	Amazon
AWG Wire	22 Gague Wire - Andrew	1	$14.58	$14.58	Amazon
GPS Module	GPS Module GPS Neo 6m Arduino GPS	1	$12.59	$12.59	Amazon
PERF Boards	Smarza 100pcs double sided pcb board kit	1	$12.99	$12.99	Amazon
Lora Module	Commimark 2Pcs LoRa SX1278 Long Range RF	1	$12.39	$12.39	Amazon
32GB SD	Mirco Center 32GB class 10 micro SDHC Flash Memory Card	1	$8.99	$8.99	Amazon
Test MPU 6050s	Hiletgo 3pc MPU6050	1	$9.99	$9.99	Amazon
9v Battery	Amazon Basic 9v performance all purpose alkaline batteries	1	$4.41	$4.41	Amazon
Arduino Starter kit	Smarza basic starter kit for arduino, breadboard, power supply, jumper wires, …	1	$12.99	$12.99	Amazon
Test BMP 280	KOOBOOK 5PCs GY - BMP 280 - 3.3 High Precision Atmospheric Pressure Sensor	1	$6.99	$6.99	Amazon

PERF Boards	10 Pieces 50mm X 70mm Copper Strip PCB board	1	$8.98	$8.98	Amazon
Arduino Nano	Nano V3.0 Nano Board ATMEGA328P	1	$24.99	$24.99	Amazon
USB Cable w/ Data line	Myfon Micro USB Cable 2 Pack, Fast Charging Cable, High Speed	1	$5.49	$5.49	Amazon
Test MPU 6050s	Hiletgo 3pc GY-521 MPU6050	1	$9.99	$9.99	Amazon
Multimeter	Katweets Digital Multimeter with case, DC AC	1	$13.19	$13.19	Amazon
Soldering Kit	Soldering Iron Kit - Soldering Iron 60 W Adjustable Temperature Solder Wire	1	$18.99	$18.99	Amazon
Test Micro SD Card Adapter	Atrip 10 PCS Micro SD Card Module with Chip level conversion for Arduino	1	$10.99	$10.99	Amazon
Test BMP 280	HiLetGo 5Pcs High Precision BMP280 3.3 Atmospheric Pressure sensor	1	$7.39	$7.39	Amazon
Test ESP32	Teyleten Robot ESP325 ESP32 ESP-Wroom-32 Development board	1	$17.88	$17.88	Amazon
1/4" Locknuts	High-Strength Steel Nylon-Insert Locknut, Black High-Stength Steel Nylon Insert Black Oxide, 1/4"-20 Thread Size, Packs of 25	1	$5.06	$5.06	Mc-Master Carr
Test Micro SD Card Adapter	Maxmoral 2Pcs Micro SD Storage baord memory	1	$6.59	$6.59	Amazon
22 AWG Pretinned Wire	22 Gauge Wire Solid Core Hookup Wires	1	$14.94	$14.94	Amazon
Shipping	1/4" Locknuts Mc-Master Shipping	1	$9.71	$9.71	Mc-Master Carr

7.2.1.4 Propulsion Budget

Item Label	Components Description	QTY	Price Each	Total Cost
K1000T	Motor Reloads	4	$182.69	$781.91
752560M	Motor Casing	1	$392.00	$419.44

7.2.1.5 Travel Budget

Item Label	Component Description	Quantity		Total Cost
gas per car	1650 miles per car / 20mpg * $4 per gallon	-9	$330.00	-$2,970.00
Airbnb 1		-1	$1,332.11	-$1,332.11
Airbnb 2		-1	$1,611.98	-$1,611.98
Airbnb 3		-1	$1,999.23	-$1,999.23
Airbnb 4		-1	$1,220.40	-$1,220.40
driver		8	$187.50	$1,447.50
non driver		21	$302.50	$6,130.16
driver late fee		1	$237.50	$229.19
non driver late fee		7	$352.50	$2,381.14

7.2.2 Funding Plan

7.2.2.1 Student Government

UCF's student government has granted our team a $3000 bill, exclusive to this project. Purchases are filed through the ASF office's accountant and have covered all fees for vehicle design and a significant portion of the payloads budget. Said money does not have to be returned, however, we must demonstrate a $3000 matching contribution which will be provide by FSGC and KXR – the hose of UCF's USLI team.

7.2.2.2 Florida Space Grant Consortium

Due to unforeseen circumstances, The Florida Space Grant Consortium did not provide the $3000 to meet our matching contribution. Although through our parent club, Knights Experimental Rocketry, we continued to acquire funds.

7.2.2.3 KXR Funding

Knight's Experimental Rocketry is the host club for UCF's USLI team. Sponsorships from Blue Origin and Lockheed Martin have allowed us alternate means to meet our matching grant, as well as afford additional expenses for the project.

7.2.2.4 Travel Funds

Our team will be making the ten-hour drive from UCF to Huntsville. Seven drivers will volunteer their vehicles. Under the assumption that gas will be $4.00 per gallon, with each vehicle at 20 miles per gallon, we have estimated a $2900 cost for gas. This is not fundable by the Student Government, so funds will be collected from the 30 attendees.

As for lodging, the Student Government has agreed to provide half the lodging costs with a similar matching contribution, rough estimates are approximately $3000 including tax which will also be accrued via member funds.

7.3 Timeline

Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Payloads				
Recovery Split	Emilio		3/21/23	3/5/23
Telemetry Split	Emilio		3/18/23	3/18/23
Experiments Split	Emilio		3/18/23	3/18/23
Coupler Complete	Emilio	100%	2/10/23	2/22/23
ATTSAB Complete	Emilio	80%	2/18/23	2/22/23
D/A Members FRR	Emilio		2/20/23	3/1/23
Recovery				
Manufacturing	Daniel & Zander	100%	2/20/23	2/24/23
Ground Test	Daniel & Zander	20%	2/20/23	2/24/23
Parachute Test	Daniel & Zander	0%	2/20/23	2/24/23
Vacuum Test	Daniel & Zander	0%	2/24/23	3/6/23
Continuity Test	Daniel & Zander	30%	2/20/23	2/24/23
Flysheet Sections	Daniel & Zander	0%	2/24/23	3/6/23
FRR	Daniel & Zander	0%	2/21/23	3/6/23
FRR Slides	Daniel & Zander	0%	2/21/23	3/6/23

Display Week: 1

TASK	ASSIGNED TO	PROGRESS	START	END
Telemetry				
ATTSAB	Andrew	60%	2/13/23	2/18/23
Software	Tristan	70%	2/13/23	3/21/23
PCB	Andrew	0%	2/13/23	3/21/23
Integration	Andrew	30%	2/13/23	3/21/23
Overall Completion		30%	2/13/23	4/5/23
Safety				
Recovery Testing	Sam	10%	2/19/23	2/24/23
Experiments Testing [	Sam	10%	3/4/23	3/11/23
Hazard Analyses	Sam	50%	2/18/23	3/1/23
	Sam		date	date
Launch Site Procedur	Sam	80%	2/22/23	2/25/23
Experiments				
PILL Complete	Keanu	0%	3/11/23	3/18/23
Outer Casing	Keanu	70%	2/21/23	2/27/23
Electronics	Keanu	20%	2/21/23	3/3/23
Software	Keanu	50%	2/21/23	3/3/23
Testing	Keanu	10%	3/4/23	3/11/23

7.4 STEM Engagement

7.4.1 Overview

Event Date	Name of Group	In-Person or Virtual	Preschool –4	5–9	10–12	Undergrad Educators Adult (noneducators)
10/30/22-11/02/22	OpenMotor workshop	In-person	X	X	X	~40
11/04/22-11/18/22	OpenRocketWorkshop	In-person	X	X	X	~30
11/14/22-11/18/22	Python/Open CV Workshop	In-person	X	X	X	~10
01/13/23	1007C Presentation	In-Person	X	X	X	~1000
Mid-January	STEM Seminar I Outreach	In-Person	X	X	X	~200
Mid-January	STEM Seminar II Outreach	In-Person	X	X	X	~200
End of January	Arduino Workshop	In-Person	X	X	X	~20
Beginning of February	Hardware/ Manufacturing Workshops	In-Person	X	X	X	~150
Mid-February	STEM Day	In-Person	X	X	X	X

7.4.3 Member Enrichment

7.4.3.1 Workshops

USLI enriches students' curiosity, engagement, and experience by holding workshops. Our workshops have a wide variety of educational materials such as learning new software to teaching hardware and manufacturing. The main goal of the workshops hosted at USLI can vary from gaining certifications in software, learning software to have proficiency, or developing skills to aid in manufacturing during the duration of all projects. The workshops that are hosted by the organization are created and hosted by students, meaning all curricula designed by the students are executed by students.

The workshops are provided for students who are involved in various projects in USLI and want to learn a specific skill or gain more experience to contribute their knowledge and skill to their project/team. USLI has broadened the horizon for various projects to emerge in the club that is hosted by our respected leads. Workshops such as Python/OpenCV, Arduino, and HAM Radio workshops were introduced to the organization and have shown extremely positive feedback.

7.4.3.2 National Society of Black Engineers

Regrettably, due to conflicting schedules, The National Society of Black Engineers was unable to host our direct/education stem engagement activity. Our USLI team aimed to provide the children in attendance with an interactive experience about rocketry, featuring bottle rockets and rocket poppers. Additionally, we prepared a presentation that explained how our rocket, Asclepius functioned and how our USLI team intended to create an experimental payload that would be fitted into the rocket for launch.

7.4.3.3 Intro to Engineering

Our USLI team, in collaboration with Knights Experimental Rocketry, seized the opportunity to share our passion for rocketry with a large group of students in an Introduction to Engineering course at The University of Central Florida. With the aim of providing an insider's view of our NASA Student Launch project, Asclepius, we organized a clear and structured presentation that showcased the principles of rocketry, engineering, and physics.

Our presentation was highly engaging, featuring interactive and visual aids such as videos and hands-on demonstrations to help illustrate our points and keep the students invested.

Our USLI Payloads Manager, Emilio Peirrea, spoke passionately about our project, encouraging the students to ask questions and fostering a deeper understanding of the topics covered. After the presentation, we provided the students with valuable resources such as the Knights Experimental Rocketry website and a QR code to our Discord, enabling them to further explore the world of rocketry and engineering.

7.4.3.4 Stem Seminar I&II

The STEM Seminar was a collaborative event organized by Eli2, an engineering organization at the University of Central Florida, and our parent club, Knights Experimental Rocketry. The event aimed to provide students within the STEM field with an in-depth insight into the campus offerings for their respective industries, as well as a unique look into their dedicated field. Esteemed speakers, ranging from P.H.D. students to employees out on the field, were invited to share their experiences and provide valuable insights on navigating the STEM world.

During the seminar, attendees had the opportunity to interact and engage with the speakers, fostering a deeper understanding of their respective fields. The event also provided a platform for networking and building connections within the STEM community. The Nasa Student Launch team was able to share their own experience working on the project as well as showcase their recently built aerostructure and experimental pill.

7.4.3.5 STEM Day

During Engineering Week at the University of Central Florida, our Student Government sponsored a STEM Day aimed at inspiring and educating young students in the third and fourth grades. As part of the event, our parent club, Knights Experimental Rocketry, hosted a table where our Nasa Student Launch students introduced the concept of our rocket, Asclepius, and explained the principles of rocketry, engineering, aerodynamics, and physics.

In addition to showcasing our rocket, we allowed the children to handle our experimental payload, providing them with a hands-on experience to understand how it can be self-oriented and its purpose in capturing images above our horizon. The interactive and engaging nature of our presentation helped the children understand the complexity of rocketry and the scientific principles that underpin it.